FUSRAP
NIAGARA FALLS STORAGE SITE

2001
ENVIRONMENTAL SURVEILLANCE TECHNICAL MEMORANDUM

US Army Corps of Engineers ®
Buffalo District

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ACRONYMS

AEC	Atomic Energy Commission
ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirement
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	chain of custody
DCG	derived concentration guide
DOE	Department of Energy
DQO	data quality objective
EA	environmental assessment
ED	effective dose
EE/CA	engineering evaluation/cost analysis
EIS	environmental impact statement
EML	Environmental Measurements Laboratory
ESP	environmental surveillance plan
FFA	federal facility agreement
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FSRD	Former Sites Restoration Division
FUSRAP	Formerly Utilized Sites Remedial Action Program
GC-EC	gas chromatography/electron capture
GC/MS	gas chromatography/mass spectrometry
GFAA	graphite furnace atomic adsorption
HWP	hazardous work permit
ICPAES	inductively coupled plasma atomic emission spectrophotometry
ID	identification
IG	instruction guide
KPA	kinetic phosphorescence analysis
LCS	laboratory control sample
LEL	lower explosive limit
LOOW	Lake Ontario Ordnance Works
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDA	Minimal Activity Amount
MED	Manhattan Engineer District
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NFSS	Niagara Falls Storage Site
NHPA	National Historic Preservation Act
NIST	National Institute for Standards and Technology
NL	National Lead
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NYSDEC	New York State Department of Environmental Conservation

(Continued)

PERALS	photon/electron-rejecting alpha liquid scintillation
PI	project instruction
PP	project procedure
PPE	personal protective equipment
QA	quality assurance
QAP	Quality Assurance Plan
QAT	Quality Assurance Team
QC	quality control
RCRA	Resource Conservation and Recovery Act
RI/FS	remedial investigation/feasibility study
RPD	relative percent difference
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SRM	standard reference material
SSHR	site safety and health representative
S/RID	Standards/Requirements Identification Document
TCLP	toxicity characteristics leaching procedure
TDS	total dissolved solids
TETLD	tissue-equivalent thermoluminescent dosimeter
TLD	thermoluminescent dosimeter
TOC	total organic carbon
TOX	total organic halides
TPH	total petroleum hydrocarbons
TSCA	Toxic Substances Control Act
USACE	United States Army Corps Of Engineers
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound
WCS	waste containment structure

EXECUTIVE SUMMARY

In 1974, the Atomic Energy Commission (AEC), a predecessor to the U.S. Department of Energy (DOE), instituted the Formerly Utilized Sites Remedial Action Program (FUSRAP). This program is now managed by United States Army Corps of Engineers (USACE) to identify and clean up, or otherwise control sites where residual radioactivity remains from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized USACE to remedy under FUSRAP. In October 1997, Congress transferred the responsibility for FUSRAP from the United States Department of Energy (DOE) to the United States Army Corps of Engineers (USACE).

This memorandum presents and interprets analytical results and measurements obtained as part of the 2001 environmental surveillance program for the Niagara Falls Storage Site (NFSS) under the Formerly Utilized Sites Remedial Action Program (FUSRAP). Because radioactive wastes and residues are stored in the waste containment structure (WCS) at NFSS, the environmental surveillance program at the site includes sampling of air, water, and streambed sediment to ensure that onsite waste does not pose a threat to human health and the environment. The discussion below provides a comparative analysis of local background conditions and regulatory criteria to results reported for external gamma radiation and for samples from the media investigated. Data tables and figures referenced in the text are included at the end of this document.

DOE and United States Environmental Protection Agency (USEPA) guidelines are presented throughout this report for comparative purposes in evaluating environmental surveillance data. The USACE continues to provide data with DOE guidelines because the facility is owned by the Federal Government and is currently maintained by the USACE, DOE has property accountability. However, those values are provided for comparative purposes only and do not necessarily reflect what the final clean up standard for the site will be. Applicable or Relevant and Appropriate Requirements (ARARs) and cleanup goals will be presented in the proposed plan, which the public will be able to comment on, and those standards will be presented in the Record of Decision (ROD). Results from the 2001 surveillance program at NFSS indicate that no measured parameter exceeded DOE or USEPA guidelines, and no dose calculated for potentially exposed members of the general public exceeded DOE or USEPA limits.

Prior to transfer of the FUSRAP to USACE in 1997, reports were generated based on DOE Orders and guidance. DOE Orders are not applicable to the activities of the US Army Corps of Engineers as the USACE is not under the authority or direction of the DOE. However, the surveillance data continues to follow a format similar to that of the previous DOE reports to provide the reader with consistent presentation of data and to facilitate historical comparison between reports.

1.0 INTRODUCTION

Niagara Falls Storage Site (NFSS) is located in the Town of Lewiston in northwestern New York state, northeast of Niagara Falls and south of Lake Ontario (Figure 1). NFSS is a 77-ha site (1 hectare=2.47 acres) which includes: one former process building (Building 401), one office building (Building 429), equipment shed, and a 4-ha (1 hectare=2.47 acres) WCS. The property is entirely fenced, and public access is restricted.

Land use in the region is primarily rural; however, the site is bordered by a chemical waste disposal facility (CWM Chemical Services, Inc.) on the north, a solid waste disposal facility (Modern Disposal, Inc.) on the east and south, and a Niagara Mohawk Power Corporation right-of-way on the west. The nearest residential areas are approximately 1.1-km southwest of the site; the residences are primarily single-family dwellings.

Beginning in 1944, NFSS was used as a storage facility for low-level radioactive residues and wastes. The residues and wastes are the process by-products of uranium extraction from pitchblende (uranium ore). The residues originated at other sites and were transferred to NFSS for storage in buildings and onsite pits and surface piles. From 1953 to 1959 and 1965 to 1971, Building 401 was used as a boron-10 isotope separation plant.

Since 1971, activities at NFSS have been confined to residue and waste storage and remediation. All onsite and offsite areas with residual radioactivity exceeding Department of Energy (DOE) guidelines were remediated between 1955 and 1992; materials generated during remedial actions (approximately 195,000 m^3) are encapsulated in the WCS, which is specifically designed to provide interim storage of the material

1.1 Measured Parameters

The key elements of the 2001 environmental surveillance program at NFSS were

- measurement of external gamma radiation;
- measurement of radon gas concentrations in air (combined contributions from radon-220 and radon-222);
- monitoring of radon-222 flux (rate of radon-222 emission from the WCS);
- sampling and analysis of surface water for isotopic uranium (233/234, 235/236, 238) & total uranium (summation of: U-238 + U-235 + U-234), isotopic thorium (228,230,232) and isotopic radium(223,224,226) (referred to collectively as radioactive constituents);
- sampling and analysis of streambed sediments for radioactive constituents; and
- sampling and analysis of groundwater for radioactive constituents, metals, and water quality parameters.

1.2 Unit Conversions

The tables listed in the Appendix A (Table -A.1&2, TABLES Section, Page T-1) list the units of measurement and appropriate abbreviations used in this document. Conventional units for radioactivity are used because the regulatory guidelines are generally provided in these terms; Système Internationale (SI) units of measurement are used in the discussion of all other parameters. Unit conversions will be provided in the text for water level information only.

2.0 REGULATORY GUIDELINES

The primary regulatory guidelines that affect activities at Formerly Utilized Sites Remedial Action Program (FUSRAP) sites are found in federal statutes and in federal, state, and local regulations. Regulatory criteria that were used to evaluate the results of the 2001 environmental surveillance program at NFSS are summarized below, categorized by media and parameters. In several cases DOE guidelines continue to be identified in the technical memorandum for comparison purposes of historical data collected by DOE or their contractors. USACE is not under the authority of the DOE orders or directives and must rely on other applicable Federal or state regulations in relation to surveillance of the WCS. The values are for comparison only and do not reflect the final clean up standards for the site.

2.1 External Gamma Radiation and Air (Radon Gas and Airborne Particulate)

The regulatory guideline criteria used in evaluation of the calculated maximum doses from external gamma radiation and inhalation of radioactive particulate, and the measured concentrations of radon gas include DOE guidelines, United States Environmental Protection Agency (USEPA) standards, and USEPA guidance.

2.1.1 DOE Order 5400.5

Dose limits for members of the public from DOE operations at some DOE-owned and DOE-operated facilities are presented in this DOE Order. The primary dose limit is expressed as an effective dose equivalent. The limit of 100-mrem effective dose equivalent above background in a year from all sources (excluding radon) is specified in this Order; external gamma radiation dose and the calculated doses from airborne particulate releases are included in the calculation of the effective dose equivalent total. Also, this calculation includes contributions from other pathways, such as ingestion.

DOE limits for radon concentrations in air from DOE operations at some DOE-owned and DOE-operated facilities are also presented in Order 5400.5. Based on the radioactive constituents in the wastes contained in the WCS, it is unlikely that radon-220 would be emitted from the WCS; it is, however, possible that radon-222 would be emitted. The DOE limits for radon-222 concentrations in the atmosphere above facility surfaces or openings in addition to background levels are: 100 pCi/L at any given point; an annual average concentration of 30 pCi/L over the facility site; and an annual average concentration of 3.0 pCi/L at or above any location outside the facility site. To provide a conservative basis for comparison, on-site radon concentrations are evaluated against the off-site limit of 3.0 pCi/L above background.

2.1.2 USEPA Standards and USEPA Guidance

The USEPA also sets a guidance action level of 4.0 pCi/L for radon concentrations in indoor air (homes), providing another conservative basis for comparison. Although these limits are specific to indoor air, they provide a conservative basis for comparison to the outdoor air results obtained during environmental surveillance activities, for details see Appendix C. For further comparison, the average radon level in homes is about 1.25 pCi/L, and ambient outdoor radon levels typically range from 0.2 to 0.7 pCi/L with an average of 0.4 pCi/L (USEPA 1993).

Clean Air Act

Section 112 of the Clean Air Act authorized the USEPA to promulgate the National Emission Standards for Hazardous Air Pollutants (NESHAPs). Compliance with Subpart H (for nonradon, radioactive constituents) is verified by applying the USEPA-approved CAP88-PC model. Compliance with Subpart Q is verified by annual monitoring of the WCS for radon-222 flux. (See Appendix A, TABLES Section, Table –B, Page T-1)

2.2 Sediment, Surface Water, and Groundwater - Radioactive Constituents

Regulatory criteria for evaluating the measured concentrations of radionuclides in sediment, surface water, and groundwater at NFSS are as follows:

2.2.1 DOE Order 5400.5

This Order provides guideline limits for radioactive constituents in water and soil at some DOE-owned and DOE-operated facilities. The environmental surveillance program does not include analysis of onsite soils; however, because there are no standards for sediment, DOE historically used the residual soil cleanup guideline criteria specified in DOE Order 5400. The USACE is continuing that process. However, those values are provided for comparative purposes only and do not necessarily reflect what the final clean up standard for the site will be. Applicable or Relevant and Appropriate Requirements and cleanup goals will be presented in the proposed plan, which the public will be able to comment on. These standards will then be presented in the Record of Decision (ROD).

DOE Order 5400.5 states that the guideline for residual concentrations of radium-226, radium-228, thorium-230 and thorium-232 in surface soil is 5 pCi/g above background, based on an average of the first 15-cm of soil below the surface. For subsequent 15-cm depth intervals (subsurface soils), the specified limit is 15 pCi/g above background. Because surveillance sediment samples are collected from the first 15-cm of sediment, only the surface soil criteria are used. If both thorium-230 and radium-226 or both thorium-232 and radium-228 are present and not in secular equilibrium, the appropriate guideline is applied as a limit for the radionuclide with the higher concentration. If other mixtures of radionuclides occur, the Order prescribes that the data be evaluated by the sum-of-the-ratios (SOR) method. By this method, the above-background concentration of each of the radioisotopes is divided by its respective criterion, and the ratios are summed. If the result is greater than 1, the mixture of radionuclides fails the sum-of-the-ratios test and is considered to exceed the soil guidelines.

DOE Order 5400.5 does not give concentration limits for uranium in soils or sediment. Therefore, the analytical data will only be compared to historical levels and not a standard.

DOE derived concentration guides (DCGs) for radionuclides in water are used to evaluate analytical data for surface water and groundwater at NFSS and are cited in the appropriate data tables in this report. These guidelines are also presented in the order. The DCG for each radionuclide represents the concentration that would result in a dose of 100 mrem during a year by ingestion of water, conservatively calculated for continuous exposure conditions. For mixtures of radionuclides in water, the sum of the ratios of each concentration to the DCG must not exceed 1.

2.2.2 Safe Drinking Water Act (SDWA)

SDWA is the primary federal law applicable to the operation of a public water system and the development of drinking water quality standards [*USEPA Drinking Water Regulations and Health Advisories* (*USEPA* 1996)]. The regulations in 40 CFR Part 141 (National Primary Drinking Water Regulations) set maximum permissible levels of organic, inorganic, radionuclides (including Uranium and combined Radium) and microbial contaminants in drinking water by specifying the maximum contaminant level (MCL) for each. MCLs have been established (promulgated) for combined concentrations of radium-226 and radium-228. Although groundwater at NFSS is not a public drinking water supply, MCLs for drinking water are used as a conservative basis for evaluation of analytical results, maintaining consistency with previous reports and facilitating trend analysis. (See Table-C in Appendix A, TABLES section, page T-2.)

2.3 Groundwater - Chemical Parameters

As noted above, although the groundwater at NFSS is not a public drinking water supply, state and federal standards for drinking water are used, Table-D (Appendix A, page T-3) as a conservative basis for evaluation of chemical analytical results and do not necessarily reflect what the final clean up standard for the site will be. Following public comment on the proposed plan and selection of cleanup goals/ARARs, those standards will be presented in the Record of Decision (ROD).

2.3.1 Safe Drinking Water Act

As indicated previously, SDWA is the primary federal law applicable to the operation of a public water system and the development of drinking water quality standards (USEPA 1996). The regulations set MCLs for organic, inorganic, radiological and microbial contaminants in drinking water. In some cases, secondary maximum contaminant levels (SMCLs), which are not federally enforceable (40 CFR 143.1), are provided as guidelines for the states. SMCLs are provided for a conservative comparison of analytical results and to provide consistency with previous reports and facilitate trend analysis.

2.3.2 New York State Department of Environmental Conservation (NYSDEC) Water Quality Criteria for Groundwater

NYSDEC has adopted the federal SDWA standards into its own regulations in Title 6 New York Codes of Rules and Regulations (NYCRR) Parts 700-705, "Water Quality Regulations for Surface and Groundwater" (NYSDEC 1996). In addition, NYSDEC has independently established standards for some constituents:

To apply established standards, the State of New York categorizes groundwater resources by groundwater quality and use. At NFSS, because of uniformly poor groundwater quality and availability in the general region, the shallow groundwater resources are of little consequence. Regional studies and studies conducted near the site (La Sala 1968; Wehran 1977; Acres American 1981) conclude that groundwater quality is poor near the site because of high mineralization. Additionally, local studies (Wehran 1977 and Acres American 1981) indicate that the permeabilities of the shallow groundwater systems are sufficiently low that it is not practicable to obtain groundwater from these systems for water supply. Onsite permeability testing at NFSS confirms the low permeabilities.

Well surveys conducted in 1988 and 1995 identified eight private wells within a 4.8-km radius of the site; these wells further confirm the impracticability of using the shallow groundwater system for obtaining water in appreciable quantities. Of the eight wells identified during the survey, only one is downgradient of the site (2-km north). None of the wells identified in the well survey is reportedly used for drinking water; most are used for irrigation (DOE 1994b). In light of these findings, the NYSDEC Class GA (water supply) groundwater standards represent a very conservative basis for comparing analytical results because the groundwater at NFSS does not meet the criteria for Class GA groundwater. However, to establish a basis for comparison of analytical results, Class GA (groundwater) water quality standards for some constituents were obtained from the NYSDEC document.

The Division of Water Technical and Operational Guidance Series (TOGS) specifically addresses source drinking water standards (NYSDEC –6 NYCRR Part 703 Surface Water and Groundwater Quality Standards and Groundwater Effluent Limitations (August 1999)). These standards have been used to establish additional Class GA (related, conservative case) state water quality standards for comparison of analytical results.

3.0 SAMPLING LOCATIONS AND RATIONALE

Radioactive materials that exceed DOE cleanup guidelines at NFSS are stored in the WCS. Exposure of members of the public to this radioactively contaminated material at NFSS is unlikely because of site access restrictions (e.g., fences) and engineering controls (e.g., pile covers). However, potential pathways include direct exposure to external gamma radiation; inhalation of air containing radon or radioactively contaminated particulates; and contact with, or ingestion of, contaminated surface water, streambed sediments, or groundwater. The environmental surveillance program at NFSS has been developed to provide surveillance of these exposure routes through periodic sampling and analysis for radioactive and chemical constituents. Figure 2, Appendix A, presents the environmental surveillance program at NFSS and indicate sampling locations and media. Table 1, Appendix A, summarizes the environmental surveillance program at NFSS for external gamma radiation, radon gas, surface water, sediment, and groundwater.

External gamma radiation monitoring and radon gas measurements occur at fenceline locations surrounding the NFSS as well as interior portions of the site, including the perimeter of the WCS, to assess potential exposures to the public and site workers. Measurement of radon-222 flux is conducted annually at discrete grid intersections on the WCS (Appendix A, Figure 2).

Groundwater monitoring wells have been selected to assess background, downgradient, and source-area (near the WCS) groundwater quality conditions in the upper groundwater system (Figure 2, Appendix A, page F-2). Groundwater monitoring includes analysis for radioactive constituents, water quality parameters, and metals. The upper groundwater system would provide the earliest indication in the unlikely event of a breach of the WCS. The lower groundwater system is not monitored because past analytical results from the upper groundwater system have not indicated migration of radioactive material from the WCS.

Surface water and streambed sediment sampling of radioactive constituents is conducted along the drainage ditch system in upstream, onsite, and downstream locations (Figure 2) to assess the migration of constituents in these media should any occur.

4.0 SURVEILLANCE METHODOLOGY

Under the NFSS environmental surveillance program, standard analytical methods approved and published by USEPA and the American Society for Testing and Materials (ASTM) are used for chemical (i.e., all nonradiological) analyses. The laboratories conducting the radiological analyses adhere to USEPA-approved methods and to procedures developed by the Environmental Measurements Laboratory (EML) and ASTM. A detailed listing of the specific procedures and the data quality objectives for the surveillance program is provided in the *Environmental Surveillance Plan* (BNI 1996a) .

All 2001 environmental surveillance activities at NFSS were conducted in accordance with the *Environmental Surveillance Plan* (BNI 1996a) and the instruction guides (IGs) listed in Table E in Appendix A (page T-3). The IGs are based on guidelines provided in *RCRA Ground Water Monitoring: Draft Technical Guidance* (USEPA 1992b); Test *Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846; USEPA 1992c); and *A Compendium of Superfund Field Operations Methods* (USEPA 1987).

5.0 ANALYTICAL DATA AND INTERPRETATION OF RESULTS

This section presents the data and interpretation of results for the environmental surveillance program at NFSS. Data for 2001 are presented in Tables 2 through 10 (Appendix A).

In data tables containing analyses for radioactive constituents, some results may be expressed as negative numbers. This phenomenon occurs if the average background activity of the laboratory counting instrument exceeds the measured sample activity. In such cases, when this instrument background activity is subtracted from the sample activity, a negative number results. For the purposes of interpretation, all values below the baseline minimum detectable activity (MDA) are interpreted as having an unknown value between zero and the MDA. Such a value is referred to as a nondetect in the text discussion.

For comparison of analytical results to the DOE soil guideline limits and the Derived Concentration Guidelines (DCGs), and subsequent assessment of potential impact, average background radioactivity in surface water, sediment, and groundwater is subtracted from the 2001 results. The analytical results and the background-corrected results are both provided in the data tables. However, for simplicity of presentation, only the analytical results (without the background subtracted) will be discussed in the text of this document.

The historical background concentration for each radioactive analyte is determined from background sampling results from 1992 to 2001, unless otherwise noted (BNI 1997a). Subtracting the calculated background from the sampling results for 2001 then gives an estimate of the above-background concentration of the measured constituent at each location, see Table 2 External Gamma Radiation Dose Rates (Appendix A, page T-7). When background is subtracted from the sampling result, it is possible that a negative number will be obtained much the same as a negative value may be obtained when the laboratory subtracts instrument background from a sample measurement. A negative number is considered indistinguishable from background.

Some of the historical data from NFSS used a method for analysis of total uranium which yields results in µg/L and µg/g for water and sediment samples, respectively. To allow direct comparison of results to the DCGs and soil guidelines, the data was converted to pCi/L and pCi/g, as appropriate. The specific activity for total uranium in its natural isotopic abundance (uranium that is neither depleted nor enriched) is 0.9 pCi/µg (USEPA 2000), which is the factor used to convert the data to pCi/L or pCi/g, as appropriate.

5.1 External Gamma Radiation

External gamma radiation dose rates are measured using thermoluminescent dosimeters (TLDs) in place at NFSS continuously throughout the year. Each TLD measures a cumulative dose over the period of exposure (approximately six months). When corrected for background and normalized to exactly one year's exposure, these detectors provide a measurement of the annual external gamma radiation dose at that location. TLD results for the 2001 external gamma radiation dose (both raw and corrected data) are summarized in Table 2, External Gamma Radiation Dose Rates (Appendix A, page T-7).

The corrected data are used to calculate the external gamma radiation dose rate at both the nearest residence and the nearest commercial/industrial facility to determine the hypothetical maximally exposed individual (MEI). Net monitoring results (average normalized location minus average normalized background reading) that are less than zero are assumed to be zero. The dose rate is a function of the site fenceline dose, the distance of the individual from the fenceline, and the amount of time the individual spends at that location. Occupancy of the nearest residence is assumed to be 24 hours/day, 365 days/year, while occupancy of the nearest commercial/industrial facility is assumed to be 40 hours/week, 50 weeks/year. Results of this calculation are expressed as a maximum dose rate to the individual (mrem/year).

Based on 2001 external gamma radiation results, the hypothetical MEI would be a commercial/industrial worker conservatively assumed to work at a location 150 feet east of the site perimeter fence for 40 hours/week, 50 weeks/year, with a dose rate of 0.0006 mrem/year (1,020 feet from the TLD monitoring line). The dose rate at the nearest residence located 3,600 feet southwest of the site conservatively assumed to reside at the location 24 hours/day, 365 days/year, would be 0.0003 mrem/year. Both dose rate values are well below the DOE guideline of 100 mrem/year (for all pathways, excluding radon).

5.2 Radon Gas

Based on the radioactive constituents in the wastes contained in the WCS, it is unlikely that radon-220 would be emitted from the WCS; however, it is possible that radon-222 would be emitted. Air surveillance is conducted to determine the concentration of radon gas at NFSS using Radtrak® detectors that are designed to measure alpha particle emissions from both isotopes of radon (radon-220 and radon-222) and to collect passive, integrated data throughout the period of exposure. Because radon-220 is not a contaminant of concern at NFSS, all concentrations are conservatively assumed to be radon-222. Results of semiannual monitoring in 2001 are presented in Table 3; the corresponding surveillance locations are shown in Figure 2.

Consistent with results from previous years, most of the radon-222 results from the 2001 environmental surveillance program were at the detection limit (0.20 pCi/L) or slightly above for the first half (average of first 6-months of 2001: 0.28 pCi/L) of the year and slightly above the detection limit (average of last 6-months of 2001: 0.36 pCi/L) for the second half of 2001. All of the on-site results compare favorably with the DOE off-site limit of 3.0 pCi/L above background (average background:0.22 pCi/L).

Radon monitoring at NFSS is performed at a level that is representative of the human breathing zone (1.7 meters above ground level). Radon concentration diminishes significantly as distance from the ground increases and mixing with ambient air takes place.

5.3 Radon-222 Flux

Measurement of radon-222 flux provides an indication of the rate of radon-222 emission from a surface. Radon-222 flux is measured with activated charcoal canisters placed at 15-m grid across the surface of the WCS for a 24-h exposure period. Measurements for 2001 are presented in Table 4; measurement locations are shown in Figure 2.

Measured results for 2001 ranged from below background (average 0.094) to 0.318 pCi/m^2/s, with an average result of 0.088 pCi/m^2/s. As in previous years, these results are well below the 20.0 pCi/m^2/s standard specified in 40 CFR Part 61, Subpart Q, and demonstrate the effectiveness of the containment cell design and construction in mitigating radon-222 migration.

5.4 Airborne Particulate Dose

To determine the dose from airborne particulates potentially released from NFSS during 2001, airborne particulate release rates were calculated using historical data for site soil contamination and weather data from the National Weather Service. (Contributions from radon gas, which is not a particulate, are not considered in this calculation.) The total airborne particulate release rate is then entered into the USEPA's CAP88-PC computer model to perform two calculations:

1. The first calculation estimates resultant doses from airborne particulates to hypothetical individuals at the distances to the nearest residences and to the nearest commercial/industrial facilities as measured from a central location onsite (center of the WCS). Hypothetical doses are then corrected for residential occupancy (conservatively assumed to be 24 hours/day, 365 days/year) and commercial/industrial facility occupancy (40 hours/week, 50 weeks/year). The hypothetical individual receiving the higher of these calculated doses is then identified as the hypothetical MEI for airborne particulate dose.

2. The second calculation estimates the hypothetical airborne particulate collective dose to the population within 80 km of the site using a population file (generated from county population densities) to determine the number of people in circular grid sections fanning out to 80 km from the center of site.

The first calculation (SAIC 2001) indicates that the 2001 airborne particulate dose to the hypothetical MEI, an occupant at the commercial/industrial facility 1475 meters east of the WCS, was 0.049 mrem per year. This value is well below the 10 mrem per year standard specified in 40 CFR, Part 61, Subpart H, and the DOE Order 5400.5. The second calculation (SAIC 2001) indicates that the hypothetical airborne particulate collective dose to the population within 80 km of the site was 0.046 person-rem per year. Details of the calculations, including methodology are presented in Appendix C (FUSRAP CY2001 NESHAP ANNUAL REPORT FOR NIAGARA

FALLS STORAGE SITE (NFSS)).

5.5 Surface Water and Sediment

In 2001, annual surface water and sediment samples were collected at five locations: SWSD009 and SWSD021 at the upstream fenceline; SWSD010 and SWSD022 onsite along the central drainage ditch; and SWSD011, downstream along the central drainage ditch. Surface water and sediment sampling location SWSD009 was selected as a background location because it is at the upstream boundary of the South 31 drainage ditch, a drainage which eventually joins the central drainage ditch. Surface water and sediment sampling location SWSD021 was selected as a background location because it is located upstream, along the NFSS fenceline, where the central drainage ditch first enters the property. Sampling locations are presented in Figure 2., Appendix A.

Surface water and sediment samples were analyzed for radium-226, radium-228, thorium-230, thorium-232, uranium-234, urnaium-235, and uranium-238. The 2001 environmental surveillance analytical results for surface water and sediment samples are presented in Appendix A, Tables 5 and 6, respectively. Analytical results for surface water in 2001 are compared with the DOE DCGs for radium-226, radium-228, thorium-230, thorium-232, and total uranium (sum of the uranium-234, -235, and -238 isotopes). Because there are no established standard for sediments, DOE historically used the surface soil criterion of 5 pCi/g as a basis of comparison of radium-226, radium-228, thorium-230 and thorium-232 analytical results. The historic values are being used as a basis for comparison of total uranium analytical results in sediment.

Background concentrations were determined by averaging historical analytical results for the appropriate constituents at surface water/sediment sampling locations SWSD009 and SWSD021. For total uranium and radium-226, background concentrations include data from 1992 through 2001 for surface water and sediment. Because analysis for thorium-232 first began in 1995 in sediment and 1996 in surface water, background concentrations for thorium-232 were determined from analytical results from 1995 and/or 1996 through 2001, as appropriate. Similarly, background concentrations for radium-228 and thorium-230 were determined from analytical results beginning in 1997.

5.5.1 Surface Water

In 2001 as in previous years surface water analytical results were consistently less than the DOE DCGs and were generally indistinguishable from the historical background (upstream) concentrations. Measured results (with background not subtracted) are provided in Table 5 and discussed below:

- The 2001 on-site analytical results for radium-226 concentrations in surface water, ranging from 0.37 to 0.59 pCi/L, are consistent with historical results and are indistinguishable from background (0.13 and 0.37 pCi/L). The historical background concentration for radium-226 ranges from nondetect to 1.81 pCi/L. The radium-226 DOE DCG is 100 pCi/L.

- The 2001 on-site analytical results for radium-228 concentrations in surface water, ranging from nondetect to 0.51 pCi/L, are consistent with historical results. Background was 0.75 and 1.02 pCi/L. The historical background concentration for radium-228 ranges from nondetect to 0.58 pCi/L . The radium-228 DOE DCG is 100 pCi/L.

- The 2001 on-site analytical results for thorium-230 concentrations in surface water, ranging from 0.24 to 0.73 pCi/L, are consistent with historical results. Background concentrations were 0.24 and 0.52 pCi/L. The historical background concentration for thorium-230 ranges from nondetect to 0.63 pCi/L. The thorium-230 DOE DCG is 300 pCi/L.

- The 2001 on-site analytical results for thorium-232 concentrations in surface water were 0.12 to 0.32 pCi/L, and are consistent with historical results. Background results were 0.14 and 0.17 pCi/L. The historical background concentration for thorium-232 ranges from nondetect to 0.13 pCi/L. The DOE DCG for thorium-232 is 50 pCi/L.

- The 2001 on-site analytical results for total uranium in surface water, ranging from 5.72 to 10.44 pCi/L, are consistent with historical results and are indistinguishable from background (5.53 and 19.92 pCi/L). The historical background concentration for total uranium ranges from 2.77 to 15.3 pCi/L. The DOE DCG for total uranium is 600 pCi/L.

5.5.2 Sediment

Concentrations of radium-226, radium-228, thorium-230, thorium-232, and total uranium in shallow sediment were less than the DOE surface soil guidelines and were generally indistinguishable from upstream (background) conditions. At all sampled locations, results were less than the DOE guideline for mixtures of radionuclides (using the sum-of-the-ratios method). Measured results (with background not subtracted) are presented in Appendix A Table 6, page T-13, and discussed below.

- The 2001 analytical results for radium-226 in sediment are consistent with historical analytical results. Radium-226 results from upstream (background) locations SWSD009 and SWSD021 were 0.93 and 0.62 pCi/g, respectively, comparing favorably with the historical background range of 0.34 to 2.10 pCi/g. The 2001 results of analysis for radium-226 in samples collected at downstream locations (SWSD010, SWSD011, and SWSD022) ranged from 0.91 to 1.19 pCi/g.

Historically, the concentration of radium-226 has ranged from nondetect to 2.9 pCi/g. All radium-226 concentrations in sediment were less than the DOE surface soil cleanup criterion of 5 pCi/g above background.

- The 2001 analytical results for radium-228 in sediment are consistent with historical analytical results. Radium-228 results from upstream (background) locations SWSD009 and SWSD021 were 0.89 and 0.79 pCi/g, respectively. The 2001 results for radium-228 in samples collected at downstream locations (SWSD010, SWSD011, and SWSD022) ranged from 1.03 to 1.60 pCi/g. Historically, the concentration of radium-228 has ranged from nondetect to 3.10 pCi/g. All radium-228 concentrations in sediment were less than the DOE surface soil cleanup criterion of 5 pCi/g above background.

- The 2001 analytical results for thorium-230 in sediment are consistent with historical analytical results. Thorium-230 results from upstream (background) locations SWSD009 and SWSD021 were 2.57 and 1.42 pCi/g, respectively. The 2001 results for thorium-230 in samples collected at downstream locations (SWSD010, SWSD011, and SWSD022) ranged from 1.33 to 2.54 pCi/g. Historically, the concentration of thorium-230 has ranged from nondetect to 2.30 pCi/g. All thorium-230 concentrations in sediment were less than the DOE surface soil cleanup criterion of 5 pCi/g above background.

- The 2001 analytical results for thorium-232 in sediment are consistent with historical analytical results. Thorium-232 results from upstream (background) locations SWSD009 and SWSD021 were 1.19 and 1.78 pCi/g, respectively. The 2001 results for thorium-232 in samples collected at downstream locations (SWSD010, SWSD011, and SWSD022) ranged from 1.27 to 1.57 pCi/g. Historically, the concentration of thorium-232 has ranged from nondetect to 1.60 pCi/g. All thorium-232 concentrations in sediment were less than the DOE surface soil cleanup criterion of 5 pCi/g above background.

- The 2001 analytical results for total uranium in sediment are consistent with historical analytical results. Total uranium results from upstream (background) locations SWSD009 and SWSD021 were 4.27 and 3.68 pCi/g, respectively. The 2001 results for total uranium in samples collected at downstream locations (SWSD010, SWSD011, and SWSD022) ranged from 3.76 to 7.65 pCi/g. Historically, the concentration of total uranium has ranged from nondetect to 9.13 pCi/g.

5.6 Groundwater

The locations of environmental surveillance groundwater monitoring wells at NFSS are shown in Figure 2. Background information, descriptions of activities performed under the groundwater surveillance program, and surveillance results are discussed below.

5.6.1 Groundwater Flow System

5.6.1.1 Natural System

Four unconsolidated units and one bedrock unit are readily identified in the subsurface at the site. The principle hydrogeologic layers zonation from top to bottom consist of the Upper Aquifer (fill and Upper Clay Till Units), and Aquitard confining unit (Glacio-Lacustrine Clay and Middle Silt Till Units), and the Lower Aquifer (Alluvial Sand and Gravel, Basal Red Till and Upper Queenston Formation). *See Figure-7 Schematic of Conceptualized Hydrostratigraphy in Appendix A, page F-7.* Groundwater at NFSS occurs in two unconsolidated deposits and the shale bedrock. In the unconsolidated deposits, two distinct groundwater systems are present: the upper groundwater system, which occurs within the uppermost clay unit, and the lower groundwater system, which occurs within the sand and gravel unit, the underlying till unit, and the weathered portion of the bedrock shale. The bedrock groundwater system occurs within the unweathered portion of the bedrock shale. Regionally, groundwater in both the upper and lower groundwater systems and the bedrock system flows northwestward toward Lake Ontario.

Surface drainage from the site originally entered Fourmile, Sixmile, and Twelvemile Creeks, which all flow northward to Lake Ontario. In the 1940s, a system of drainage ditches was installed to drain surface water to a central drainage ditch. The drainage ditches significantly influence groundwater flow in the upper groundwater system near the WCS and ditch. Historically low concentrations of constituents in groundwater wells completed in the lower groundwater system and the continuously low concentrations of constituents monitored in the upper groundwater system indicate that annual monitoring of the lower groundwater system is not currently necessary. Because the monitoring wells completed in the upper groundwater system provide an early detection network by which to monitor the performance of the WCS, the lower groundwater system is not routinely monitored as part of the environmental surveillance program. Special groundwater studies that are conducted periodically at NFSS typically include sampling and analysis of groundwater samples from the lower groundwater system. These studies help to verify the effectiveness of the upper groundwater system monitoring well network for monitoring WCS performance.

Background concentrations for the upper groundwater system were determined by averaging 1992 through 1997 analytical results for the appropriate constituents at the background monitoring well B02W20S. This well was selected as the background well because it is distant and is not downgradient from the WCS.

5.6.1.2 Water Level Measurements

Water level measurements are obtained using an electronic depth-to-water meter. Eighty-one groundwater monitoring wells are used to monitor groundwater levels in both the upper and lower groundwater systems (41 in the upper ground water system, 34 in the lower groundwater system & 6 in bedrock). Of these wells, 41 are screened in the upper groundwater system, including fifteen that were installed in 2001. The screened intervals for wells completed in the upper groundwater zone range from 1.7 to 8.4 m (5.5 to 27.6 ft) below ground surface. Thirty-four of these wells are screened in the lower groundwater system. The screened intervals for wells completed in the lower groundwater zone range from 7.7 to 14.0 m (25.2 to 46.0 ft) below ground surface. Groundwater monitoring wells were located primarily on the perimeter of the WCS and along the northern property fenceline (Figure 2), however the new wells were placed throughout the site.

The groundwater elevations at the monitoring well pairs were examined for some information about vertical gradients. In the first quarter the elevations in the upper system were almost uniformly greater to the corresponding measurements in the lower unit. In the third and fourth quarters the majority of elevations in the lower system were significantly greater than those measured in the upper system. Therefore, it appears that the direction and magnitude of the vertical gradient changes seasonally. While groundwater flow is primarily horizontal, this vertical hydraulic gradient indicates that there may be small components of vertical flow in either direction.

In the upper groundwater system, the depth to water ranged from 0.5 to 5.9 m (1.8 to 19.4 ft) below ground surface during 2001, and average quarterly water level fluctuations in the upper groundwater system were 0.9 m (3.0 ft). This system is contained significant local high and low elevations, particularly in the September measurement.

In the lower groundwater system, the depth to water ranged from 0.3 to 3.7 m (1.1 to 12.1 ft) below ground surface during the year. Average water level fluctuations in the lower groundwater system were 0.5 m (1.5 ft). Current and historical results indicate that the upper groundwater system responds more rapidly than the lower groundwater system to seasonal fluctuations in groundwater recharge and the effects of watering the WCS to maintain the appropriate soil-moisture content in the capping material. Groundwater level fluctuations in the lower groundwater system occur over a significantly longer period than in the upper groundwater system, indicating that the glaciolacustrine clay aquitard slows and dampens recharge to the lower groundwater system. The Glacio-Lacustrine Clay Unit and intervening Middle Silt Till Unit act as an aquitard between the Upper Aquifer and the underlying units.

In Appendix A Figures 3 (lower groundwater system) and 4 (upper groundwater system) present piezometric surfaces and groundwater flow directions representative of the high condition in the groundwater systems. Figures 5 (lower groundwater system) and 6 (upper groundwater system) present piezometric surfaces and groundwater flow directions representative of the low conditions. Surfer® software was employed for all piezometric surface and groundwater flow diagrams.

5.6.1.3 Groundwater Flow

Groundwater occurs in near-surface lacustrine sediments consisting mostly of horizontal layers of unconsolidated sand, silt, and clay. Two groundwater systems monitored at the site are associated with the uppermost clay unit and the sand and gravel unit, corresponding to the upper and lower groundwater systems, respectively. Hydrologic data indicate that the glaciolacustrine clay unit hydraulically isolates the upper clay unit and the lower sand and gravel unit, which is present across the entire site. The gradient for the upper system (ranging between 0.003 and 0.013) was erratic. However, general trends towards the drainage ditch east of the waste containment system were consistently apparent. In the lower system, groundwater flow was generally north to northwest with local low points on the edge of the waste containment system. The approximate gradients were between 0.0015 and 0.003. Dewatering activities on the adjacent property (Modern Landfill) entails the pumping out of groundwater to lower groundwater levels in order to minimize lifting affects on developing cell liners. Excessive dewatering by Modern Landfill can affect area groundwater flow. No effects of the dewatering activities, were apparent in the 2001 measurements.

A groundwater flow velocity of 38 cm/yr (15 in./yr) has previously been estimated at NFSS (DOE 1994b). This velocity does not necessarily represent the rate at which a contaminant could migrate, because contaminant-dependent transport factors such as retardation (caused by physical interactions such as contaminants binding to clay particles) can significantly slow the rate of transport.

Groundwater elevations during the seasonal high condition in the lower system (June 20, 2001 –see Figure 3) ranged from 95.24 to 96.75 m (312.46 to 317.42 ft) above mean sea level. The range of elevations during the seasonal low condition in the lower system (September 27, 2001 –see Figure 5) was 93.69 m (307.37 ft) to 95.92 m (314.71 ft) above mean sea level. Elevations above mean sea level in the upper system ranged between 92.93 and 96.23 m (304.90 and 315.73 ft) for the low conditions (September 19,2001 – see Figure 6) and between 94.43 and 98.09 m (309.80 and 321.83 ft) for the high conditions (March 24, 2001 – see Figure 4).

5.6.2 Groundwater Analytical Results

5.6.2.1 Field Parameters

Table 7, Appendix A summarizes field measurements (temperature, pH, specific conductance, oxidation-reduction potential, and turbidity) for 2001 environmental surveillance sampling. These measurements represent water conditions at the time of sampling.

5.6.2.2 Water Quality Parameters

At NFSS, the upper groundwater system water quality indicates relatively recently recharged groundwater. The lower groundwater system water quality parameters indicate longer residence times or distance traveled. It is likely that the primary recharge of the lower groundwater system occurs at the base of the Niagara Escarpment, situated approximately 3.2 km south of the site (DOE 1994b). Water quality parameter data for 2001 are provided in Table 8, Appendix A.

Analytical results for sodium, sulfate, and total dissolved solids were consistently above the drinking water standards in both the upstream (background) and downstream samples. These values indicate that groundwater in the area is naturally slightly saline and confirm the findings of the regional studies and studies conducted near the site (La Sala 1968; Wehran 1977; Acres American 1981) that groundwater quality is poor near the site because of high mineralization. Groundwater at NFSS is not used as a public water supply; however, the comparison to the drinking water standard will continue to be used to provide a conservative evaluation of groundwater analytical results.

Total dissolved solids (TDS), sulfate, and sodium were present onsite and upgradient (background) in concentrations exceeding NYSDEC water quality standards; there are no federal standards for these water quality parameters. TDS results in all wells including the background well (ranging from 915 to 1,700 mg/L) exceed the NYSDEC water quality standard (500 mg/L). Sodium was detected in all wells, including the background well, at concentrations ranging from 43.1 mg/L to 76.5 mg/L. The results are consistently greater than the NYSDEC groundwater quality standard for sodium (20 mg/L). Sulfate was also detected in all wells at concentrations ranging from 240 mg/L to 850 mg/L . All wells except one had sulfate concentrations greater than the NYSDEC groundwater quality standard for sulfate (250 mg/L).

5.6.2.3 Groundwater - Radioactive Constituents

In 2001, unfiltered groundwater samples collected from eight groundwater monitoring wells completed in the upper groundwater system were analyzed for radium-226, radium-

228, thorium-230, thorium-232, uranium-234, uranium-235, and uranium-238. Environmental surveillance analytical results for radioactive constituents in groundwater are presented in Table 9. Only results for detected analytes are discussed.

Radium-226 concentrations in groundwater at NFSS have been consistently low, with almost all measured concentrations (background not subtracted) less than 1 pCi/L. Radium-228 is present at essentially negligible concentrations. Combined concentrations of radium-226 and radium-228 at NFSS are well below the SDWA MCL. Thorium concentrations for 230&232 are well below DOE DCGs (Derived Concentration Guide for water). The 2001 total uranium analytical results are consistent with the historical results. Since 1992, total uranium concentrations in all sampled wells have been less than 60 pCi/L.

All analytical results for radium-226, radium-228, thorium-230, thorium-232, and total uranium in groundwater were well below the DOE DCGs. At all sampled locations, results were less than the DOE guideline for mixtures of radionuclides (using the sum-of-the-ratios method). Current analytical results (background not subtracted) are summarized below.
Note: Groundwater at NFSS is not a drinking water source, samples at time of sampling are unfiltered.

- The 2001 analytical results for radium-226 ranged from 0.02 to 0.74 pCi/L with an average value of 0.34 pCi/L. The DOE DCG for radium-226 is 100 pCi/L above background (2001 background level: 0.23 pCi/L).

- The 2001 analytical results for radium-228 ranged from non-detect to 0.92 pCi/L with an average value of 0.43 pCi/L. The DOE DCG for radium-228 is 100 pCi/L above background (2001 background level: 0.70 pCi/L).

- The 2001 analytical results for thorium-230 ranged from 0.14 to 0.49 pCi/L with an average value of 0.30 pCi/L. The DOE DCG for thorium-230 is 300 pCi/L above background (2001 background level: 0.46 pCi/L).

- The 2001 analytical results for thorium-232 ranged from non-detect to 0.32 pCi/L with an average value of 0.10 pCi/L. The DOE DCG for thorium-232 is 50 pCi/L above background (Background: 0.01 pCi/L).

- The 2001 analytical results for total uranium ranged from 7.61 to 52.1 pCi/L (OW04B) with an average value of 23.5 pCi/L (background: 9.37 pCi/L). The USEPA National Primary Drinking Water Regulation for Radionuclides (Final Rule – effective 2003) states a MCL of 30µg/L for total uranium. Conversion of the 52.1

pCi/L to µg/L (assuming a 0.9 mass:activity ratio) is 57.9 µg/L. This is above the drinking water final ruling effective 2003. *Note: The above concentration (30µg/L) is for comparative purposes only*.

5.6.2.4 Groundwater - Chemical Constituents/Metals

The 2001 environmental surveillance analytical results for metals in groundwater are presented in Table 10, Appendix A, and discussed below.

Groundwater at NFSS is not used as a public drinking water supply; however, as a conservative basis for comparison of analytical results, SDWA MCLs and New York State Water Quality Regulation Class GA standards were used. Although copper was present in four groundwater monitoring wells sampled at NFSS and lead in three, the 2001 analytical results indicate that neither the SDWA MCLs nor the New York State Water Quality Regulation Class GA standards for thess metals was exceeded at any of the wells. Vanadium was not detected in the eight wells sampled in 2001.

- In 2001 copper results were nondetect to 11.6 µg/L. The SDWA MCL is 1,300 µg/L and the New York State Water Quality Regulation Class GA standard of 200 µg/L. Historically, the concentration of copper has ranged from nondetect to 41.1 µg/L.

- In 2001 lead results were nondetect to 5.0 µg/L. The SDWA MCL is 15 µg/L and the New York State Water Quality Regulation Class GA standard of 25 µg/L. Historically, the concentration of lead has ranged from nondetect to 6.8 µg/L.

- In 2001, vanadium results were nondetect. Historically, the concentration of vanadium has ranged from nondetect to 53.4 µg/L. Neither an SDWA MCL nor a New York State Water Quality Regulation Class GA standard has been established for vanadium.

6.0 CONCLUSIONS

6.1 External Gamma Radiation

The 2001 external gamma radiation dose rate to a hypothetical maximally exposed individual is negligible at a calculated value of 0.0006 mrem/year.

6.2 Radon Gas

Results of the 2001 radon gas surveillance program indicate that the radon gas concentrations at the site were consistently low (nondetect to 0.5 pCi/L, including background) and in many cases were at or below the detection limit. All radon gas concentration analytical results at NFSS were well below the DOE limit for radon-222 of 3.0 pCi/L above background.

6.3 Radon-222 Flux

The 2001 radon-222 flux measurements at NFSS ranged from 0.001 to 0.318 pCi/m^2/s, with an average result of 0.088 pCi/m^2/s. The average value is less than one per cent of the standard of 20 pCi/m^2/s specified in 40 CFR Part 61, Subpart Q of the National Emission Standards for Hazardous Air Pollutants (NESHAPs), demonstrating the effectiveness of the containment cell design and construction in mitigating radon-222 migration.

6.4 Airborne Particulate Dose

The 2001 airborne particulate dose rate from the wind erosion of soil to a hypothetical maximally exposed individual is calculated at 0.049 mrem/year. The hypothetical dose to the individual is negligible relative to the 10 mrem/y standard in 40 CFR Part 61, Subpart H of NESHAPs. The 2001 hypothetical airborne particulate collective dose to the population within a 80 km radius of the site is calculated at 0.046 personrem/year.

6.5 Cumulative Dose from External Gamma Radiation and Airborne Particulates

The 2001 maximum cumulative external gamma radiation and airborne particulate dose to a hypothetical individual is 0.0496 mrem/year. This value is negligible when compared with the DOE limit of 100 mrem/year.

6.6 Surface Water

In 2001, onsite radionuclide concentrations in surface water samples were consistent with historical results that are comparable to background and contribute negligibly to dose.

6.7 Sediment

In 2001, onsite radionuclide concentrations in sediment samples were consistent with historical results that are comparable to background and contribute negligibly to dose.

6.8 Groundwater

1n 2001, onsite radionuclide concentrations in groundwater samples were consistent with historical results and were comparable to background. Groundwater sample results for quality parameters and chemical constituents were also consistent with historical results that are comparable to background and contribute negligibly to dose.

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APPENDIX A

NFSS 2001 Environmental Surveillance Technical Memorandum

Environmental Monitoring at NFSS

This appendix documents the results of non-routine environmental monitoring activities conducted in 2001 and supplements the environmental surveillance information included in the body of this technical memorandum. These activities are described to present a more complete picture of the site activities during the year and to provide technical reviewers with sufficient information to determine how much these activities influenced site conditions and ultimately the environmental surveillance program.

Two distinct activities compose the FUSRAP monitoring program at NFSS: environmental monitoring and environmental surveillance. Environmental monitoring consists of measuring the quantities and concentrations of pollutants in solid wastes, liquid effluents, and air that are discharged directly to the environment from onsite activities. Environmental surveillance documents the effects, if any, of USACE activities on onsite and offsite environmental and natural resources. At FUSRAP sites, because there are typically no onsite waste treatment facilities with routine point discharges, the monitoring program consists primarily of environmental surveillance (BNI 1996). The Environmental Surveillance Technical Memorandum specifically reports the results of routine environmental surveillance sampling and, at applicable sites, includes information about routine environmental monitoring (stormwater discharges and radon flux measurement).

The two part remedial investigation that began in 1999 continued through the year 2001 at NFSS.

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FUSRAP NIAGARA FALLS STORAGE SITE

2001

TABLES

ENVIRONMENTAL SURVEILLANCE TECHNICAL MEMORANDUM

US Army Corps of Engineers ®
Buffalo District

Table A.1
(Section 1.2 Unit Conversions)
Units of Measurement and Conversion Factors - Radioactivity

Parameter	Conventional Units	SI Units	Conversion Factor
Dose	millirem (mrem)	milliSievert (mSv)	1 mrem = 0.01 mSv
Activity	picoCurie (pCi)	becquerel (Bq)	1 pCi = 0.037 Bq

Table A.2
Units of Measurement and Conversion Factors - Mass, Length, Area, and Volume

Parameter	SI Units	English Units	Conversion Factor
Mass	gram (g)	Ounce (oz)	1 g = 0.035 oz
	kilogram (kg)	Pound (lb)	1 kg = 2.2046 lb
Length	centimeter (cm)	Inch (in.)	1 cm = 0.394 in.
	meter (m)	foot (ft)	1 m = 3.281 ft
	kilometer (km)	mile (mi.)	1 km = 0.621 mi.
Area	hectare (ha)	Acre	1 ha = 2.47 acres
Volume	milliliter (mL)	Fluid ounce (fl. oz.)	1 ml = 0.0338 fl. oz.
	liter (L)	gallon (gal)	1 L = 0.264 gal
	cubic meter (m^3)	Cubic yard (yd^3)	1 m^3 = 1.307 yd^3

Table B
(Section: 2.1.2 USEPA Standards and USEPA Guidance – Clean Air Act)
Summary of Radiological Standards and Guidelines
- External Gamma Radiation and Air –

Parameter	DOE Order 5400.5 [a]	Other Federal Standard or Guidelines
Radon-222 flux	20 pCi/m^2/s	20 pCi/m^2/s [b]
Radon-222	3.0 pCi/L [e]	-
Radionuclide emissions (airborne particulates and radioactive gases excluding radon-220 and radon-222)	10 mrem/y	10 mrem/y [b]
Effective dose equivalent (total contribution from all sources[c])	100 mrem/y	100 mrem/y [d]

a *Guidelines provided in the DOE Order are above background concentrations or exposure rates.*
b *Federal (USEPA) Standard from 40 CFR, Part 61, subparts H (radionuclide emissions) and Q (radon-222 flux).*
c *Contributing sources at NFSS consist of external gamma radiation exposure, radionuclide emissions listed above, and ingested radionuclides in water and soil/sediment (listed in the following table).*
d *Federal (Nuclear Regulatory Commission) Standard 10 CFR 20 and proposed (USEPA) Radiation Protection Guidance for Exposure of the General Public (FR 59:66414, December 23, 1994)*
e *The guideline of 3.0 pCi/L is based on an annual average value at or above any location outside of the facility site.*

Table C

(Section: 2.2.2 Safe Drinking Water Act (SDWA))

Summary of Radiological Standards and Guidelines - Water and Sediment

Parameter	DOE DCG [a] for Water [b]	Other Federal Standards	DOE Guideline Limit for Residual Radioactivity in Surface Soil [c,d]
Total uranium	600 pCi/L	30 µg/L [e]	90 pCi/g
Thorium-232	50 pCi/L	15 pCi/L [f]	5 pCi/g
Thorium-230	300 pCi/L	15 pCi/L [f]	5 pCi/g
Combined Radium-226&228	100 pCi/L	5 pCi/L [e]	5 pCi/g

a. *DOE derived concentration guideline (DOE Order 5400.5) for drinking water. Groundwater at NFSS is not a drinking water source The above concentration is for comparative purposes only.*

b. *Surface water and groundwater (non-drinking water values); criteria represent concentrations above background. If a mixture of radionuclides is present, the sum of the ratios of each isotope to its respective DCG must be less than one.*

c. *Above-background concentrations in* soil, *averaged over the topmost 15-cm of soil.*

d. *There are no standards for sediment; therefore, the DOE residual (radium and thorium) and site-specific (uranium) surface soil cleanup guideline criteria are used as a basis for evaluating analytical results for sediment. If a mixture of the radionuclides is present in soil, then the sum of the ratios of the concentration of each isotope to the allowable limit must be less than one. This guideline applies for total uranium in natural isotopic abundance.*

e. *(This regulation is effective December 8, 2003 –National Primary Drinking Water Regulations;Radionuclide; FinalRule (Federal Register- December 7, 2000. Current SDWA MCL for the combined concentration of radium-226 and radium-228 in drinking water (40CFR141.1) Radium-228 has not been routinely detected at NFSS. Groundwater at NFSS is not a drinking water source. The above concentration is for comparative purposes only.*

e. *"Adjusted" gross alpha MCL of 15 pCi/L, excluding Ra-226, radon, and uranium –National Primary Drinking Water Regulations;Radionuclide; FinalRule (Federal Register- December 7,2000)*

Table D

(Section: 2.3 Groundwater - Chemical Parameters)

Groundwater - Chemical Parameters

Analyte	Related Regulations[a] Federal (mg/L)	State[c] (mg/L)
Alkalinity, Total as $CaCO_3$	NE	NE
Bicarbonate (HCO_3)	NE	NE
Calcium (Ca)	NE	NE
Carbonate (CO_3)	NE	NE
Chloride	250[d]	250
Copper	1.3 [e]	0.2 [e]
Lead	0.015[e]	0.025 [e]
Magnesium (Mg)	NE	35
Nitrogen, Nitrate as N (NO_3-N)	10[b]	10
Phosphorous, Total	NE	NE
Potassium (K)	NE	NE
Sodium (Na)	NE	20
Solids, Total Dissolved (TDS)	500 [d]	500
Sulfate (SO_4)	250 [d]	250
Vanadium	NE	NE

a. **Regulations presented pertain to drinking water quality and are listed for comparison only. No drinking water supply is obtained from groundwater at NFSS.** NE - Not established.

b. Federal Safe Drinking Water Act maximum contaminant levels from USEPA Drinking Water Regulations (40CFR141.62)

c. Water Quality Criteria (class GA) per 6 NYCRR, Part 703.

d. National Secondary Drinking Water Regulations (40CFR143.3) These regulations control primarily affect the aesthetic qualities of drinking water

f. Action Level

Table E

(Section: **4.0 SURVEILLANCE METHODOLOGY)**

FUSRAP Instruction Guides Used for Environmental Surveillance Activities

Document Number	Document Title
191-IG-007	Groundwater Level and Meteorological Measurements (BNI 1996b)
191-IG-011	Decontamination of Field Sampling Equipment at FUSRAP Sites (BNI 1996c)
191-IG-028	Surface Water and Sediment Sampling Activities (BNI 1993a)
191-IG-029	Radon/Thoron and TETLD Exchange (BNI 1993b)
191-IG-033	Groundwater Sampling Activities (BNI 1996d)

Table 1a
Environmental Surveillance Summary
External Gamma Radiation, Radon Gas, and Radon-222 Flux
Niagara Falls Storage Site

Measured Parameter	Station Identification	Number of Analyses or Measurements: No. of Sample Locations, CY Quarter 1	2	3	4	Sample Duplicate, CY Quarter 1	2	3	4	Ship Blank, CY Quarter 1	2	3	4	Contingency Sample, CY Quarter 1	2	3	4	Total Analyses per Year
LABORATORY MEASUREMENTS																		
External gamma radiation (TLDs)[a]	1, 7, 8, 10, 11, 12, 13, 15	20		20		1		1		1		1		20		20		84
	18, 21, 23, 24, 28, 29, 36																	
Radon gas	105, 116, 120 122, 123	20		20		1		1										42
Radon-222 flux	WCS[b]			183														183

a. TLD = Thermoluminescent Dosimeter.

b. Waste Containment Structure

Table 1b
Environmental Surveillance Summary
Groundwater
Niagara Falls Storage Site

Number of Analyses or Measurements

Measured Parameter	Station Identification	No. of Sample Locations (CY Quarter)				Rinsate Blank (CY Quarter)				Trip Blank (CY Quarter)				Sample Duplicate (CY Quarter)				Matrix Spike (CY Quarter)				Matrix Spike Duplicate (CY Quarter)				Total Analyses per Year
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
FIELD MEASUREMENTS																										
Dissolved oxygen	A45, A50, OW04B, OW06B, OW07B, OW15B, OW17B, B02W20S		8																							8
Eh			8																							8
Turbidity			8																							8
Temperature			8																							8
Specific conductivity			8																							8
pH			8																							8
LABORATORY MEASUREMENTS																										
Radiological																										
Total uranium	A45, A50, OW04B, OW06B, OW07B, OW15B, OW17B, B02W20S		8												1				1				1			11
Radium-226			8												1				1				1			11
Thorium-232			8												1				1				1			11
Metals																										
Copper			8												1				1				1			11
Lead			8												1				1				1			11
Vanadium			8												1				1				1			11
Water Quality [a]			8												1				1				1			11

a. Table 8 lists water quality parameters.

Table 1c
Environmental Surveillance Summary
Surface Water and Sediment
Niagara Falls Storage Site

Measured Parameter	Station Identification	Number of Analyses or Measurements																								
		No. of Sample Locations				Rinsate Blank				Trip Blank				Sample Duplicate				Matrix Spike				Matrix Spike Duplicate				Total Analyses per Year
		CY Quarter				CY Quarter				CY Quarter				CY Quarter				CY Quarter				CY Quarter				
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
FIELD MEASUREMENTS																										
Chemical																										
Dissolved oxygen	SWSD009		5																							5
Eh	SWSD010		5																							5
Turbidity	SWSD011		5																							5
Temperature	SWSD021		5																							5
Specific conductivity	SWSD022		5																							5
pH			5																							5
LABORATORY MEASUREMENTS																										
Radiological																										
Surface Water																										
Total uranium	SWSD009		5												1				1				1			8
Radium-226/228	SWSD010		5												1				1				1			8
Thorium-230/232	SWSD011		5												1				1				1			8
Sediment	SWSD021																									
Total uranium	SWSD022		5				1								1				1				1			9
Radium-226/228			5				1								1				1				1			9
Thorium-230/232			5				1								1				1				1			9

Table 2
2001 External Gamma Radiation Dose Rates
Niagara Falls Storage Site

NFSS - 2001 Data (TLD Exposure from: Jan.11, 2001 to Jan.03, 2002)

From 01/11/01 to 07/10/01 (180 days)

Monitoring Location[b]		TETLD[a] Dose Rate Total[c] (mrem)[f]	Corrected[d] (mrem/yr)[g]	Above Background[e] (mrem/yr)[g]
NFSS	1	22.2	45.0	1.3
Perimeter	1[i]	19.7	44.9	1.3
	7	19.4	39.3	-4.3
	7[i]	17.1	39.0	-4.7
	11	14.1	28.6	-15.1
	11[i]	15.8	36.0	-7.6
	12	15.6	31.6	-12.0
	12[i]	15.9	36.3	-7.4
	13	16.1	32.6	-11.0
	13[i]	18.4	42.0	-1.7
	15	17.8	36.1	-7.6
	15[i]	18.2	41.5	-2.2
	28	20.8	42.2	-1.5
	28[i]	20.1	45.9	2.2
	29	23.8	48.3	4.6
	29[i]	22.3	50.9	7.2
	36	18.2	36.9	-6.8
	36[i]	17.3	39.5	-4.2
	122	13.2	26.8	-16.9
	122[i]	19.6	44.7	1.0
	123	17.8	36.1	-7.6
	123[i]	16.8	38.3	-5.3
WCS[h]	8	12.1	24.5	-13.8
Perimeter	8[i]	15.3	34.9	-3.4
	10	20.7	42.0	3.7
	10[i]	19.2	43.8	5.5
	18	20.1	40.8	2.4
	18[i]	17.8	40.6	2.3
	21	17.7	35.9	-2.4
	21[i]	13.1	29.9	-8.4
	23	12.5	25.3	-13.0
	23[i]	20.2	46.1	7.8
	24	16.1	32.6	-5.7
	24[i]	15.3	34.9	-3.4

Background	105	13.6	27.6
Locations	105[i]	14.9	34.0
	116	18.4	37.3
	116[i]	15.3	34.9
	120	31.4	63.7
	120[i]	28.3	64.6
Average		**Total[c]**	**Corrected[d]**
Background		*20.3*	*43.7*

From 07/10/01 to 01/03/02 (177 days)

Monitoring Location[b]		TETLD[a] Dose Rate Total[c] (mrem)[f]	Corrected[d] (mrem/yr)[g]	Above Background[e] (mrem/yr)[g]
NFSS	1	23.6	48.7	4.7
Perimeter	1	19.2	39.6	-4.4
	7	18.3	37.7	-6.3
	7	0.6	1.2	-42.8
	11	15.6	32.2	-11.8
	11	18.9	39.0	-5.0
	12	19.2	39.6	-4.4
	12	12.8	26.4	-17.6
	13	20.9	43.1	-0.9
	13	5.5	11.3	-32.7
	15	18.6	38.4	-5.6
	15	21.1	43.5	-0.5
	28	22.8	47.0	3.0
	28	24.7	50.9	6.9
	29	27.7	57.1	13.1
	29	24.5	50.5	6.5
	36	18.2	37.5	-6.5
	36	23.4	48.3	4.3
	122	21.5	44.3	0.3
	122	11.2	23.1	-20.9
	123	19.2	39.6	-4.4
	123	17.2	18.9	-25.1
WCS[h]	8	18.9	20.7	1.9
Perimeter	8	7.0	7.7	-11.2
	10	24.0	26.3	7.5
	10	25.5	27.9	9.1
	18	17.3	19.0	0.1
	18	16.9	18.5	-0.3
	21	20.8	22.8	3.9
	21	19.2	21.0	2.2
	23	24.8	27.2	8.3
	23	23.6	25.9	7.0
	24	16.8	18.4	-0.4
	24	15.2	16.7	-2.2

Background	105	17.6	36.3
Locations	105	17.6	36.3
	116	17.4	35.9
	116	15.3	31.6
	120	30.8	63.5
	120	29.3	60.4
Average		**Total[c]**	**Corrected[d]**
Background		*21.3*	*44.0*

a. TLD = Thermoluminescent dosimeter. There are two TLDs per monitoring location.
b. Monitoring locations are shown in Figure 2.
c. Reported values are the average chip reading per TLD. There are five chips in each TLD.
d. TLD are normalized to a one-year exposure.
Corrected yearly exposure = TLD reading * 365 days/number of days of exposure.
Example (Location 1, First TLD):
22.2 mrem * 365 days per year/180 days = 45.0 mrem/year.
e. Average background (corrected) is subtracted from corrected yearly exposure.
Above-background exposure = corrected yearly exposure - corrected average background.
Example (Location 1, First TLD): 45.0 mrem/year - 43.7 mrem/year = 1.3 mrem/year.

f. mrem - millirem.
g. mrem/yr - millrem per year.
h. Monitoring locations along the perimeter of the waste containment structure (WCS).
i. Contengency TLDs started on 01/31/01 ended on 07/10/01 (exposure of 160 days).

Table 3
2001 Radon Gas [a] Concentrations
Niagara Falls Storage Site

NFSS - 2001 Data

Monitoring Location[c]	Monitoring Station	Average Daily Concentration (pCi/L)[b]		
		Start Dates[d]:	**01/11/2001**	**07/10/2001**
		End Dates[d]:	**07/10/2001**	**01/03/2002**
NFSS Perimeter	1		0.3	0.4
	7		0.4	0.4
	11		0.2	0.3
	12		0.3	0.4
	12 (dup[e])		0.3	0.3
	13		0.2	0.2
	15		0.3	0.3
	28		0.2	0.4
	29		0.4	0.3
	36		0.3	0.3
	122		0.3	0.3
	123		0.3	0.4
WCS[f] Perimeter	8		0.3	0.5
	10		0.4	<0.2
	18		0.3	0.5
	21		0.2	0.5
	23		0.4	0.2
	24		0.3	0.3
Background	105		0.2	0.2
	116		0.2	0.3
	120		0.2	0.2

a. Radon gas concentrations in 2001 were measured with RadTrack detectors. These detectors measure the combined concentration of radon-220 and radon-222 in air.
b. pCi/L - picocuries per liter.
c. Monitoring locations are shown in Figure 2.
d. Detectors were installed and removed on the dates listed.
e. A quality control duplicate is collected at the same time and location and is analyzed by the same method for evaluating precision in sampling and analysis.
f. Monitoring locations are at the perimeter of the waste containment structure (WCS).

Note: The DOE limit for radon-222 is 3.00 pCi/L above background.
(<0.2) Indicates detection limit is reported. Actual result is less than this value.
1 pCi = 0.037 becquerel

Table 4
2001 Radon Flux Monitoring Results[a]
Niagara Falls Storage Site

NFSS Sample ID	Radon-222 Flux ($pCi/m^2/s$)	NFSS Sample ID	Radon-222 Flux ($pCi/m^2/s$)	NFSS Sample ID	Radon-222 Flux ($pCi/m^2/s$)
1	0.095 ± 0.043	41	0.049 ± 0.034	81	0.105 ± 0.072
2	0.141 ± 0.030	42	0.084 ± 0.057	82	0.047 ± 0.031
3	0.163 ± 0.080	43	0.065 ± 0.038	83	0.036 ± 0.045
4	0.118 ± 0.026	44	0.074 ± 0.043	84	0.061 ± 0.034
5	0.068 ± 0.054	45	0.126 ± 0.056	85	0.049 ± 0.044
6	0.090 ± 0.040	46	0.066 ± 0.063	86	0.052 ± 0.034
7	0.106 ± 0.035	47	0.118 ± 0.059	87	0.082 ± 0.047
8	0.079 ± 0.040	48	0.143 ± 0.067	88	0.043 ± 0.033
9	0.207 ± 0.081	49	0.069 ± 0.035	89	0.020 ± 0.038
10	0.110 ± 0.043	50	0.091 ± 0.046	90	0.140 ± 0.069
10 DUP	0.081 ± 0.038	50 DUP	0.083 ± 0.046	90 DUP	0.176 ± 0.078
11	0.139 ± 0.039	51	0.067 ± 0.041	91	0.121 ± 0.086
12	0.182 ± 0.075	52	0.063 ± 0.037	92	0.086 ± 0.066
13	0.002 ± 0.001	53	0.057 ± 0.050	93	0.084 ± 0.038
14	0.091 ± 0.057	54	0.109 ± 0.025	94	0.074 ± 0.039
15	0.069 ± 0.038	55	0.176 ± 0.075	95	0.074 ± 0.040
16	0.087 ± 0.049	56	0.103 ± 0.024	96	0.040 ± 0.024
17	0.083 ± 0.037	57	0.074 ± 0.061	97	0.046 ± 0.032
18	0.173 ± 0.080	58	0.042 ± 0.040	98	0.029 ± 0.038
19	0.077 ± 0.022	59	0.060 ± 0.034	99	0.044 ± 0.034
20	0.069 ± 0.057	60	0.117 ± 0.067	100	0.090 ± 0.068
20 DUP	0.108 ± 0.069	60 DUP	0.094 ± 0.049	100 DUP	0.034 ± 0.041
21	0.071 ± 0.022	61	0.135 ± 0.063	101	0.024 ± 0.028
22	0.067 ± 0.058	62	0.318 ± 0.066	102	0.074 ± 0.041
23	0.055 ± 0.028	63	0.107 ± 0.028	103	0.073 ± 0.049
24	0.080 ± 0.059	64	0.003 ± 0.048	104	0.145 ± 0.072
25	0.081 ± 0.046	65	0.128 ± 0.032	105	0.102 ± 0.026
26	0.001 ± 0.000	66	0.057 ± 0.047	106	0.009 ± 0.029
27	0.081 ± 0.043	67	0.049 ± 0.033	107	0.033 ± 0.035
28	0.093 ± 0.068	68	0.079 ± 0.055	108	0.097 ± 0.064
29	0.100 ± 0.045	69	0.057 ± 0.031	109	0.090 ± 0.044
30	0.101 ± 0.056	70	0.128 ± 0.037	110	0.161 ± 0.078
30 DUP	0.107 ± 0.077	70 DUP	0.107 ± 0.033	110 DUP	0.162 ± 0.074
31	0.098 ± 0.046	71	0.147 ± 0.072	111	0.137 ± 0.031
32	0.105 ± 0.027	72	0.088 ± 0.052	112	0.054 ± 0.033
33	0.085 ± 0.051	73	0.162 ± 0.071	113	0.083 ± 0.048
34	0.056 ± 0.032	74	0.112 ± 0.053	114	0.060 ± 0.046
35	0.044 ± 0.042	75	0.155 ± 0.047	115	0.010 ± 0.037
36	0.112 ± 0.033	76	0.085 ± 0.023	116	0.024 ± 0.028
37	0.217 ± 0.037	77	0.127 ± 0.059	117	0.038 ± 0.042
38	0.182 ± 0.074	78	0.109 ± 0.055	118	0.050 ± 0.036
39	0.046 ± 0.028	79	0.101 ± 0.071	119	0.096 ± 0.057
40	0.085 ± 0.053	80	0.077 ± 0.041	120	0.008 ± 0.022
40 DUP	0.079 ± 0.043	80 DUP	0.097 ± 0.049	120 DUP	0.051 ± 0.041

NOTE: The EPA Standard for Radon-222 Flux is 20 pCi/m2/sec

a. Radon-222 flux was performed in July 30-31, 2001

b. Every 10th canister is counted twice as a quality control (QC) duplicate (DUP) to evaluate analytical precision

c. Background

Table 4
2001 Radon Flux Monitoring Results[a]
Niagara Falls Storage Site

NFSS Sample ID	Radon-222 Flux ($pCi/m^2/s$)	NFSS Sample ID	Radon-222 Flux ($pCi/m^2/s$)	NFSS Sample ID	Radon-222 Flux ($pCi/m^2/s$)
121	0.063 ± 0.046	161	0.104 ± 0.057		
122	0.076 ± 0.044	162	0.102 ± 0.050		
123	0.073 ± 0.062	163	0.132 ± 0.060		
124	0.104 ± 0.027	164	0.092 ± 0.047		
125	0.098 ± 0.055	165	0.088 ± 0.051		
126	0.078 ± 0.038	166	0.107 ± 0.055		
127	0.106 ± 0.064	167	0.081 ± 0.058		
128	0.119 ± 0.053	168	0.097 ± 0.027		
129	0.148 ± 0.069	169	0.103 ± 0.062		
130	0.090 ± 0.047	170	0.077 ± 0.045		
130 DUP	0.099 ± 0.026	170 DUP	0.075 ± 0.038		
131	0.018 ± 0.033	171	0.028 ± 0.031		
132	0.096 ± 0.051	172	0.133 ± 0.069		
133	0.049 ± 0.035	173	0.074 ± 0.038		
134	0.043 ± 0.045	174	0.084 ± 0.037	Average:	0.088 ($pCi/m^2/s$)
135	0.052 ± 0.033	175	0.102 ± 0.045	High	0.318 ($pCi/m^2/s$)
136	0.091 ± 0.067	176	0.126 ± 0.060	Low	0.002 ($pCi/m^2/s$)
137	0.063 ± 0.041	177	0.077 ± 0.038		
138	0.046 ± 0.039	178	0.174 ± 0.098		
139	0.045 ± 0.028	179	0.058 ± 0.020		
140	0.084 ± 0.048	180	0.185 ± 0.093		
140 DUP	0.104 ± 0.070	180 DUP	0.180 ± 0.084		
141	0.104 ± 0.046	181[c]	0.070 ± 0.047		
142	0.096 ± 0.051	182[c]	0.126 ± 0.087		
143	0.085 ± 0.040	183[c]	0.086 ± 0.045		
144	0.107 ± 0.058				
145	0.076 ± 0.047				
146	0.088 ± 0.062				
147	0.052 ± 0.033				
148	0.026 ± 0.037				
149	0.077 ± 0.036				
150	0.026 ± 0.037				
150 DUP	0.125 ± 0.059				
151	0.118 ± 0.049				
152	0.115 ± 0.048				
153	0.087 ± 0.066				
154	0.023 ± 0.031				
155	0.079 ± 0.029				
156	0.025 ± 0.031				
157	0.085 ± 0.055				
158	0.062 ± 0.038				
159	0.114 ± 0.071				
160	0.084 ± 0.047				
160 DUP	0.107 ± 0.025				

NOTE: The EPA Standard for Radon-222 Flux is 20 pCi/m2/sec

a. Radon-222 flux was performed in July 30-31, 2001

b. Every 10th canister is counted twice as a quality control (QC) duplicate (DUP) to evaluate analytical precision

c. Background

Table 5
2001 Surface Water Analytical Results - Radioactive Constituents
Niagara Falls Storage Site

NFSS - 2001 Data
Surface Water Samples

Sampling Location	Date Collected	Analyte	Result (pCi/L)[a]			MDA[b] (pCi/L)[a]	DCG[c] (pCi/L)[a]
SWSD009	5/7/01	Radium-226	0.37	±	0.26	0.32	100
Background	5/7/01	Radium-228	0.75	±	0.65	1.05	100
	5/7/01	Thorium-230	0.24	±	0.21	0.23	300
	5/7/01	Thorium-232	0.14	±	0.17	0.28	50
	5/7/01	Uranium-234	3.55	±	1.20	0.56	600[d]
	5/7/01	Uranium-235	0.19	±	0.27	0.46	600[d]
	5/7/01	Uranium-238	1.79	±	0.77	0.46	600[d]
		Total uranium[e]	*5.53*				*600*[d]
SWSD021	5/7/01	Radium-226	0.37	±	0.24	0.44	100
Background	5/7/01	Radium-228	1.02	±	0.64	1.00	100
	5/7/01	Thorium-230	0.52	±	0.39	0.46	300
	5/7/01	Thorium-232	0.17	±	0.24	0.43	50
	5/7/01	Uranium-234	10.92	±	2.75	0.49	600[d]
	5/7/01	Uranium-235	0.23	±	0.27	0.39	600[d]
	5/7/01	Uranium-238	8.77	±	2.29	0.41	600[d]
		Total uranium[e]	*19.92*				*600*[d]
SWSD010	5/7/01	Radium-226	0.59	±	0.27	0.19	100
	5/7/01	Radium-228	0.28	±	0.64	1.10	100
	5/7/01	Thorium-230	0.66	±	0.36	0.38	300
	5/7/01	Thorium-232	0.12	±	0.15	0.25	50
	5/7/01	Uranium-234	5.35	±	1.75	0.81	600[d]
	5/7/01	Uranium-235	0.43	±	0.42	0.50	600[d]
	5/7/01	Uranium-238	4.66	±	1.57	0.55	600[d]
		Total uranium[e]	*10.44*				*600*[d]
SWSD011	5/7/01	Radium-226	0.46	±	0.29	0.42	100
	5/7/01	Radium-228	-0.23	±	0.72	1.32	100
	5/7/01	Thorium-230	0.24	±	0.23	0.32	300
	5/7/01	Thorium-232	0.16	±	0.19	0.32	50
	5/7/01	Uranium-234	4.12	±	1.20	0.32	600[d]
	5/7/01	Uranium-235	0.17	±	0.21	0.28	600[d]
	5/7/01	Uranium-238	2.42	±	0.84	0.34	600[d]
		Total uranium[e]	*6.71*				*600*[d]

Table 5
2001 Surface Water Analytical Results - Radioactive Constituents
Niagara Falls Storage Site

NFSS - 2001 Data
Surface Water Samples

Sampling Location	Date Collected	Analyte	Result (pCi/L)[a]			MDA[b] (pCi/L)[a]	DCG[c] (pCi/L)[a]
SWSD022	5/7/01	Radium-226	0.37	±	0.22	0.28	100
	5/7/01	Radium-228	0.51	±	0.65	1.10	100
	5/7/01	Thorium-230	0.28	±	0.25	0.37	300
	5/7/01	Thorium-232	0.18	±	0.22	0.39	50
	5/7/01	Uranium-234	2.65	±	0.86	0.22	600[d]
	5/7/01	Uranium-235	0.40	±	0.31	0.16	600[d]
	5/7/01	Uranium-238	2.75	±	0.89	0.30	600[d]
		Total uranium[e]	*5.80*				*600*[d]
Duplicate[f]	5/7/01	Radium-226	0.52	±	0.24	0.21	100
	5/7/01	Radium-228	0.31	±	0.59	1.01	100
	5/7/01	Thorium-230	0.73	±	0.37	0.24	300
	5/7/01	Thorium-232	0.32	±	0.24	0.27	50
	5/7/01	Uranium-234	3.35	±	1.11	0.51	600[d]
	5/7/01	Uranium-235	0.11	±	0.20	0.37	600[d]
	5/7/01	Uranium-238	2.26	±	0.84	0.36	600[d]
		Total uranium[e]	*5.72*				*600*[d]

a. pCi/L - picocuries per liter.
b. MDA - Minimum detectable activity.
c. DOE Derived Concentration Guide (DCG) for water.
d. 600 pCi/L DCG is for total uranium concentration.
e. Sum of uranium isotope concentrations.
f. A quality control duplicate is collected at the same time and location and is analyzed by the same method for evaluating precision in sampling and analysis (SWSD022).

Table 6
2001 Sediment Analytical Results - Radioactive Constituents
Niagara Falls Storage Site

Sampling Location	Date Collected	Analyte	Result (pCi/g)[a]			MDA[b] (pCi/g)[a]	Cleanup Criteria[c] (pCi/g)[a]
SWSD009	5/7/01	Radium-226	0.93	±	0.10	0.14	5
	5/7/01	Radium-228	0.89	±	0.21	0.28	5
Background	5/7/01	Thorium-230	2.57	±	0.80	0.29	5
	5/7/01	Thorium-232	1.19	±	0.48	0.22	5
	5/7/01	Uranium-234	1.85	±	0.66	0.33	90[d]
	5/7/01	Uranium-235	0.12	±	0.19	0.34	90[d]
	5/7/01	Uranium-238	2.30	±	0.76	0.34	90[d]
		Total uranium[e]	*4.27*				*90*[d]
SWSD021	5/7/01	Radium-226	0.62	±	0.12	0.19	5
	5/7/01	Radium-228	0.79	±	0.26	0.32	5
Background	5/7/01	Thorium-230	1.42	±	0.54	0.36	5
	5/7/01	Thorium-232	1.78	±	0.62	0.34	5
	5/7/01	Uranium-234	1.95	±	0.68	0.31	90[d]
	5/7/01	Uranium-235	0.00	±	0.00	0.13	90[d]
	5/7/01	Uranium-238	1.73	±	0.62	0.24	90[d]
		Total uranium[e]	*3.68*				*90*[d]
SWSD010	5/7/01	Radium-226	0.91	±	0.13	0.14	5
	5/7/01	Radium-228	1.03	±	0.24	0.30	5
	5/7/01	Thorium-230	1.33	±	0.56	0.34	5
	5/7/01	Thorium-232	1.28	±	0.55	0.34	5
	5/7/01	Uranium-234	1.96	±	0.71	0.40	90[d]
	5/7/01	Uranium-235	0.08	±	0.16	0.33	90[d]
	5/7/01	Uranium-238	1.72	±	0.66	0.48	90[d]
		Total uranium[e]	*3.76*				*90*[d]
SWSD022	5/7/01	Radium-226	0.97	±	0.21	0.29	5
	5/7/01	Radium-228	1.26	±	0.39	0.61	5
	5/7/01	Thorium-230	2.05	±	0.81	0.71	5
	5/7/01	Thorium-232	1.57	±	0.65	0.34	5
	5/7/01	Uranium-234	2.01	±	0.80	0.41	90[d]
	5/7/01	Uranium-235	0.29	±	0.31	0.36	90[d]
	5/7/01	Uranium-238	2.00	±	0.80	0.43	90[d]
		Total uranium[e]	*4.30*				*90*[d]

Table 6
2001 Sediment Analytical Results - Radioactive Constituents
Niagara Falls Storage Site

Sampling Location	Date Collected	Analyte	Result (pCi/g)[a]			MDA[b] (pCi/g)[a]	Cleanup Criteria[c] (pCi/g)[a]
SWSD011	5/7/01	Radium-226	1.19	±	0.31	0.46	5
	5/7/01	Radium-228	1.60	±	0.60	0.83	5
	5/7/01	Thorium-230	2.22	±	1.10	0.58	5
	5/7/01	Thorium-232	1.27	±	0.79	0.50	5
	5/7/01	Uranium-234	2.92	±	1.19	0.89	90[d]
	5/7/01	Uranium-235	0.39	±	0.44	0.58	90[d]
	5/7/01	Uranium-238	4.34	±	1.51	0.94	90[d]
		Total uranium[e]	*7.65*				*90*[d]
Duplicate[f]	5/7/01	Radium-226	0.95	±	0.13	0.16	5
	5/7/01	Radium-228	1.03	±	0.22	0.27	5
	5/7/01	Thorium-230	2.54	±	0.81	0.25	5
	5/7/01	Thorium-232	1.37	±	0.55	0.27	5
	5/7/01	Uranium-234	2.39	±	0.80	0.39	90[d]
	5/7/01	Uranium-235	0.13	±	0.19	0.36	90[d]
	5/7/01	Uranium-238	2.38	±	0.79	0.31	90[d]
		Total uranium[e]	*4.90*				*90*[d]

a. pCi/g - picocuries per gram.
b. MDA - Minimum detectable activity.
c. DOE surface soil cleanup criteria, averaged over topmost 6 in. (15 cm) of soil. Because there are no standards for radioactive constituents in sediment, these soil values are used as a basis for camparison of sediment results.
d. NFSS site-specific cleanup criterion for total uranium.
e. Sum of uranium isotope concentrations.
f. A quality control duplicate is collected at the same time and location and is analyzed by the same method for evaluating precision in sampling and analysis.

Table 7
2001 Field Parameter Summary
Niagara Falls Storage Site

Sampling Location	Date	Temperature (°F[a])	pH	Spec. Cond.[b] (mS/cm[c])	DO[d] (mg/L[e])	Eh[f] (mV[g])	Turbidity (NTU[h])	Volume Purged (Liters[i])	Discharge milliter PM[j]
GROUNDWATER									
A45	05/07/2001	50.5	6.75	2.157	1.0	-107	34	2.56	87
A50	05/10/2001	50.3	7.16	1.803	1.3	358	5.1	1.80	60
OW04B	05/07/2001	48.1	7.15	1.592	0.3	320	11.2	6.32	79
OW06B	05/09/2001	47.6	6.83	2.005	5.8	256	5.0	4.92	60
OW07B	05/09/2001	47.4	7.12	1.971	0.2	182	50	1.98	60
OW15B	05/08/2001	46.6	7.12	1.247	0.4	342	28	1.51	72
OW17B	05/09/2001	47.6	7.22	1.524	0.2	295	5.3	2.14	67
B02W20S	05/08/2001	49.4	7.12	1.297	0.3	313	12	2.59	70
SURFACE WATER									
SWSD009	05/07/01	68.7	7.37	0.978	5.8	369	15.4	---[k]	---[k]
SWSD010	05/07/01	69.8	7.41	1.173	6.1	384	53.3	---[k]	---[k]
SWSD011	05/07/01	68.5	7.78	0.833	6.7	386	44.0	---[k]	---[k]
SWSD021	05/07/01	69.6	7.81	0.806	6.7	398	19.7	---[k]	---[k]
SWSD022	05/07/01	68.6	7.43	1.026	5.9	412	>1100	---[k]	---[k]

a. °F - Degrees Fahrenheit.
b. Spec. Cond. - Specific conductance.
c. mS/cm - milliSiemens/centimeter.
d. DO - Dissolved oxygen.
e. mg/L - milligrams per liter.
f. Eh - Oxidation/reduction potential.
g. mV - milliVolts.
h. NTU - Nephelometric turbidity units.
i. 1-Liter = 0.26 gallons
j. Milliter PM = milliter per minute (1000ml = 1.0 liter)
k. Parameter not applicable.
l. Measurement not valid.

Table 8
2001 Groundwater Quality Results for Niagara Falls Storage Site

Sampling Location	Date Collected	Analyte	Result (mg/L)[a]	Reporting Limit (mg/L)[a]	Related Regulations[b] Federal[c] (mg/L)[a]	Related Regulations[b] State[d] (mg/L)[a]
B02W20S	5/8/01	Alkalinity, Total as CaCO3	402	1	NE	NE
Background	5/8/01	Bicarbonate (HCO3)	402	1	NE	NE
	5/8/01	Calcium (Ca)	75.9	1	NE	NE
	5/8/01	Carbonate (CO3)	<1	1	NE	NE
	5/8/01	Chloride	7.94	0.5	250	250
	5/8/01	Magnesium (Mg)	118	0.25	4	1.5
	5/8/01	Nitrogen, Nitrate as N (NO3-N)	<0.05	0.05	10	10
	5/8/01	Nitrogen, Nitrite as N (NO2-N)	<0.02	0.02	1	1
	5/8/01	Phosphorous, Total	<0.02	0.02	NE	NE
	5/8/01	Potassium (K)	2.04	0.25	NE	NE
	5/8/01	Sodium (Na)	57.9	2.5	NE	20
	5/8/01	Solids, Total Dissolved (TDS)	915	10	500	500
	5/8/01	Sulfate (SO4)	635	25	NE	250
A45	5/7/01	Alkalinity, Total as CaCO3	436	1	NE	NE
	5/7/01	Bicarbonate (HCO3)	436	1	NE	NE
	5/7/01	Calcium (Ca)	273	1	NE	NE
	5/7/01	Carbonate (CO3)	<1	1	NE	NE
	5/7/01	Chloride	52.6	0.5	250	250
	5/7/01	Magnesium (Mg)	140	0.25	4	1.5
	5/7/01	Nitrogen, Nitrate as N (NO3-N)	<0.05	0.05	10	10
	5/7/01	Nitrogen, Nitrite as N (NO2-N)	<0.02	0.02	1	1
	5/7/01	Phosphorous, Total	0.193	0.02	NE	NE
	5/7/01	Potassium (K)	10.9	0.25	NE	NE
	5/7/01	Sodium (Na)	51.7	2.5	NE	20
	5/7/01	Solids, Total Dissolved (TDS)	1700	10	500	500
	5/7/01	Sulfate (SO4)	811	25	NE	250
A50	5/10/01	Alkalinity, Total as CaCO3	381	1	NE	NE
	5/10/01	Bicarbonate (HCO3)	381	1	NE	NE
	5/10/01	Calcium (Ca)	122	1	NE	NE
	5/10/01	Carbonate (CO3)	<1	1	NE	NE
	5/10/01	Chloride	22.3	0.5	250	250
	5/10/01	Magnesium (Mg)	149	0.25	4	1.5
	5/10/01	Nitrogen, Nitrate as N (NO3-N)	0.085	0.05	10	10
	5/10/01	Nitrogen, Nitrite as N (NO2-N)	<0.02	0.02	1	1
	5/10/01	Phosphorous, Total	0.023	0.02	NE	NE
	5/10/01	Potassium (K)	2.18	0.25	NE	NE
	5/10/01	Sodium (Na)	76.5	2.5	NE	20
	5/10/01	Solids, Total Dissolved (TDS)	1290	10	500	500
	5/10/01	Sulfate (SO4)	702	25	NE	250
OW04B	5/7/01	Alkalinity, Total as CaCO3	304	1	NE	NE
	5/7/01	Bicarbonate (HCO3)	304	1	NE	NE
	5/7/01	Calcium (Ca)	184	1	NE	NE
	5/7/01	Carbonate (CO3)	<1	1	NE	NE
	5/7/01	Chloride	84.4	0.5	250	250
	5/7/01	Magnesium (Mg)	134	0.25	4	1.5
	5/7/01	Nitrogen, Nitrate as N (NO3-N)	<0.05	0.05	10	10
	5/7/01	Nitrogen, Nitrite as N (NO2-N)	<0.02	0.02	1	1
	5/7/01	Phosphorous, Total	0.013	0.02	NE	NE
	5/7/01	Potassium (K)	2.4	0.25	NE	NE
	5/7/01	Sodium (Na)	63.4	2.5	NE	20
	5/7/01	Solids, Total Dissolved (TDS)	1410	10	500	500
	5/7/01	Sulfate (SO4)	724	25	NE	250
Duplicate[e]	5/7/01	Alkalinity, Total as CaCO3	320	1	NE	NE
	5/7/01	Bicarbonate (HCO3)	320	1	NE	NE
	5/7/01	Calcium (Ca)	187	1	NE	NE
	5/7/01	Carbonate (CO3)	<1	1	NE	NE
	5/7/01	Chloride	84.9	1	250	250
	5/7/01	Magnesium (Mg)	133	0.25	4	1.5
	5/7/01	Nitrogen, Nitrate as N (NO3-N)	<0.05	0.05	10	10
	5/7/01	Nitrogen, Nitrite as N (NO2-N)	<0.02	0.02	1	1
	5/7/01	Phosphorous, Total	0.017	0.02	NE	NE
	5/7/01	Potassium (K)	2.24	0.25	NE	NE
	5/7/01	Sodium (Na)	62.6	2.5	NE	20
	5/7/01	Solids, Total Dissolved (TDS)	1410	10	500	500
	5/7/01	Sulfate (SO4)	721	25	NE	250

Table 8
2001 Groundwater Quality Results for Niagara Falls Storage Site

Sampling Location	Date Collected	Analyte	Result (mg/L)[a]	Reporting Limit (mg/L)[a]	Related Regulations[b] Federal[c] (mg/L)[a]	State[d] (mg/L)[a]
OW06B	5/9/01	Alkalinity, Total as CaCO3	557	1	NE	NE
	5/9/01	Bicarbonate (HCO3)	557	1	NE	NE
	5/9/01	Calcium (Ca)	136	1	NE	NE
	5/9/01	Carbonate (CO3)	<1	1	NE	NE
	5/9/01	Chloride	29.8	0.5	250	250
	5/9/01	Magnesium (Mg)	203	0.25	4	1.5
	5/9/01	Nitrogen, Nitrate as N (NO3-N)	<0.05	0.05	10	10
	5/9/01	Nitrogen, Nitrite as N (NO2-N)	<0.02	0.02	1	1
	5/9/01	Phosphorous, Total	0.025	0.02	NE	NE
	5/9/01	Potassium (K)	3.4	0.25	NE	NE
	5/9/01	Sodium (Na)	68.6	2.5	NE	20
	5/9/01	Solids, Total Dissolved (TDS)	1550	10	500	500
	5/9/01	Sulfate (SO4)	732	25	NE	250
OW07B	5/9/01	Alkalinity, Total as CaCO3	412	1	NE	NE
	5/9/01	Bicarbonate (HCO3)	412	1	NE	NE
	5/9/01	Calcium (Ca)	135	1	NE	NE
	5/9/01	Carbonate (CO3)	<1	1	NE	NE
	5/9/01	Chloride	19.4	0.5	250	250
	5/9/01	Magnesium (Mg)	195	0.25	4	1.5
	5/9/01	Nitrogen, Nitrate as N (NO3-N)	1.78	0.05	10	10
	5/9/01	Nitrogen, Nitrite as N (NO2-N)	<0.02	0.02	1	1
	5/9/01	Phosphorous, Total	<0.02	0.02	NE	NE
	5/9/01	Potassium (K)	3.95	0.25	NE	NE
	5/9/01	Sodium (Na)	74.5	2.5	NE	20
	5/9/01	Solids, Total Dissolved (TDS)	1550	10	500	500
	5/9/01	Sulfate (SO4)	850	25	NE	250
OW15B	5/8/01	Alkalinity, Total as CaCO3	345	1	NE	NE
	5/8/01	Bicarbonate (HCO3)	345	1	NE	NE
	5/8/01	Calcium (Ca)	110	1	NE	NE
	5/8/01	Carbonate (CO3)	<1	1	NE	NE
	5/8/01	Chloride	8.93	0.5	250	250
	5/8/01	Magnesium (Mg)	82.5	0.25	4	1.5
	5/8/01	Nitrogen, Nitrate as N (NO3-N)	0.186	0.05	10	10
	5/8/01	Nitrogen, Nitrite as N (NO2-N)	<0.02	0.02	1	1
	5/8/01	Phosphorous, Total	0.078	0.02	NE	NE
	5/8/01	Potassium (K)	1.83	0.25	NE	NE
	5/8/01	Sodium (Na)	43.1	2.5	NE	20
	5/8/01	Solids, Total Dissolved (TDS)	826	10	500	500
	5/8/01	Sulfate (SO4)	240	10	NE	250
OW17B	5/9/01	Alkalinity, Total as CaCO3	383	1	NE	NE
	5/9/01	Bicarbonate (HCO3)	383	1	NE	NE
	5/9/01	Calcium (Ca)	85.9	1	NE	NE
	5/9/01	Carbonate (CO3)	<1	1	NE	NE
	5/9/01	Chloride	12.4	0.5	250	250
	5/9/01	Magnesium (Mg)	137	0.25	4	1.5
	5/9/01	Nitrogen, Nitrate as N (NO3-N)	4.22	0.15	10	10
	5/9/01	Nitrogen, Nitrite as N (NO2-N)	0.036	0.02	1	1
	5/9/01	Phosphorous, Total	<0.02	0.02	NE	NE
	5/9/01	Potassium (K)	2.35	0.25	NE	NE
	5/9/01	Sodium (Na)	72.1	2.5	NE	20
	5/9/01	Solids, Total Dissolved (TDS)	1080	10	500	500
	5/9/01	Sulfate (SO4)	658	25	NE	250

a. mg/L - milligrams per liter.

b. Regulations presented pertain to drinking water quality and are listed for comparison only. No drinking water supply is obtained from groundwater at NFSS. NE - Not established.

c. Federal Safe Drinking Water Act maximum contaminant levels from EPA Drinking Water Regulations and Health Advisories (October 1996).

d. Water Quality Criteria (class GA) per 6 NYCRR, Part 703.

e. A quality control (QC) duplicate is collected at the same time and location and is analyzed by the same method for evaluating precision in sampling and analysis.

Table 9
2001 Groundwater Analytical Results - Radioactive Constituents
Niagara Falls Storage Site

Sampling Location	Date Collected	Analyte	Result[a] (pCi/L)[b]		MDA[c] (pCi/L)[b]	DCG[d] (pCi/L)[b]
B02W20S	05/08/01	Radium-226	0.23	± 0.21	0.45	100[h]
Background	05/08/01	Radium-228	0.70	± 0.58	0.94	100[h]
		Total Radium [h]	*0.93*			100[h]
	05/08/01	Thorium-230	0.46	± 0.32	0.36	300
	05/08/01	Thorium-232	0.01	± 0.10	0.30	50
	05/08/01	Uranium-234	5.37	± 1.38	0.32	600[f]
	05/08/01	Uranium-235	0.31	± 0.26	0.24	600[f]
	05/08/01	Uranium-238	3.69	± 1.05	0.40	600[f]
		Total Uranium [f]	*9.37*			*600* [f]
A45	05/07/01	Radium-226	0.52	± 0.25	0.23	100[h]
	05/07/01	Radium-228	-0.47	± 0.53	0.93	100[h]
		Total Radium [h]	*0.05*			100[h]
	05/07/01	Thorium-230	0.43	± 0.31	0.38	300
	05/07/01	Thorium-232	0.07	± 0.13	0.24	50
	05/07/01	Uranium-234	17.36	± 3.63	0.34	600[f]
	05/07/01	Uranium-235	0.29	± 0.26	0.31	600[f]
	05/07/01	Uranium-238	13.23	± 2.86	0.33	600[f]
		Total Uranium [f]	*30.88*			*600* [f]
A50	05/10/01	Radium-226	0.16	± 0.19	0.44	100[h]
	05/10/01	Radium-228	0.92	± 0.74	1.20	100[h]
		Total Radium [h]	*1.08*			100[h]
	05/10/01	Thorium-230	0.37	± 0.30	0.44	300
	05/10/01	Thorium-232	-0.06	± 0.10	0.43	50
	05/10/01	Uranium-234	7.50	± 1.97	0.56	600[f]
	05/10/01	Uranium-235	0.25	± 0.47	0.31	600[f]
	05/10/01	Uranium-238	7.62	± 1.99	0.38	600[f]
		Total Uranium [f]	*15.37*			*600* [f]
OW04B	05/07/01	Radium-226	0.10	± 0.12	0.25	100[h]
	05/07/01	Radium-228	0.22	± 0.67	1.18	100[h]
		Total Radium [h]	*0.32*			100[h]
	05/07/01	Thorium-230	0.49	± 0.32	0.34	300
	05/07/01	Thorium-232	0.08	± 0.15	0.31	50
	05/07/01	Uranium-234	26.47	± 5.36	0.26	600[f]
	05/07/01	Uranium-235	0.65	± 0.39	0.15	600[f]
	05/07/01	Uranium-238	25.03	± 5.09	0.29	600[f]
		Total Uranium [f]	*52.15*			*600* [f]
Duplicate[g]	05/09/01	Radium-226	0.02	± 0.07	0.22	100[h]
	05/09/01	Radium-228	0.55	± 0.61	1.02	100[h]
		Total Radium [h]	*0.57*			100[h]
	05/09/01	Thorium-230	0.44	± 0.34	0.41	300
	05/09/01	Thorium-232	0.15	± 0.24	0.47	50
	05/10/01	Uranium-234	20.47	± 3.92	0.17	600[f]
	05/10/01	Uranium-235	1.11	± 0.50	0.32	600[f]
	05/10/01	Uranium-238	20.02	± 3.84	0.10	600[f]
		Total Uranium [f]	*41.60*			*600* [f]

Table 9
2001 Groundwater Analytical Results - Radioactive Constituents
Niagara Falls Storage Site

Sampling Location	Date Collected	Analyte	Result[a] (pCi/L)[b]		MDA[c] (pCi/L)[b]	DCG[d] (pCi/L)[b]
OW06B	05/09/01	Radium-226	0.49	± 0.36	0.73	100[h]
	05/09/01	Radium-228	0.89	± 0.62	0.99	100[h]
		Total Radium [h]	*1.38*			100[h]
	05/09/01	Thorium-230	0.14	± 0.23	0.47	300
	05/09/01	Thorium-232	0.15	± 0.20	0.34	50
	05/09/01	Uranium-234	14.45	± 3.45	0.46	600[f]
	05/09/01	Uranium-235	0.32	± 0.31	0.37	600[f]
	05/09/01	Uranium-238	9.99	± 2.52	0.43	600[f]
		Total Uranium [f]	*24.76*			*600* [f]
OW07B	05/09/01	Radium-226	0.74	± 0.42	0.72	100[h]
	05/09/01	Radium-228	0.11	± 0.61	1.08	100[h]
		Total Radium [h]	0.85			100[h]
	05/09/01	Thorium-230	0.19	± 0.25	0.45	300
	05/09/01	Thorium-232	0.07	± 0.18	0.41	50
	05/09/01	Uranium-234	12.77	± 3.05	0.52	600[f]
	05/09/01	Uranium-235	0.53	± 0.39	0.18	600[f]
	05/09/01	Uranium-238	9.91	± 2.46	0.44	600[f]
		Total Uranium [f]	*23.21*			*600* [f]
OW15B	05/08/01	Radium-226	0.21	± 0.16	0.28	100[h]
	05/08/01	Radium-228	0.73	± 0.67	1.10	100[h]
		Total Radium [h]	*0.94*			100[h]
	05/08/01	Thorium-230	0.16	± 0.23	0.45	300
	05/08/01	Thorium-232	-0.05	± 0.14	0.49	50
	05/08/01	Uranium-234	5.75	± 1.45	0.38	600[f]
	05/08/01	Uranium-235	0.29	± 0.26	0.31	600[f]
	05/08/01	Uranium-238	4.50	± 1.20	0.31	600[f]
		Total Uranium [f]	*10.54*			*600* [f]
OW17B	05/09/01	Radium-226	0.17	± 0.19	0.49	100[h]
	05/09/01	Radium-228	0.15	± 0.66	1.16	100[h]
		Total Radium [h]	0.17			100[h]
	05/09/01	Thorium-230	0.41	± 0.30	0.29	300
	05/09/01	Thorium-232	0.32	± 0.27	0.26	50
	05/09/01	Uranium-234	4.45	± 1.30	0.44	600[f]
	05/09/01	Uranium-235	0.37	± 0.32	0.35	600[f]
	05/09/01	Uranium-238	2.79	± 0.93	0.36	600[f]
		Total Uranium [f]	*7.61*			*600* [f]

a. Results reported with (±) radiological error quoted at 2-sigma (95 percent confidence level).
b. pCi/L - picocuries per liter.
c. MDA - Minimum detectable activity.
d. DOE derived concentration guide for water.
e. 600 pCi/L DCG is for total uranium concentration.
f. Sum of uranium isotope concentrations.
g. A quality control duplicate is collected at the same time and location and is analyzed by the same method for evaluating precision of sampling and analysis.
h. Sum of radium isotope concentrations.

Table 10
2001 Groundwater Analytical Results - Metals
Niagara Falls Storage Site

Sampling Location	Date Collected	Detected Analyte	Result (µg/L)[a]	Reporting Limit (µg/L)[a]	Related Regulations[c] Federal[d] (µg/L)[a]	State[e] (µg/L)[a]
B02W20S	05/08/01	Copper	<10.0	10.0	1300	200
Background	05/08/01	Lead	<10.0	10.0	15	25
	05/08/01	Vanadium	<10.0	10.0	NE[b]	NE[b]
A45	05/07/01	Copper	<10.0	10.0	1300	200
	05/07/01	Lead	5.0	10.0	15	25
	05/07/01	Vanadium	<10.0	10.0	NE[b]	NE[b]
A50	05/10/01	Copper	<10.0	10.0	1300	200
	05/10/01	Lead	<10.0	10.0	15	25
	05/10/01	Vanadium	<10.0	10.0	NE[b]	NE[b]
OW04B	05/07/01	Copper	<10.0	10.0	1300	200
	05/07/01	Lead	<10.0	10.0	15	25
	05/07/01	Vanadium	<10.0	10.0	NE[b]	NE[b]
Duplicate[f]	05/07/01	Copper	<10.0	10.0	1300	200
	05/07/01	Lead	<10.0	10.0	15	25
	05/07/01	Vanadium	<10.0	10.0	NE[b]	NE[b]
OW06B	05/09/01	Copper	9.2	10.0	1300	200
	05/09/01	Lead	2.6	10.0	15	25
	05/09/01	Vanadium	<10.0	10.0	NE[b]	NE[b]
OW07B	05/09/01	Copper	9.0	10.0	1300	200
	05/09/01	Lead	3.1	10.0	15	25
	05/09/01	Vanadium	<10.0	10.0	NE[b]	NE[b]
OW15B	05/08/01	Copper	11.6	10.0	1300	200
	05/08/01	Lead	<10.0	10.0	15	25
	05/08/01	Vanadium	<10.0	10.0	NE[b]	NE[b]
OW17B	05/09/01	Copper	5.9	10.0	1300	200
	05/09/01	Lead	<10.0	10.0	15	25
	05/09/01	Vanadium	<10.0	10.0	NE[b]	NE[b]

a. µg/L - micrograms per liter.

b. NE - Not Established

c. Regulations presented pertain to drinking water quality and are listed for comparison only. No drinking water supply is obtained from groundwater at NFSS.

d. Federal Safe Drinking Water Act maximum contaminant levels from EPA Drinking Water Regulations and Health Advisories (October 1996).

e. Water Quality Criteria (Class GA) per 6 NYCRR, Chapter X, Subchapter A.

f. A quality control duplicate is collected at the same time and location and is analyzed by the same method for evaluating precision in sampling and analysis.

FUSRAP NIAGARA FALLS STORAGE SITE

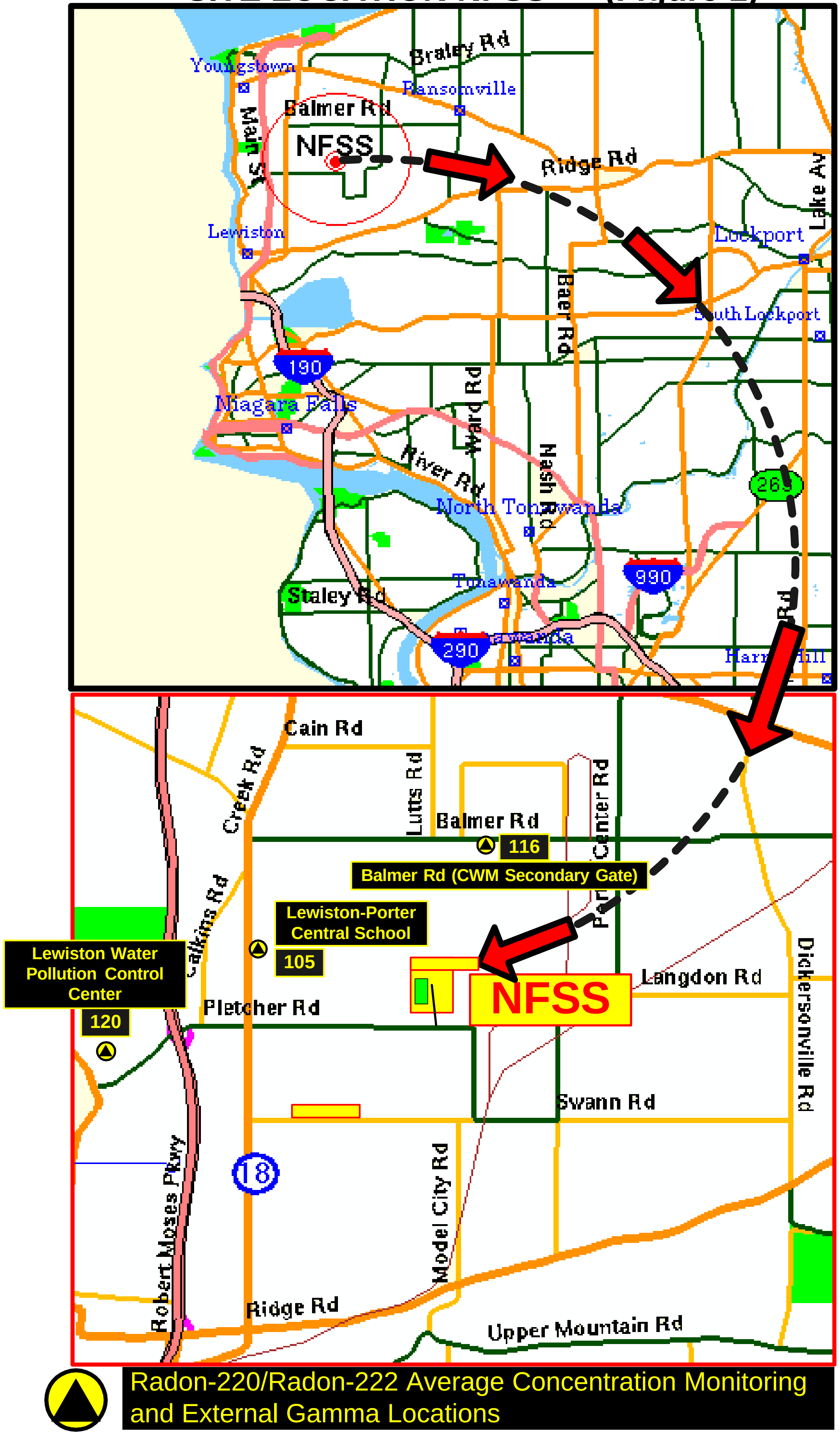
2001

FIGURES

ENVIRONMENTAL SURVEILLANCE TECHNICAL MEMORANDUM

US Army Corps
of Engineers ®
Buffalo District

SITE LOCATION NFSS (Figure 1)



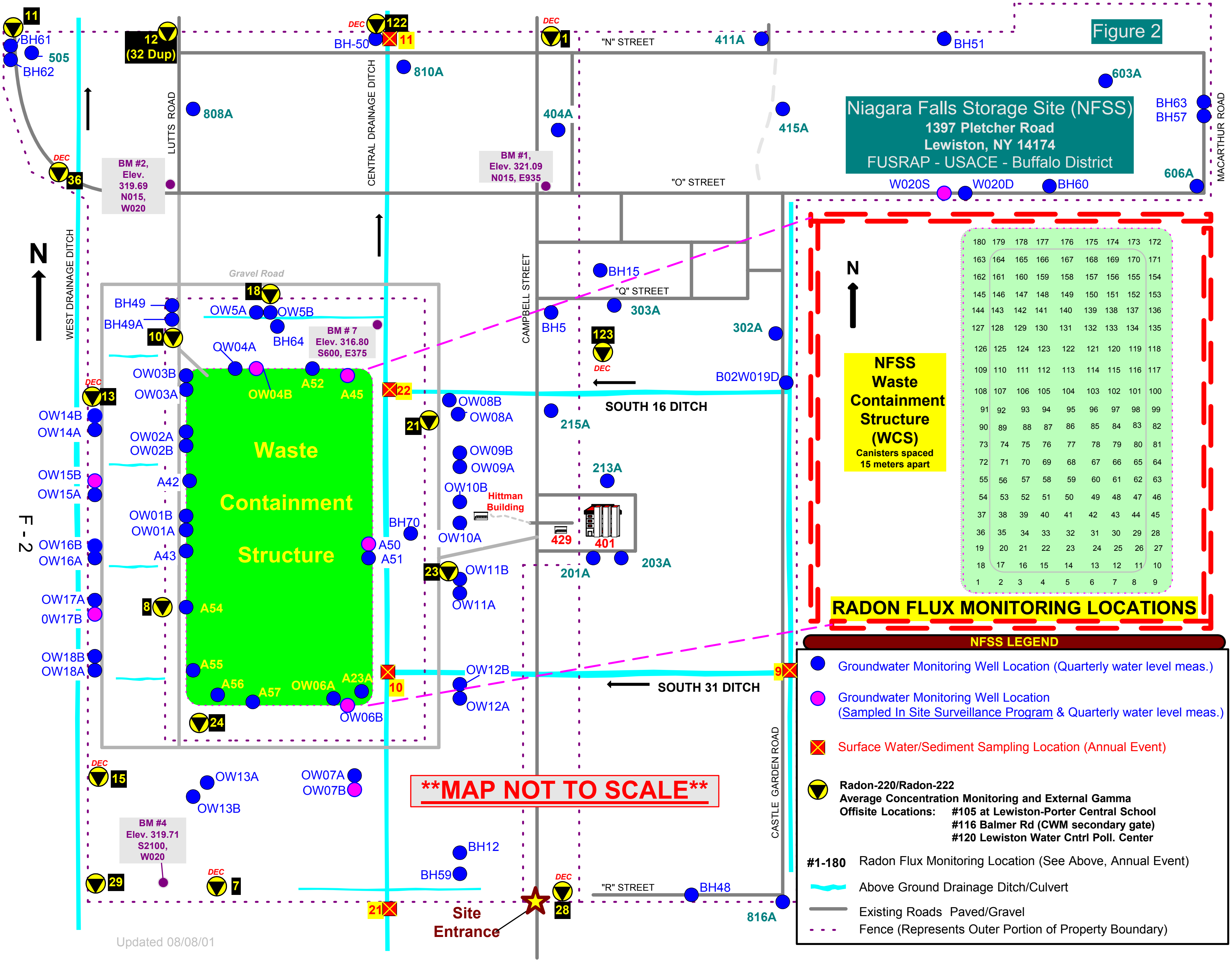


Figure 2
Niagara Falls Storage Site (NFSS)
1397 Pletcher Road
Lewiston, NY 14174
FUSRAP - USACE - Buffalo District
"N" STREET
"O" STREET
"Q" STREET
"R" STREET
LUTTS ROAD
CENTRAL DRAINAGE DITCH
WEST DRAINAGE DITCH
CAMPBELL STREET
CASTLE GARDEN ROAD
MACARTHUR ROAD
Gravel Road
SOUTH 16 DITCH
SOUTH 31 DITCH
N
BM #2, Elev. 319.69 N015, W020
BM #1, Elev. 321.09 N015, E935
BM # 7 Elev. 316.80 S600, E375
BM #4 Elev. 319.71 S2100, W020
Waste Containment Structure
Hittman Building
429
401
NFSS Waste Containment Structure (WCS)
Canisters spaced 15 meters apart
RADON FLUX MONITORING LOCATIONS
MAP NOT TO SCALE
Site Entrance
DEC
11
12 (32 Dup)
122
1
123
36
18
10
13
21
23
8
24
15
29
7
28
22
9
BH61
505
BH62
BH-50
810A
808A
404A
411A
415A
BH51
603A
BH63
BH57
606A
W020S
W020D
BH60
BH15
303A
BH5
302A
B02W019D
215A
213A
201A
203A
BH49
BH49A
OW5A
OW5B
BH64
OW04A
OW04B
A52
A45
OW03B
OW03A
OW14B
OW14A
OW02A
OW02B
OW15B
OW15A
A42
OW01B
OW01A
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OW16B
OW16A
OW17A
OW17B
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OW18B
OW18A
A55
A56
A57
OW06A
A23A
OW06B
BH70
A50
A51
OW08B
OW08A
OW09B
OW09A
OW10B
OW10A
OW11B
OW11A
OW12B
OW12A
OW13A
OW13B
OW07A
OW07B
BH12
BH59
BH48
816A
NFSS LEGEND
Groundwater Monitoring Well Location (Quarterly water level meas.)
Groundwater Monitoring Well Location (Sampled In Site Surveillance Program & Quarterly water level meas.)
Surface Water/Sediment Sampling Location (Annual Event)
Radon-220/Radon-222
Average Concentration Monitoring and External Gamma
Offsite Locations: #105 at Lewiston-Porter Central School
#116 Balmer Rd (CWM secondary gate)
#120 Lewiston Water Cntrl Poll. Center
#1-180 Radon Flux Monitoring Location (See Above, Annual Event)
Above Ground Drainage Ditch/Culvert
Existing Roads Paved/Gravel
Fence (Represents Outer Portion of Property Boundary)
Updated 08/08/01

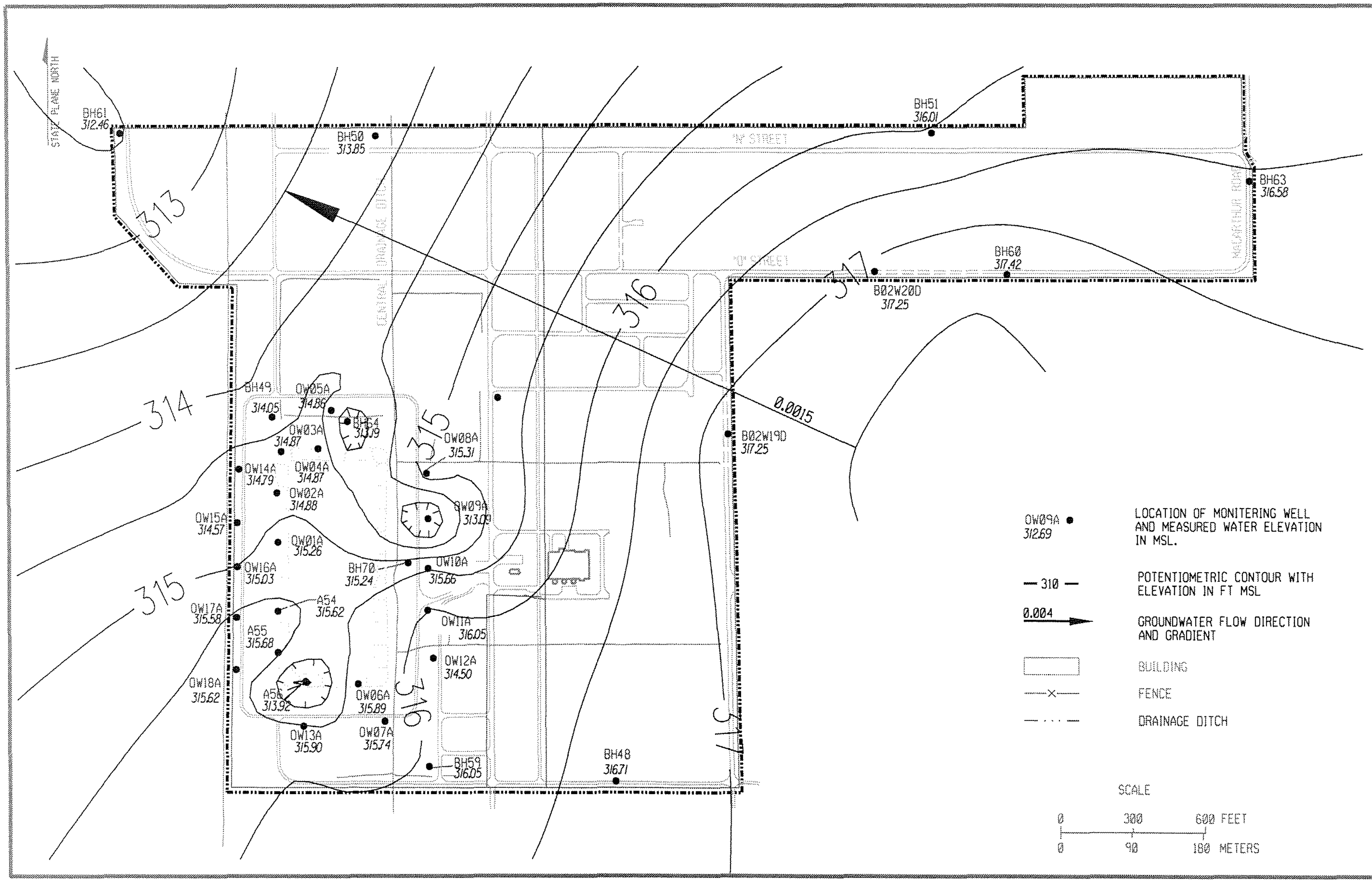


Figure 3
Potentiometric Surface Map (June 20, 2001)
Lower Groundwater System

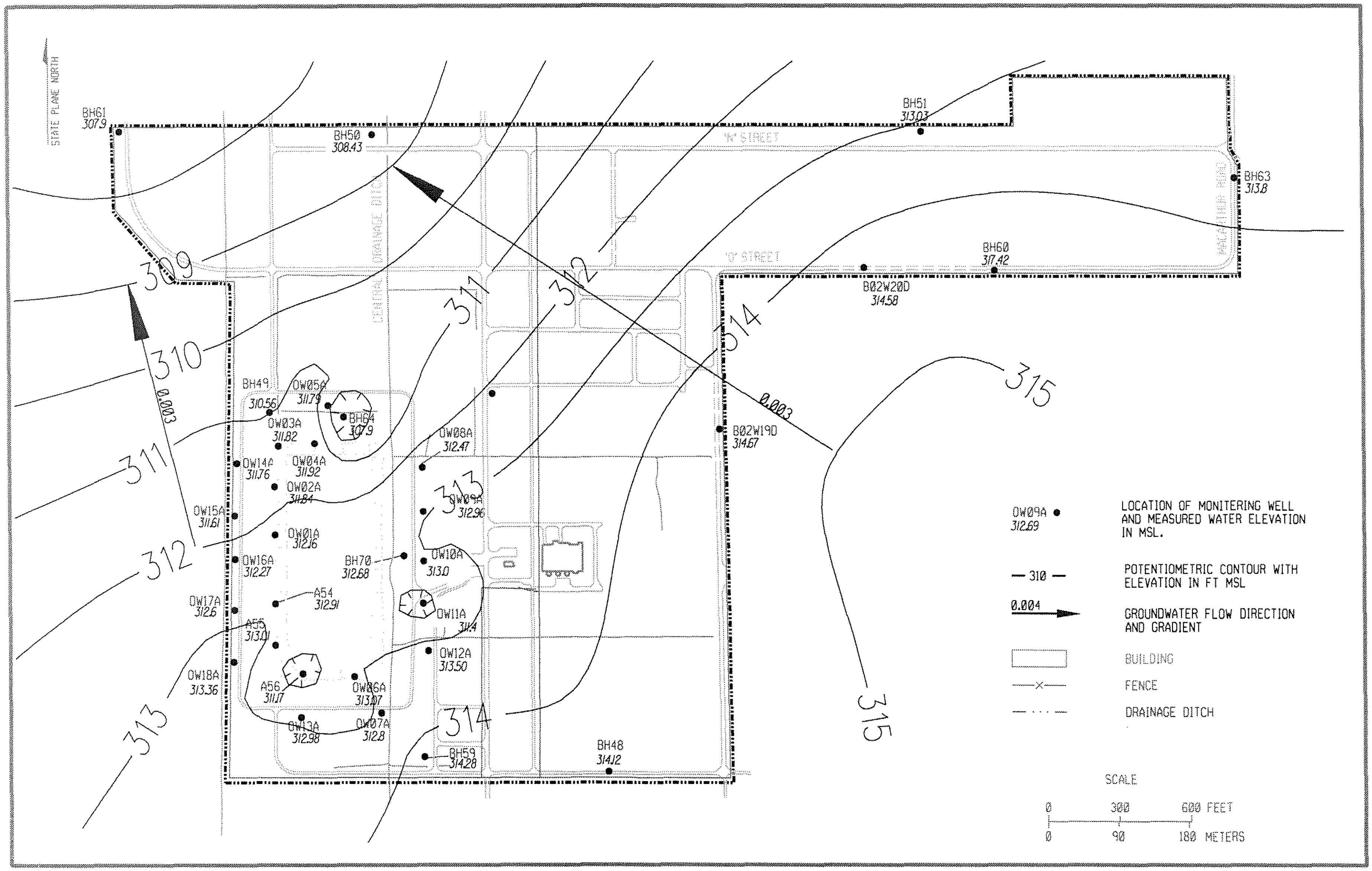


Figure 5
Potentiometric Surface Map (September 27, 2001)
Lower Groundwater System

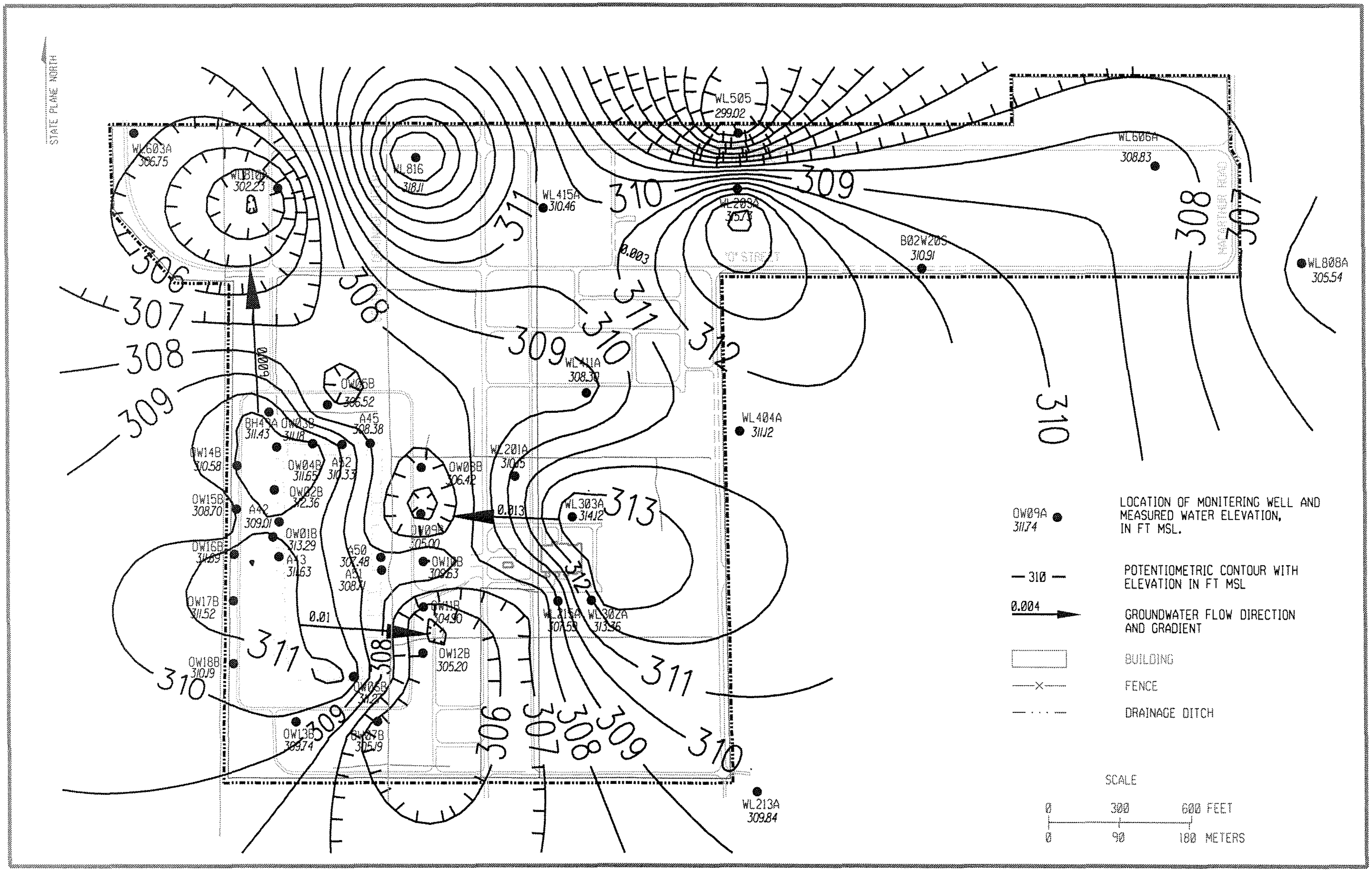
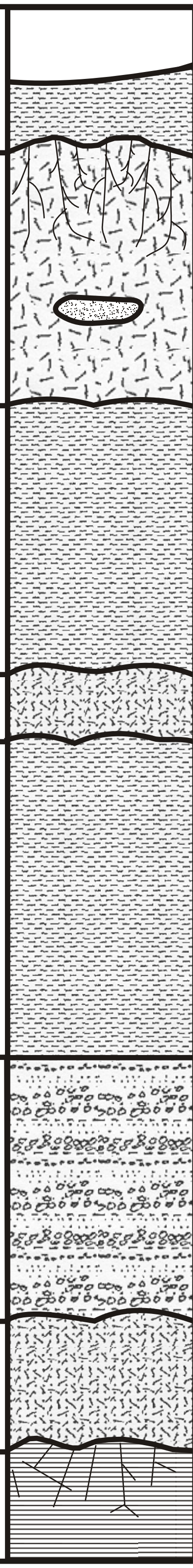


Figure 6
Potentiometric Surface Map (September 27, 2001)
Upper Groundwater System



Fill		Upper Water-Bearing Zone
UCT	Upper Clay Till: Brown or reddish-brown clay with significant amounts of silt or sand and interspersed lenses of sand and gravel.	Elevation Range (Feet above MSL): 329 to 278
GLC	Glacio-Lacustrine Clay: Homogeneous gray clay with occasional laminations of red-brown silt and minor amounts of sand and gravel.	Aquitard
MST	Middle Silt Till: Gray to gray-brown silt with little sand and gravel.	
GLC	Glacio-Lacustrine Clay: Homogeneous gray clay with occasional laminations of red-brown silt and minor amounts of sand and gravel.	Elevation Range (Feet above MSL): 319 to 259
ASG	Alluvial Sand and Gravel: Stratified coarse sands, non-stratified coarse silt and sand or interlayered silt, sand and clay.	Lower Water-Bearing Zone
BRT	Basal Red Till: Reddish-brown silt and coarse to fine sand.	Elevation Range (Feet above MSL): 314 to 246
QFM	Queenston Formation: Reddish-brown fissile shale.	Aquitard Two

Filename: S:\Buf001\ArcView\Flow Calibration Tech Memo\hydrostratigraphy.cdr
Project: BUF001-004-05-03
Created by: apassarelli 03/26/02
Revised: 04/17/02 asp
Source: HydroGeoLogic, Inc., 2002

FIGURE 7

Schematic of Conceptualized Hydrostratigraphy

FINAL

APPENDIX B: NFSS CY2001 ENVIRONMENTAL SURVEILLANCE TECHNICAL MEMORANDUM

CY2001 CALCULATION OF EXTERNAL GAMMA RADIATION DOSE RATES FOR NIAGARA FALLS STORAGE SITE (NFSS)

LEWISTON, NEW YORK

JULY 2002

U.S. Army Corps of Engineers
Buffalo District Office
Formerly Utilized Sites Remedial Action Program

FINAL

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CY2001 CALCULATION OF EXTERNAL GAMMA RADIATION DOSE RATES FOR NIAGARA FALLS STORAGE SITE (NFSS)

LEWISTON, NEW YORK

JULY 2002

prepared by

U.S. Army Corps of Engineers, Buffalo District Office, Formerly Utilized Sites Remedial Action Program

with assistance from

Science Applications International Corporation
under Contract No. DAHA90-94-D-007-DN04

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LIST OF FIGURES

LIST OF ATTACHMENTS

1.0 PURPOSE

This calculation estimates the external gamma radiation dose rates at the Niagara Falls Storage Site (NFSS), Lewiston, New York (see Figure 1), during calendar year 2001 (CY2001). Dose rates from external gamma radiation to hypothetical members of the public are calculated from dose measurements taken by tissue-equivalent thermoluminescent dosimeters (TETLD) located at the perimeter of the NFSS facility and the waste containment structure (WCS) (see Figure 2).

2.0 ASSUMPTIONS

Calculations for the external gamma radiation dose rate to residence-based and off-site worker-based receptors are incorporated using the following assumptions:

Distance from each TETLD above the source (the ground) is 3 feet (ft),
Distance from the TETLDs to the nearest resident is 3,600 ft,
Distance from the TETLDs to the nearest off-site worker is 1,020 ft,
Length of the western TETLD monitoring line (perimeter fence) is 2,766 ft,
Length of the eastern TETLD monitoring line (East of Campbell Street) is 2,700 ft.

3.0 TETLD DATA

The TETLD measures gamma radiation from gamma-emitting site contaminants and from sources of background radiation. The relevant sources of background radiation can be divided into three categories including cosmic radiation, terrestrial radiation and, to an insignificant extent, man-made sources. NCRP Report 93 states that average levels of cosmic and terrestrial radiation in the United States are 27 millirem per year (mrem/yr) and 28 mrem/yr, respectively. These background doses can be measured by the TETLD and are subtracted to estimate the net dose from site-related contaminants, if any.

Gamma radiation was measured at the NFSS during CY2001 using TETLDs located at the facility perimeter boundaries and the perimeter of the Waste Containment Facility (WCS). The TETLDs were placed at the monitoring locations approximately 3 ft [1.6 meters (m)] above the ground surface inside a housing shelter. The TLDs were collected semi-annually and sent to an off-site vendor for analysis.

Gamma radiation monitoring was performed at NFSS during CY2001 at eleven locations around the perimeter of the site and six locations around the WCS (see Figure 2). In addition to these locations, three background locations (Figure 1) were monitored to compare on-site and background exposures. In January 2001, two environmental TETLDs were placed at each monitoring location. The program utilizes two TETLDs at each monitoring location (for each monitoring period) to provide additional quality control of monitoring data.

TETLD monitoring data for CY2001 is found in Table 1. The TETLD data reported from the vendor for each period is shown as "Uncorrected Gross TETLD Data" in Table 1. The uncorrected gross TETLD data was then normalized to a daily dose rate for each period, averaged, and corrected for shelter absorption and normalized to a one-year exposure. Net monitoring results (average normalized location reading minus average normalized background reading) that are less than zero are assumed to be zero. A more detailed description of CY2001 TETLD results is presented in Attachment 1.

Table 1. External Gamma Radiation at NFSS

Monitoring Location	Monitoring Station	Uncorrected Gross TETLD Data[a] (mrem) (First period)	Uncorrected Gross TETLD Data[a] (mrem) (Second period)	Corrected Gross TETLD Data[b] (mrem/yr)	CY2001 Net TETLD Data[c] (mrem/yr)
NFSS Perimeter	1	22.2	23.6	50.4	3.2
	1	19.7	19.2	45.4	0.0
	7	19.4	18.3	41.4	0.0
	7	17.1	0.6	21.6	0.0
	11	14.1	15.6	32.7	0.0
	11	15.8	18.9	40.3	0.0
	12	15.6	19.2	38.3	0.0
	12	15.9	12.8	33.7	0.0
	13	16.1	20.9	40.7	0.0
	13	18.4	5.5	28.7	0.0
	15	17.8	18.6	40.0	0.0
	15	18.2	21.1	45.7	0.0
	28	20.8	22.8	47.9	0.8
	28	20.1	24.7	52.0	4.9
	29	23.8	27.7	56.6	9.5
	29	22.3	24.5	54.5	7.4
	36	18.2	18.2	40.0	0.0
	36	17.3	23.4	47.1	0.0
	122	13.2	21.5	38.2	0.0
	122	19.6	11.2	36.4	0.0
	123	17.8	19.2	40.7	0.0
	123	16.8	17.2	39.7	0.0
WCS Perimeter	8	12.1	18.9	34.1	0.0
	8	15.3	7.0	26.5	0.0
	10	20.7	24.0	49.2	2.0
	10	19.2	25.5	51.8	4.7
	18	20.1	17.3	41.1	0.0
	18	17.8	16.9	40.6	0.0
	21	17.7	20.8	42.3	0.0
	21	13.1	19.2	37.3	0.0
	23	12.5	24.8	41.1	0.0
	23	20.2	23.6	50.9	3.8
	24	16.1	16.8	36.2	0.0
	24	15.3	15.2	35.6	0.0

Table 1. External Gamma Radiation at NFSS (Cont'd)

Monitoring Location	Monitoring Station	Uncorrected Gross TETLD Data[a] (mrem) (First period)	Uncorrected Gross TETLD Data[a] (mrem) (Second period)	Corrected Gross TETLD Data[b] (mrem/yr)	CY2001 Net TETLD Data[c] (mrem/yr)
Background	105	13.6	17.6	34.3	---
	105	14.9	17.6	37.8	---
	116	18.4	17.4	39.3	---
	116	15.3	15.3	35.7	---
	120	31.4	30.8	68.4	---
	120	28.3	29.3	67.2	---
Average Background	---	20.3	21.3	47.1	---

[a] All data reported from the vendor was uncorrected gross results in mrem per monitoring period.

[b] Uncorrected gross data for each period are normalized to a daily dose rate, averaged, and corrected for shelter absorption (s/a = 1.075) to account for the shielding properties of the shelter around the TETLD and normalized for the length of the year (365 days) (BNI, 1992).

[c] Net data are corrected by subtracting the average corrected background value.

4.0 ASSESSMENT METHODOLOGY AND RESULTS

Gamma radiation exposure measured at the perimeter fenceline represents doses to a hypothetical receptor that would be at the same locations 24 hours/day, 365 days/year. Off-site dose to the nearest member of the public is significantly affected based on their proximity to the gamma source and amount of time spent at the affected site. A more realistic approach to project dose is to evaluate members of the public as either residence-based or off-site worker-based receptors. A residence-based off-site exposure assumes a 100 percent occupancy rate at a given location. An off-site worker exposure assumes that a worker's occupancy rate is 23 percent, based on an 8 hour/day, 5 day/week, 50 week/year. Thus, a realistic assessment of dose can be performed using conservative assumptions of occupancy rate and distance from the source.

4.1 NEAREST RESIDENT

For the dose calculation to the nearest resident, the line of TETLD's along the western perimeter fence are used. The TETLD's along this side of the facility include NFSS perimeter fence monitoring locations 11, 13, 15, 29, and 36, and WCS perimeter fence monitoring locations 8 and 10. The two WCS locations are added due to their close proximity to the western NFSS perimeter fence. These TETLD locations are shown in Figure 2. Net dose rates (corrected for shelter absorption and background) for these TETLDs are summed and divided by the total number of observations (14 for CY2001). This value represents the dose at the site perimeter (D1 = 1.7 mrem/yr for CY2001). The site perimeter dose is then used in the following equation for a line source:

$$D_2 = D_1 * h1/h2 * (ArcTan(L/h2)/ArcTan(L/h1))$$

where:

D2	= dose calculated at the residence from the line source (the site)
D1	= dose at the site perimeter as described above
h1	= the distance of the TETLDs from the source (3 ft for CY2001)
h2	= the distance of the resident from the fence line (3,600 ft for CY2001)
L	= half the length of line of TETLDs measuring the line source (1,383 ft for CY2001)

This yields a dose of 3E-04 mrem/yr at the residence.

4.2 NEAREST OFF-SITE WORKER

For the dose to the nearest off-site worker, the TETLDs in a line closest to the eastern perimeter fence (Castle Garden Road) are used. The TETLDs used include monitoring locations 1, 28, and 123. These TETLDs are located along an interior fence (East of Campbell Street). Their locations are shown in Figure 2. There are no WCS perimeter fence monitoring locations in close proximity to those along the line East of Campbell Street; therefore, none are included in the dose calculations. Net dose rates (corrected for shelter absorption and background) for TETLD monitoring locations 1, 28, and 123 are summed and divided by the total number observations (6 for CY2001). This represents the dose at the site perimeter (D1 = 1.5 mrem/yr for CY2001).

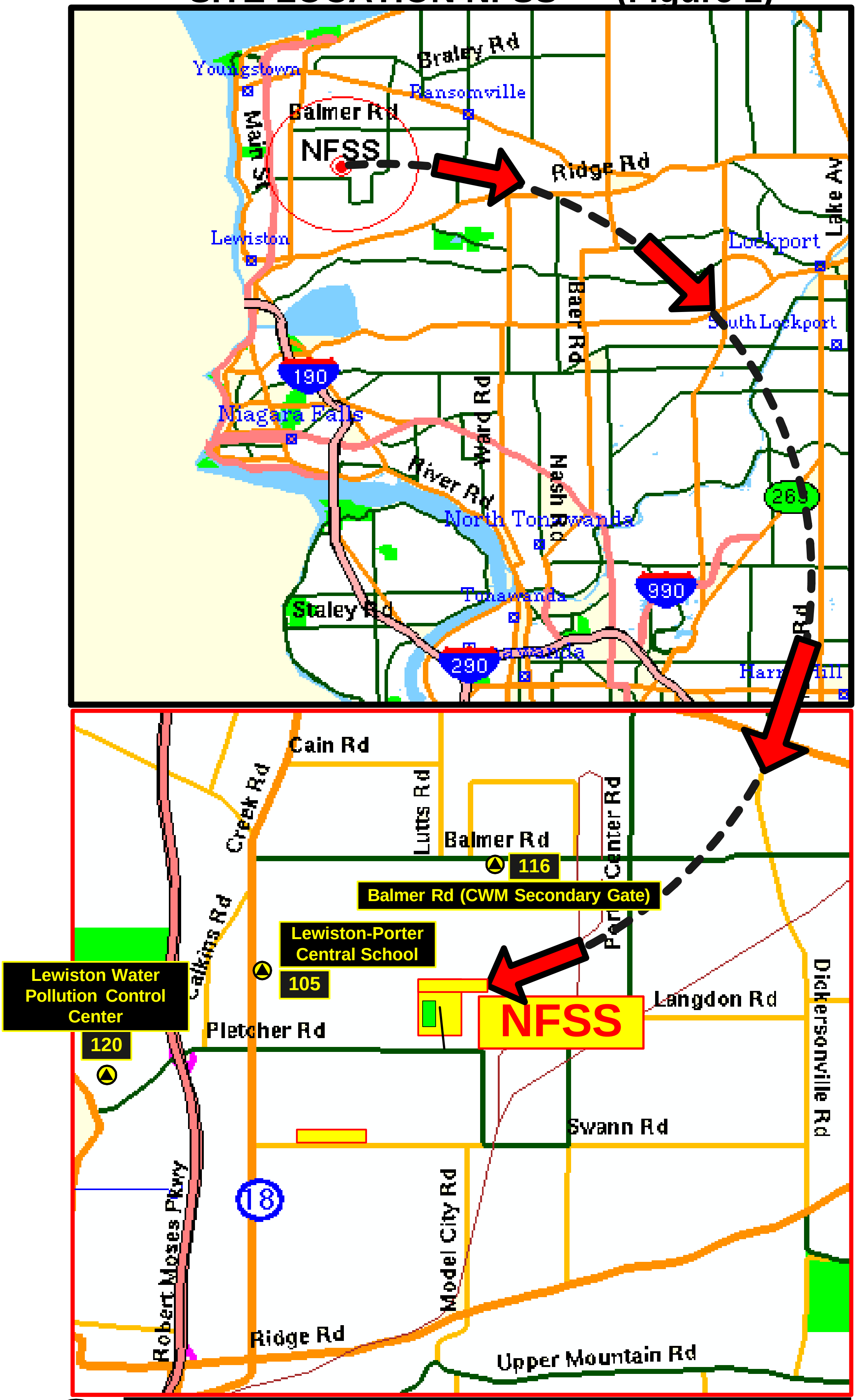
Using the equation above and a correction factor for off-site worker occupancy (i.e., 2000 hours/8760 hours), the dose to the nearest off-site worker is 6E-04 mrem/yr.

5.0 REFERENCES

Bechtel National, Inc. (BNI), 1997. "1996 Public External Gamma Dose," 14501-158-CV-031, Rev. 0, Oak Ridge, TN.

BNI, 1992. “Attenuation Factor for TLD Weather Housings,” 14501-191-CV-014, Rev. 0, Oak Ridge, TN.

SITE LOCATION NFSS (Figure 1)



Radon-220/Radon-222 Average Concentration Monitoring and External Gamma Locations

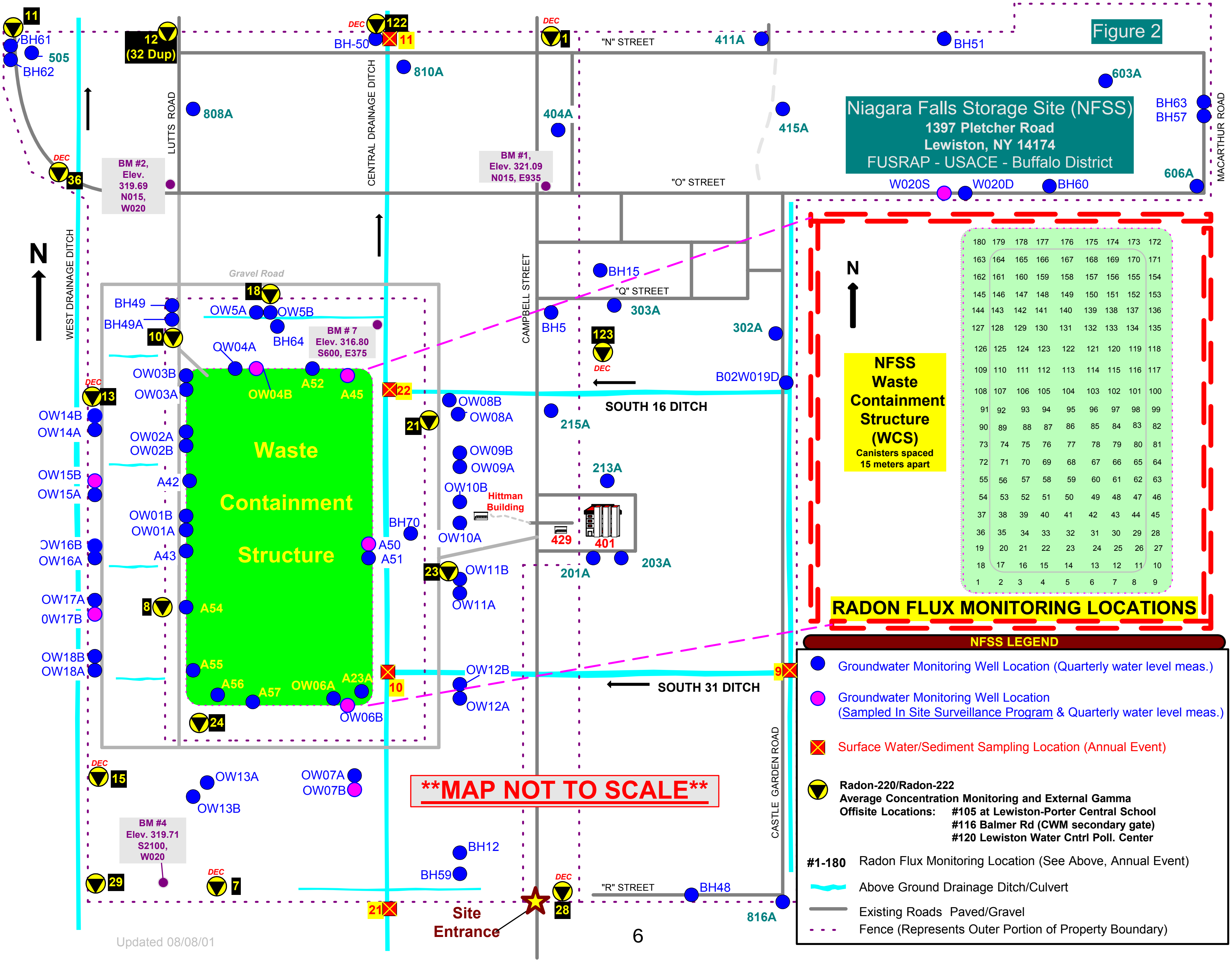


Figure 2
Niagara Falls Storage Site (NFSS)
1397 Pletcher Road
Lewiston, NY 14174
FUSRAP - USACE - Buffalo District
"N" STREET
"O" STREET
"Q" STREET
"R" STREET
LUTTS ROAD
CENTRAL DRAINAGE DITCH
WEST DRAINAGE DITCH
CAMPBELL STREET
CASTLE GARDEN ROAD
MACARTHUR ROAD
SOUTH 16 DITCH
SOUTH 31 DITCH
Gravel Road
N
BM #2, Elev. 319.69 N015, W020
BM #1, Elev. 321.09 N015, E935
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Waste Containment Structure
Hittman Building
429
401
NFSS Waste Containment Structure (WCS)
Canisters spaced 15 meters apart
RADON FLUX MONITORING LOCATIONS
180 179 178 177 176 175 174 173 172
163 164 165 166 167 168 169 170 171
162 161 160 159 158 157 156 155 154
145 146 147 148 149 150 151 152 153
144 143 142 141 140 139 138 137 136
127 128 129 130 131 132 133 134 135
126 125 124 123 122 121 120 119 118
109 110 111 112 113 114 115 116 117
108 107 106 105 104 103 102 101 100
91 92 93 94 95 96 97 98 99
90 89 88 87 86 85 84 83 82
73 74 75 76 77 78 79 80 81
72 71 70 69 68 67 66 65 64
55 56 57 58 59 60 61 62 63
54 53 52 51 50 49 48 47 46
37 38 39 40 41 42 43 44 45
36 35 34 33 32 31 30 29 28
19 20 21 22 23 24 25 26 27
18 17 16 15 14 13 12 11 10
1 2 3 4 5 6 7 8 9
BH61
505
BH62
11
12 (32 Dup)
DEC
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BH-50
11
810A
808A
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411A
BH51
603A
404A
415A
BH63
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606A
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BH15
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BH5
123
302A
B02W019D
BH49
BH49A
18
OW5A
OW5B
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OW04A
OW03B
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OW04B
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A56
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OW06A
A23A
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OW12B
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#116 Balmer Rd (CWM secondary gate)
#120 Lewiston Water Cntrl Poll. Center
#1-180 Radon Flux Monitoring Location (See Above, Annual Event)
Above Ground Drainage Ditch/Culvert
Existing Roads Paved/Gravel
Fence (Represents Outer Portion of Property Boundary)

ATTACHMENT 1

CY2001 EXTERNAL GAMMA RADIATION DOSE RATES
NIAGARA FALLS STORAGE SITE

Attachment 1
CY2001 External Gamma Radiation Dose Rates Niagara Falls Storage Site

Monitoring Location[b]		TETLD[a] Dose Rate Total[c] First[j] (mrem)[f]	Total[c] Second[k] (mrem)[f]	Corrected[d] (mrem/yr)[g]	Above Background[e] (mrem/yr)[g]
NFSS	1	22.2	23.6	50.4	3.2
Perimeter	1	19.7	19.2	45.4	0.0
	7	19.4	18.3	41.4	0.0
	7	17.1	0.6	21.6	0.0
	11	14.1	15.6	32.7	0.0
	11	15.8	18.9	40.3	0.0
	12	15.6	19.2	38.3	0.0
	12	15.9	12.8	33.7	0.0
	13	16.1	20.9	40.7	0.0
	13	18.4	5.5	28.7	0.0
	15	17.8	18.6	40.0	0.0
	15	18.2	21.1	45.7	0.0
	28	20.8	22.8	47.9	0.8
	28	20.1	24.7	52.0	4.9
	29	23.8	27.7	56.6	9.5
	29	22.3	24.5	54.5	7.4
	36	18.2	18.2	40.0	0.0
	36	17.3	23.4	47.1	0.0
	122	13.2	21.5	38.2	0.0
	122	19.6	11.2	36.4	0.0
	123	17.8	19.2	40.7	0.0
	123	16.8	17.2	39.7	0.0

Monitoring Location[b]		TETLD[a] Dose Rate Total[c] First[j] (mrem)[f]	Total[c] Second[k] (mrem)[f]	Corrected[d] (mrem/yr)[g]	Above Background[e] (mrem/yr)[g]
WCS[h]	8	12.1	18.9	34.1	0.0
Perimeter	8	15.3	7.0	26.5	0.0
	10	20.7	24.0	49.2	2.0
	10	19.2	25.5	51.8	4.7
	18	20.1	17.3	41.1	0.0
	18	17.8	16.9	40.6	0.0
	21	17.7	20.8	42.3	0.0
	21	13.1	19.2	37.3	0.0
	23	12.5	24.8	41.1	0.0
	23	20.2	23.6	50.9	3.8
	24	16.1	16.8	36.2	0.0
	24	15.3	15.2	35.6	0.0
TETLD Dose Rate[a]					
Background	105	13.6	17.6	34.3	---
	105	14.9	17.6	37.8	---
	116	18.4	17.4	39.3	---
	116	15.3	15.3	35.7	---
	120	31.4	30.8	68.4	---
	120	28.3	29.3	67.2	---
Average Background		20.3	21.3	47.1	

Nearest Resident Dose Calculations (3,600 feet Southwest of NFSS)

- NFSS Perimeter Monitoring Locations 11, 13, 15, 29, and 36
- WCS Perimeter Monitoring Locations 8 and 10

h1	3	feet	distance of TETLD from the source
h2	3,600	feet	distance of resident from the TETLDs
L	1,383	feet	half the length of the line source (West perimeter fence)
d1	1.7	mrem/yr	average dose rate at the TETLD monitoring locations [i]
d2	0.0003	mrem/yr	resident dose rate at 3,600 feet from the TETLD

Nearest Off-Site Worker Dose Calculations (150 feet East of Castle Garden Road)

- NFSS Perimeter Monitoring Locations 1, 28, and 123
- Off-Site Worker Receives 8-Hour Dose per Day

h1	3	feet	distance of TETLD from the source
h2	1,020	feet	distance of off-site worker from the TETLDs
L	1,350	feet	half the length of the line source (Campbell Street)
d1	1.5	mrem/yr	average dose rate at the TETLD monitoring locations [i]
d2	0.0006	mrem/yr	off-site worker dose rate at 1,020 feet from the TETLD (8-hour day)

a. TETLD = Tissue-equivalent thermoluminescent dosimeter. There are two TETLDs per monitoring location.
b. Monitoring locations are shown in Figure 2.
c. Reported values are the average chip reading per TETLD. There are five chips in each TETLD.
d. TETLD readings are corrected for shelter/absorption factor (a/s = 1.075) and normalized to a one-year exposure.
Corrected yearly exposure = (Average of First TETLD reading/exposure duration and Second TETLD reading/exposure duration) * 1.075 * 365 days.
Example (Location 1, First TETLD): (22.2 mrem / 180 days + 23.6 mrem / 177 days) / 2 * 1.075 * 365 days per year = 50.4 mrem/year.
e. Average background (corrected) is subtracted from corrected yearly exposure.
Above-background exposure = corrected yearly exposure - corrected average background.
Example (Location 1, First TETLD): 50.4 mrem/year - 47.1 mrem/year = 3.2 mrem/year.
f. mrem - millirem.
g. mrem/yr - millirem per year.
h. Monitoring locations along the perimeter of the waste containment structure (WCS).
i. The average dose rate was calculated summing the corrected TETLD measurements and dividing by the total number of TETLD measurements.
If the above background dose rate is negative, then it is assumed to be zero for calculational purposes.
j. First Monitoring Period
k. Second Monitoring Period

FINAL

APPENDIX C: NFSS CY2001 ENVIRONMENTAL SURVEILLANCE TECHNICAL MEMORANDUM

FUSRAP CY2001 NESHAP ANNUAL REPORT FOR NIAGARA FALLS STORAGE SITE (NFSS)

LEWISTON, NEW YORK

JULY 2002

U.S. Army Corps of Engineers
Buffalo District Office
Formerly Utilized Sites Remedial Action Program

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prepared by

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with assistance from

Science Applications International Corporation
under Contract No. DAHA90-94-D-007-DN04

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ACRONYMS AND ABBREVIATIONS

BNI	Bechtel National, Inc.
°C	degree Celsius
CAP88-PC	Clean Air Act Assessment Package-1988, Version 2.0
cm	centimeter
Ci	curie(s)
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
E_w	annual wind erosion emission
EPA	Environmental Protection Agency
FUSRAP	Formerly Utilized Sites Remedial Action Program
g	gram(s)
ha	hectare
hr	hour
m	meter
m^2	square meter(s)
MARSSIM	Multi-Agency Radiation Survey & Site Investigation Manual
MEI	maximally exposed individual
mph	miles per hour
mrem	millirem
NOAA	National Oceanic and Atmospheric Administration
NESHAP	National Emission Standards for Hazardous Air Pollutants
NFSS	Niagara Falls Storage Site
s	second
TETLD	tissue-equivalent thermoluminescent dosimeters
USACE	United States Army Corps of Engineers
WCS	waste containment structure
yr	year(s)

1.0 INTRODUCTION

In 1974, the Atomic Energy Commission, a predecessor to the Department of Energy (DOE), instituted the Formerly Utilized Sites Remedial Action Program (FUSRAP). This program is now managed by United States Army Corps of Engineers (USACE) to identify and clean up, or otherwise control sites where residual radioactivity remains from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized USACE to remedy under FUSRAP. The Niagara Falls Storage Site (NFSS) is a DOE owned storage site managed under FUSRAP. In October 1997, Congress transferred the responsibility for FUSRAP from DOE to USACE.

1.1 SITE DESCRIPTION

NFSS is located in the Town of Lewiston in northwestern New York state, northeast of Niagara Falls and south of Lake Ontario (Figure 1). The 77-ha site includes one former process building (Building 401), a maintenance building (Hittman Building), a building used for both maintenance and office space (Building 429), a small equipment shed, and a 4-ha Waste Containment Structure (WCS). The property perimeter is fenced and public access is restricted.

Land use in the region is primarily rural; however, the site is bordered by a chemical waste disposal facility (ChemWaste Management Chemical Services, Inc.) on the north, a solid waste disposal facility (Modern Disposal, Inc.) on the east and south, and a Niagara Mohawk Power Corporation right-of-way on the west. The nearest residential areas are approximately 1.1 km southwest of the site; the residences are primarily single-family dwellings.

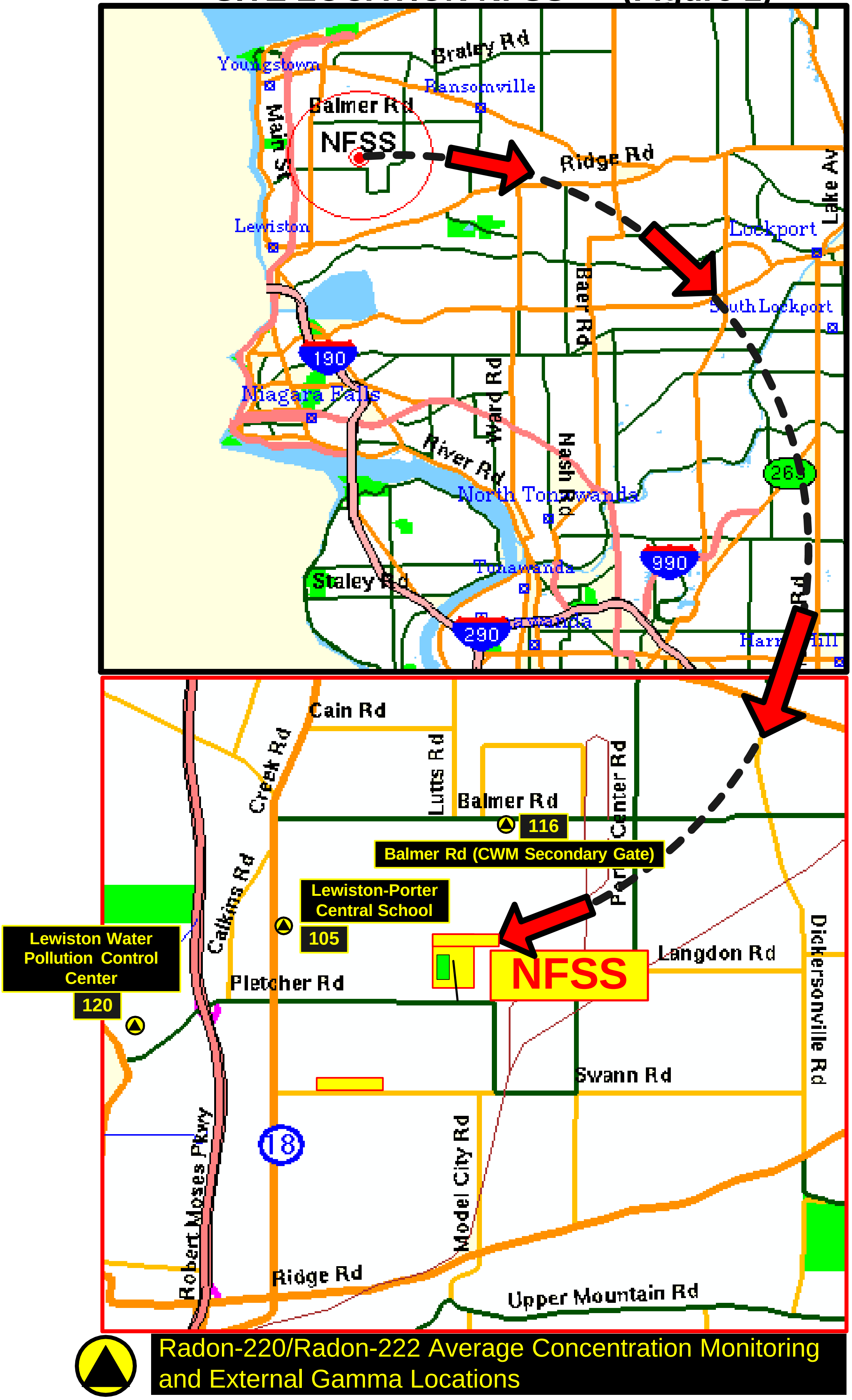
1.2 SOURCE DESCRIPTION

Beginning in 1944, NFSS was used as a storage facility for low-level radioactive residues and wastes. The residues and wastes are the process by-products of uranium extraction from pitchblende (uranium ore). Waste was also generated from remediation of buildings and process equipment used in the uranium extraction process. The residues originated at other sites and were transferred to NFSS for storage in buildings, on-site pits, and surface piles. Table 1 includes a brief history and description of the major radioactive residues and wastes transferred to NFSS. From 1953 to 1959 and 1965 to 1971, Building 401 was used as a boron-10 isotope separation plant.

Table 1. History and Description of Wastes Transferred to NFSS

Material	Description	Transferred to NFSS
L-50	Low-level, high-activity radioactive residues from the processing of low-grade uranium ores at Linde Air Products, Tonawanda, New York.	1944
R-10	Low-level, low-activity radioactive residues from the processing of low-grade uranium ores at Linde Air Products, Tonawanda, New York.	1944
F-32	Low-level, high-activity radioactive residues from the processing of high-grade uranium ores at Middlesex, New Jersey.	1944 to early 1950
L-30	Low-level, high-activity radioactive residues from the processing of low-grade uranium ores at Linde Air Products, Tonawanda, New York.	1945
K-65	Low-level, high-activity radioactive residues from the processing of low-grade uranium ores at Mallinckrodt Chemical Works, St. Louis, Missouri.	1949
Middlesex Sands	Sand and abraded material from the sandblasting of buildings and process equipment where the F-32 residue was generated at Middlesex Metal Refinement Plant, Middlesex, New Jersey.	1950

SITE LOCATION NFSS (Figure 1)



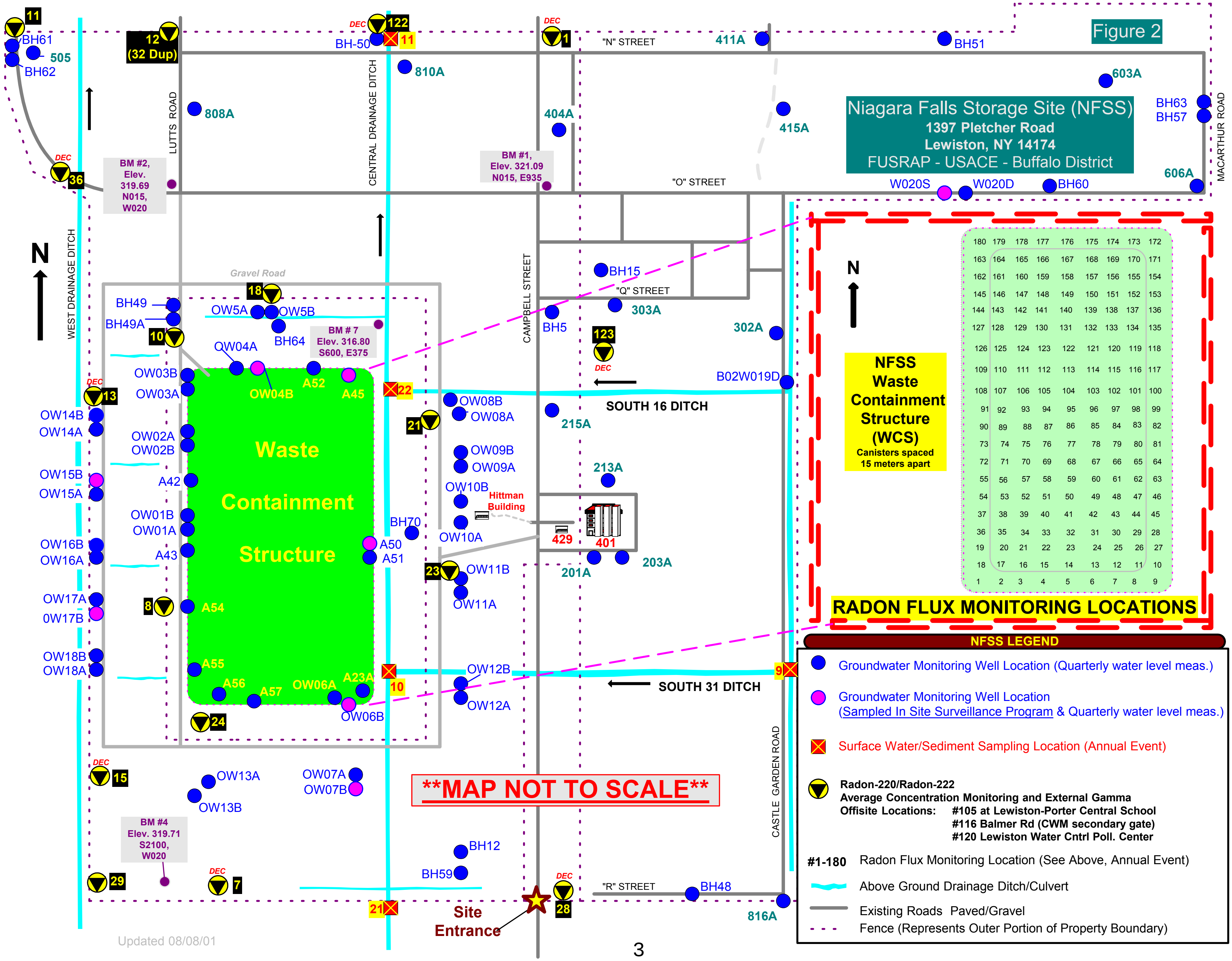


Figure 2
Niagara Falls Storage Site (NFSS)
1397 Pletcher Road
Lewiston, NY 14174
FUSRAP - USACE - Buffalo District
"N" STREET
"O" STREET
"Q" STREET
"R" STREET
LUTTS ROAD
CENTRAL DRAINAGE DITCH
WEST DRAINAGE DITCH
CAMPBELL STREET
MACARTHUR ROAD
CASTLE GARDEN ROAD
Gravel Road
SOUTH 16 DITCH
SOUTH 31 DITCH
N
BM #2, Elev. 319.69 N015, W020
BM #1, Elev. 321.09 N015, E935
BM # 7 Elev. 316.80 S600, E375
BM #4 Elev. 319.71 S2100, W020
Waste Containment Structure
Hittman Building
12 (32 Dup)
BH61
505
BH62
BH-50
810A
808A
404A
411A
415A
BH51
603A
BH63
BH57
606A
W020S
W020D
BH60
BH15
303A
BH5
302A
B02W019D
215A
213A
BH49
BH49A
OW5A
OW5B
BH64
OW04A
OW04B
A52
A45
OW03B
OW03A
OW14B
OW14A
OW02A
OW02B
OW15B
OW15A
A42
OW01B
OW01A
OW16B
OW16A
A43
OW17A
OW17B
A54
OW18B
OW18A
A55
A56
A57
OW06A
A23A
OW06B
BH70
A50
A51
OW08B
OW08A
OW09B
OW09A
OW10B
OW10A
OW11B
OW11A
OW12B
OW12A
429
401
201A
203A
OW13A
OW13B
OW07A
OW07B
BH12
BH59
BH48
816A
DEC
MAP NOT TO SCALE
Site Entrance
Updated 08/08/01
NFSS Waste Containment Structure (WCS)
Canisters spaced 15 meters apart
RADON FLUX MONITORING LOCATIONS
NFSS LEGEND
Groundwater Monitoring Well Location (Quarterly water level meas.)
Groundwater Monitoring Well Location (Sampled In Site Surveillance Program & Quarterly water level meas.)
Surface Water/Sediment Sampling Location (Annual Event)
Radon-220/Radon-222
Average Concentration Monitoring and External Gamma
Offsite Locations: #105 at Lewiston-Porter Central School
#116 Balmer Rd (CWM secondary gate)
#120 Lewiston Water Cntrl Poll. Center
#1-180 Radon Flux Monitoring Location (See Above, Annual Event)
Above Ground Drainage Ditch/Culvert
Existing Roads Paved/Gravel
Fence (Represents Outer Portion of Property Boundary)

Since 1971, activities at NFSS have been confined to residue and waste storage and remediation. All on-site and off-site areas with residual radioactivity exceeding DOE guidelines were remediated between 1955 and 1992. The materials generated during remedial actions (approximately 195,000 m^3) are encapsulated in the WCS (Figure 2), which is specifically designed to provide long-term storage of the materials. Remedial investigation began at the end of 1999 to see if any areas of elevated activity were missed during the DOE cleanup. Initial results show that isolated areas of elevated activity were missed. This investigation is currently ongoing.

2.0 REGULATORY STANDARDS

The Environmental Protection Agency's (EPA) National Emission Standards for Hazardous Air Pollutants (NESHAP) are compliance standards that require annual reporting of emissions of radionuclides and radon gas from operations at nuclear facilities.

2.1 40 CFR 61, SUBPART H

40 CFR 61, Subpart H provides standards for reporting of emissions of radionuclides (excluding radon-222 and radon-220) into the air. Compliance with Subpart H is verified by applying the EPA approved CAP88-PC version 2.0 (CAP88-PC) model (EPA 1997). 40 CFR 61.92 states that emissions "shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr."

2.2 40 CFR 61, SUBPART Q

40 CFR 61, Subpart Q applies to all storage and disposal facilities that store radium-containing material that emits radon-222 into air. Compliance with Subpart Q is verified by annual monitoring of the WCS for radon-222 flux. Subpart Q states that "no source shall emit more than 20 pCi/m^2-s of radon-222."

3.0 AIR EMISSION DATA

Table 2 summarizes the sources of air emissions. Appendix A contains the annual wind erosion emission (E_w) calculation. Appendix B contains the source term calculations and annual air releases.

The area of the Multi-Agency Radiation Survey & Site Investigation Manual (MARSSIM) Class 1 units designated in planning the activities for the Phase II remedial investigation was used to determine the *in situ* emission rates for each radionuclide. The WCS was identified as a Class 1 MARSSIM unit, but was not used in the source term development because it is covered with vegetation and at least 3 to 4 feet of clean clay and topsoil (Appendix B). Although the total area of each Class 1 unit is not contaminated with elevated levels of radionuclides, it was used to provide a conservative estimate for *in situ* emission rates.

Table 2. Air Emission Data - NFSS

Point Sources	Type Control	Efficiency	Distance to Hypothetical Maximally Exposed Individual
none	not applicable	not applicable	not applicable
Non-Point Sources	**Type Control**	**Efficiency**	**Distance to Hypothetical Maximally Exposed Individual**
in situ soil	vegetative cover	75 percent[a]	1475 meters southwest (resident)[b] 275 meters east (off-site worker) 3050 meters west-northwest (school) 595 meters south (Farm)
Group Sources	**Type Control**	**Efficiency**	**Distance to Hypothetical Maximally Exposed Individual**
none	not applicable	not applicable	not applicable

[a] This efficiency is the reduction factor used to correct emissions for vegetative cover (Appendix A,B).
[b] Distance from center of non-point source to nearest resident and worker were defined previously (BNI 1997).

4.0 DOSE ASSESSMENTS

4.1 MODEL SOURCE DESCRIPTION

To determine the dose from airborne particulates potentially released from NFSS during CY2001, the annual wind erosion emission, E_w (Appendix A) is first calculated using local climatological data (Appendix F) from the National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center. The E_w factor combines the frequency at which a defined velocity occurs with the resuspension rate to provide the annual dust lost per unit area. The E_w factor is then applied to the source term and applicable area to calculate annual radionuclide emissions for each radionuclide. The source term was developed from sample data compiled during the CY2000 Phase I remedial investigation for site soil contamination (Appendix B). Contributions from radon gas, per regulatory guidance, are not considered in this calculation. The total annual radionuclide emissions for each radionuclide are then entered into the EPA's CAP88-PC computer model.

The model estimates resultant doses from airborne particulates to hypothetical individuals at the distances to the nearest residence, commercial/industrial facility, school, and farm as measured from a central location on-site. Hypothetical doses are then corrected for residential home and farm occupancy (conservatively assumed to be 24 hours/day, 365 days/year) and commercial/industrial facility and school occupancy (40 hours/week, 50 weeks/year). The hypothetical individual receiving the higher of these calculated doses is then identified as the hypothetical Maximally Exposed Individual (MEI) for airborne particulate dose.

4.2 DESCRIPTION OF DOSE MODEL

4.2.1 CAP88-PC Computer Program

The CAP88-PC model is a set of computer programs, databases, and associated utility programs that estimate the dose and risk from airborne radioactivity emissions. The EPA NESHAP compliance procedures for airborne radioactivity emissions at DOE facilities (40 CFR 61.93(a)) require the use of the CAP88-PC model, or other approved procedures to calculate effective dose equivalents to members of the public.

CAP88-PC uses a modified Gaussian plume equation to estimate the average dispersion of radionuclides released from a site. Assessments are done for a circular grid of distances and directions for a radius of 80 kilometers (50 miles) around the facility. Agricultural arrays of milk cattle, beef cattle and agricultural crop area are generated automatically, requiring the user to supply only the State name or agricultural productivity values. Organs and weighting factors are modified to follow the International Commission on Radiological Protection (ICRP) 26/30 Effective Dose Equivalent calculations. The calculation of deposition velocity and the default scavenging coefficient is also modified to incorporate current EPA policy. The default scavenging coefficient is calculated as a function of annual precipitation. The program calculates the effective dose equivalents by combining the inhalation and ingestion intake rates and the air and ground surface concentrations with dose conversion factors.

4.2.2 CAP88-PC Input

Input parameters for CAPP88-PC include:

Radionuclide emissions (Appendix B),
Weather data (average annual temperature, total annual precipitation) (Appendix F),
Emission source height and area (Section 4.3), and
Distances to nearest resident, off-site worker, school, and farm (Section 4.3).

4.2.3 CAP88-PC Output

The "Dose and Risk Equivalent Summaries" from CAP88-PC contains the resulting effective dose equivalents for each modeled scenario. The effective dose equivalent summary contains results for the 16 directions around the facility. The effective dose equivalent for the nearest resident, off-site worker, school, and farm is found by extracting the value for the appropriate distance and direction. CY2001 CAP88-PC individual receptor and population output summaries are located in Appendix C and D, respectively.

4.3 Compliance Assessment

The released activity data from Appendix B is entered into the CAP88-PC modeling program to derive the dose to the defined receptors. To derive the dose to the MEI, the CAP88-PC model must have weather data for the appropriate year, information on the emission source, and the distances and directions to the nearest residence, off-site worker, school, and farm. The following CY2001 meteorological data for the Buffalo area was entered into CAP88-PC (see Appendix F):

Average temperature, CY2001 -	9.89 °C,
Precipitation, CY2001 -	75 cm, and
Mixing height, CY2001 -	1000 m.

The following emission source and nearest receptor distances and direction information were also entered into the program:

Source height -	0 meters,
Source area -	26,045 square meters,
Resident -	1475 meters southwest,
Off-site worker -	275 meters east,
School -	3050 meters west-northwest, and
Farm -	595 meters south.

The CAP88-PC annual dose to the nearest resident, off-site worker, school, and farm at the corresponding directions and distances taken from page six of the "Dose and Risk Equivalent Summaries" document for individual modeling (Appendix C) are:

Resident -	2.4E-03 mrem per year,
Off-site worker -	4.9E-02 mrem per year,
School -	1.4E-03 mrem per year, and
Farm -	8.7E-03 mrem per year.

The nearest off-site worker and school doses are corrected to 2,000 hours out of 8,760 possible hours per year. The adjusted doses are:

Off-site worker -	1.1E-02 mrem per year and
School -	3.2E-04 mrem per year.

5.0 SUPPLEMENTAL INFORMATION

5.1 POPULATION DOSE

The CAP88-PC model was used to estimate the hypothetical airborne particulate collective dose to the population within 80 km of the site. A population file (generated from county population densities) to determine the number of people in circular grid sections fanning out to 80 km from the center of site. The effective dose equivalent for the collective population is the total collective population (person-rem/year) result from any of the summaries in the "Dose and Risk Equivalent Summaries" report from the population assessment.

The population data for the area around the facility was taken from previous calculations (BNI 1994). This population data was entered into a text file that the program could read and incorporate into the model for the population dose.

The CAP88-PC annual effective dose for the population within 80 km of the facility taken from page two of the “Dose and Risk Equivalent Summaries” document for the population modeling run (Appendix D) is:

Population - 4.60E-02 person-rem per year.

5.2 RADON-222 FLUX

Measurement of radon-222 flux provides an indication of the rate of radon-222 emission from a surface. Radon-222 flux is measured with activated charcoal canisters placed at 15-m intervals across the surface of the WCS for a 24-h exposure period. Measurements for CY2001 are presented in Appendix E; measurement locations are shown in Figure 2.

Measured results for CY2001 ranged from 0.001 to 0.318 pCi/m^2-s, with an average result of 0.09 pCi/m^2-s. As in previous years, these results are well below the 20 pCi/m^2-s standard specified in 40 CFR Part 61, Subpart Q, and demonstrate the effectiveness of the containment cell design and construction in mitigating radon-222 migration.

5.3 NON-APPLICABILITY

Requirements from section 61.93(b) of 40 CFR for continuous monitoring from point sources (stacks or vents) are not applicable to NFSS.

6.0 REFERENCES

Bechtel National, Inc. (BNI), 1997. "1996 Public Inhalation Dose" 14501-158-CV-030, Rev. 0, Oak Ridge, TN.

BNI 1994. "CAP88-PC Population Files for NFSS" 14501-158-CV-012, Rev. 0, Oak Ridge, TN.

Environmental Protection Agency (EPA), 1995. *Compilation of Air Pollutant Emission Factors, Fifth Edition*, AP-42, Office of Air Quality Planning and Standards, Research Triangle Park, NC (January).

EPA 1997. CAP88PC Version 2.0 Computer Code, U.S. Environmental Protection Agency.

NRC 1987. Regulatory Guide 3.59, *Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations*, U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, March.

40 CFR 61, Subpart H. *National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities.*

40 CFR 61, Subpart Q. *National Emission Standards for Radon Emissions From Department of Energy Facilities.*

APPENDIX A

ANNUAL WIND EROSION EMISSION CALCULATION

A.1 CALCULATED *IN SITU* WINDBLOWN PARTICLE EMISSIONS

The windblown particle emissions for the Niagara Falls Storage Site is based on local climatological data collected from the Niagara Falls International Airport by the NOAA, National Climatic Data Center (Appendix D).

Wind speed frequency data was obtained from the ten-year (1991 to 2000) average daily wind velocity (see Table A-1).

Table A-1. Niagara Falls Storage Site Wind Speed Frequency

Wind Speed Group, knots*	Frequency
0 – 3	0.09
4 – 6	0.23
7 – 10	0.35
11 – 16	0.27
17 – 21	0.05
21+	0.01

*knot = 1.151 miles/hr

Wind direction frequency was obtained from the CAP-88 wind file, IAG0905.WND (see Table A-2).

Table A-2. Niagara Falls Storage Site Wind Rose Frequency

Wind direction (wind towards)	Wind From	Wind Frequency	Wind direction (wind towards)	Wind From	Wind Frequency
N	S	0.062	S	N	0.049
NNW	SSE	0.020	SSE	NNW	0.050
NW	SE	0.029	SE	NW	0.077
WNW	ESE	0.032	ESE	WNW	0.077
W	E	0.063	E	W	0.087
WSW	ENE	0.043	ENE	WSW	0.100
SW	NE	0.045	NE	SW	0.141
SSW	NNE	0.032	NNE	SSW	0.092

Windblown particle emissions per unit area are estimated using Equation 2 from NRC 1987. The equation is:

$$E_w = \frac{3.1536E7}{0.5} \times \sum R_s F_s$$

where:

E_w is the annual dust loss per unit area (g/m^{2}yr),

F_s is the annual average wind speed frequency for Niagara Falls (Table A-1),

R_s is the resuspension rate at the average wind speed for particles <20 µm (g/m^2s), Table A-3 below,
3.1536E7 is the number of seconds per year, and
0.5 is the fraction of dust loss by particles < 20 µm.

Table A-3. *In situ* Windblown Dust Emission Calculation

Wind Speed Group, knots	Frequency F_s	Resuspension Rate R_s (g/m^2s)	$F_s R_s$
0 – 3	0.09	0	0
4 – 6	0.23	0	0
7 – 10	0.35	3.92 E-7	1.38 E-7
11 – 16	0.27	9.68 E-6	2.64 E-6
17 – 21	0.05	5.71 E-5	2.91 E-6
21+	0.01	2.08 E-4	2.29E-6
		Σ =	7.98 E-6

The annual dust loss per unit area is calculated to be **503 g/m^2yr**.

The total annual wind blown *in situ* emission rate, by radionuclide, is calculated using Equation 3 from NRC 1987.

$$S_{Ci/yr} = E_w \times A \times C_{pCi/g} \times \frac{Ci}{10^{12}\, pCi} \times (1 - RF)$$

where:

E_w is the annual dust loss per unit area = 503 g/m^2y,
A is the surface area = 26,045 m^2,
C is the soil concentration (Appendix B), and
RF is a unitless factor of 0.75 for Effective Reduction in Emission for vegetative cover from NRC 1987.

Wind blown *in situ* emission rates for each radionuclide are calculated and illustrated in Appendix B.

A.2 REFERENCES

NRC 1987. Regulatory Guide 3.59, *Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations*, U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, March.

APPENDIX B

SOURCE TERM CALCULATIONS AND ANNUAL AIR RELEASES

B.1 SOURCE TERM DEVELOPMENT

The source term for NFSS NESHAPS calculations was developed considering the radionuclides in the uranium, thorium, and actinium decay series as shown in Table B-1. Concentration data for these radioisotopes were taken from the 2000 Phase I remedial investigation and is listed in Table B-2. The newer data set was used given that many areas around NFSS have already been remediated and covered with clean backfill. Phase I sampling performed at the end of 1999 and beginning of 2000 focused on identifying areas with elevated activity in surface soil, if any, and would still be conservative, but would be more realistic than using the historical data set.

The waste containment structure (WCS), completed in 1986 and added to in 1991, is surrounded by sufficient topsoil and compacted clay to consider radionuclide emissions negligible. In 1986, the entire WCS was covered with 3 feet of low-permeability, compacted clay, a 12 inch-thick layer of loosely compacted soil, 6 inches of topsoil and covered with shallow-rooted grass. A clay cutoff wall and dike measuring 11 to 29 feet in thickness formed the perimeter. In 1991, additional soil with residual radioactivity from a vicinity property, along with 60 drums containing radioactive material, were placed over the existing WCS. Six inches of clay was placed over the waste material and two feet of compacted clay was added on top along with 1.5 feet of topsoil material.

Radium-226 was detected at an elevated concentration of 1,140 pCi/g in one area during the Phase I remedial investigation. This was analyzed and determined to come from a stone in the sample. Since release rates are based on dust erosion and not buried stones, this detection was not used in the source term calculation.

The area over which the annual dust loss was applied included all areas receiving a Class 1 designation as part of the current remedial investigation. This is a conservative assumption since many of the Class 1 areas reported elevated radionuclide concentrations over only a portion of the defined area.

Concentration data are not available for all the radionuclides in Table B-1. If explicit results for a radionuclide was not available, it was assumed that the radionuclide was present in equilibrium with (at the same concentration as) the nearest long-lived parent. Branching ratios were also used, as appropriate, to more accurately estimate source term concentrations. Tables B-3 through B-5 list source term values used in the CAP-88PC modeled scenarios.

Table B-1. Radionuclides Considered in NESHAPS Evaluation

Uranium Series	Thorium Series	Actinium Series
U-238	Th-232	U-235
Th-234	Ra-228	Th-231
Pa-234m	Ac-228	Pa-231
Pa-234 (0.13%)	Th-228	Ac-227
U-234	Ra-224	Th-227 (98.62%)
Th-230	Rn-220 (thoron)	Fr-223 (1.38%)
Ra-226	Po-216	Ra-223
Rn-222 (radon)	Pb-212	Rn-219 (actinon)
Po-218	Bi-212	Po-215
Pb-214 (99.98%)	Po-212 (64.07%)	Pb-211 (≈ 100%)
At-218 (0.02%)	Tl-208 (35.93%)	At-215 (0.00023%)
Bi-214	Pb-208 (stable)	Bi-211
Po-214 (99.979%)		Po-211 (0.273%)
Tl-210 (0.021%)		Tl-207 (99.73%)
Pb-210		Pb-207 (stable)
Bi-210		
Po-210 (≈ 100%)		
Tl-206 (0.00013%)		
Pb-206 (stable)		

Nuclides in shaded cells were excluded from dose calculations for the following reasons: 1) The radon isotopes including thoron and actinon are specifically excluded per the regulation, 2) extremely short lived nuclides were excluded, and 3) stable nuclides do not contribute to radiological dose.

Nuclides are presented from top to bottom in order of decay starting from the parent radionuclides. Branching fractions are shown, as appropriate, for consideration in source term development. Fractions taken from (Shleien, 1992).

Table B-2. Summary of CY00 Phase I Characterization Data Used in NESHAP Dose Calculations

Analyte	Units	Results > Detection Limit	Minimum Detect	Maximum Detect	Average Result	95% UCL of the Mean	Exposure Concentration
Radium-226 [a]	(pCi/g)	198/ 202	0	1140	7.11	16.4	16.4
Radium-226 [b]	(pCi/g)	197/ 201	0	16	1.48	1.67	1.67
Thorium-228	(pCi/g)	201/ 201	0	24	1.24	1.5	1.5
Thorium-230	(pCi/g)	200/ 201	0	16	1.74	1.99	1.99
Thorium-232	(pCi/g)	195/ 196	0	21	1.17	1.39	1.39
Uranium-234	(pCi/g)	176/ 176	0	119	1.88	2.99	2.99
Uranium-235	(pCi/g)	33/ 112	0	6	0.0536	0.142	0.142
Uranium-238	(pCi/g)	176/ 176	0	120	1.9	3.02	3.02

[a] Including 1140 pCi/g outlier NiagAir1 on 25JUL00 at 15:36 using dataset allradnq
[b] Excluding 1140 pCi/g outlier NiagAir1 on 26JUL00 at 08:00 using dataset allradnq
Except where noted, all values generated by program NiagAir1 and NiagAir2 using dataset allradnq. Values used in the uranium series source term estimate bolded for ease of reference.

Table B-3. Uranium Series Release Estimates

Analyte	(C_m) Measured Activity (pCi/g)	(F) Activity Fraction [a]	(C) Source Unit Activity (pCi/g) [b]	(S) Released Activity (Ci/yr) [c]
U-238	3.02	1.0	3.02	9.89E-06
Th-234		1.0	3.02	9.89E-06
Pa-234m		1.0	3.02	9.89E-06
Pa-234		1.3E-03	0.003926	1.29E-08
U-234	2.99	1.0	2.99	9.79E-06
Th-230	1.99	1.0	1.99	6.52E-06
Ra-226	1.67	1.0	1.67	5.47E-06
Rn-222 (radon)		0.0	0	0.00E+00
Po-218		1.0	1.67	5.47E-06
Pb-214		0.9998	1.7	5.47E-06
At-218		0.0002	0.00033	1.09E-09
Bi-214		1.0	1.67	5.47E-06
Po-214		0.99979	1.7	5.47E-06
Tl-210		0.00021	0.00035	1.15E-09
Pb-210		1.0	1.67	5.47E-06
Bi-210		1.0	1.67	5.47E-06
Po-210		1.0	1.67	5.47E-06
Tl-206		0.0	0	0.00E+00
Pb-206 (stable)		0.0	0	0.00E+00

Erosion Rate (E_w)[d]	503 grams/m^2-year
Area (A)	26,045 m^2
Constant (Fc)	1.00E-12 Ci/pCi
Reduction (RF)[e]	0.75 unitless

[a] F = 0.0 for radon and stable isotopes, and isotpoes with activity fractions << 0.01. F applied to nearest long-lived isotope with measured result.

[b] $C = C_m \times F$

[c] $S = E_w \times A \times C \times Fc \times (1\text{-}RF)$

[d] From Appendix A

[e] Reduction factor for vegetative cover from NRC 1987

Table B-4. Thorium Series Release Estimates

Analyte	(C_m) Measured Activity (pCi/g)	(F) Activity Fraction [a]	(C) Source Unit Activity (pCi/g) [b]	(S) Released Activity (Ci/yr) [c]
Th-232	1.39	1.0	1.39	4.55E-06
Ra-228		1.0	1.39	4.55E-06
Ac-228		1.0	1.39	4.55E-06
Th-228	1.5	1.0	1.5	4.91E-06
Ra-224		1.0	1.5	4.91E-06
Rn-220 (thoron)		0.0	0	0.00E+00
Po-216		1.0	1.5	4.91E-06
Pb-212		1.0	1.5	4.91E-06
Bi-212		1.0	1.5	4.91E-06
Po-212		0.6707	1.01	3.29E-06
Tl-208		0.3593	0.539	1.77E-06
Pb-208 (stable)		0.0	0	0.00E+00

Erosion Rate (E_w)[d] 503 grams/m^2-year
Area (A) 26,045 m^2
Constant (Fc) 1.00E-12 Ci/pCi
Reduction (RF)[e] 0.75 unitless

[a] F = 0.0 for radon and stable isotopes, and isotpoes with activity fractions << 0.01. F applied to nearest long-lived isotope with measured result.
[b] $C = C_m \times F$
[c] $S = E_w \times A \times C \times Fc \times (1\text{-}RF)$
[d] From Appendix A
[e] Reduction factor for vegetative cover from NRC 1987

Table B-5. Actinium Series Release Estimates

Analyte	(C_m) Measured Activity (pCi/g)	(F) Activity Fraction [a]	(C) Source Unit Activity (pCi/g) [b]	(S) Released Activity (Ci/yr) [c]
U-235	0.142	1.0	0.142	4.65E-07
Th-231		1.0	0.142	4.65E-07
Pa-231		1.0	0.142	4.65E-07
Ac-227		1.0	0.142	4.65E-07
Th-227		0.9862	0.140	4.59E-07
Fr-223		0.0138	0.0020	6.42E-09
Ra-223		1.0	0.142	4.65E-07
Rn-219 (actinon)		0.0	0	0.00E+00
Po-215		1.0	0.142	4.65E-07
Pb-211		1.0	0.142	4.65E-07
At-215		0.0	0	0.00E+00
Bi-211		1.0	0.142	4.65E-07
Po-211		0.00273	0.00038766	1.27E-09
Tl-207		0.9973	0.142	4.64E-07
Pb-207 (stable)		0.0	0	0.00E+00

Erosion Rate (E_w)[d]	503 grams/m^2-year
Area (A)	26,045 m^2
Constant (Fc)	1.00E-12 Ci/pCi
Reduction (RF)[e]	0.75 unitless

[a] F = 0.0 for radon and stable isotopes, and isotpoes with activity fractions << 0.01. F applied to nearest long-lived isotope with measured result.

[b] $C = C_m \times F$

[c] $S = E_w \times A \times C \times Fc \times (1-RF)$

[d] From Appendix A

[e] Reduction factor for vegetative cover from NRC 1987

B.2 REFERENCES

Shleien, 1992. *The Health Physics and Radiological Health Handbook*, Scinta, Inc., Silver Spring, MD.

NRC 1987. Regulatory Guide 3.59, *Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations*, U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, March.

APPENDIX C

CAPP88-PC REPORTS – INDIVIDUAL

C A P 8 8 - P C

Version 2.00

Clean Air Act Assessment Package - 1988

D O S E A N D R I S K E Q U I V A L E N T S U M M A R I E S

Non-Radon Individual Assessment
Jul 3, 2002 08:11 am

Facility: Niagara Falls Storage Site
Address:
City: Lewiston
State: NY Zip:

Source Category: Area
Source Type: Area
Emission Year: 2001

Comments: Air emissions NFSS CY2001 individual

Dataset Name: NFSSCY01individu
Dataset Date: Jul 3, 2002 08:10 am
Wind File: C:\CAP88PC2\WNDFILES\IAG0905.WND

Jul 3, 2002 08:11 am SUMMARY
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ORGAN DOSE EQUIVALENT SUMMARY

Organ	Selected Individual (mrem/y)
GONADS	1.56E-03
BREAST	1.33E-03
R MAR	2.85E-02
LUNGS	3.94E-01
THYROID	1.30E-03
ENDOST	3.48E-01
RMNDR	4.66E-03
EFFEC	6.31E-02

PATHWAY EFFECTIVE DOSE EQUIVALENT SUMMARY

Selected

Nfss01in - App C.sum

Pathway	Individual (mrem/y)
INGESTION	1.39E-03
INHALATION	6.09E-02
AIR IMMERSION	1.11E-07
GROUND SURFACE	8.61E-04
INTERNAL	6.23E-02
EXTERNAL	8.61E-04
TOTAL	6.31E-02

NUCLIDE EFFECTIVE DOSE EQUIVALENT SUMMARY

Nuclide	Selected Individual (mrem/y)
U-235	4.63E-04
TH-231	3.70E-09
PA-231	1.80E-03
AC-227	2.36E-03
TH-227	4.25E-05
RA-223	3.16E-05
PO-215	0.00E+00
PB-211	3.38E-08
BI-211	2.28E-09
TL-207	2.67E-11
FR-223	1.31E-10
PO-211	0.00E+00
TH-232	1.29E-02
RA-228	1.41E-04
AC-228	3.11E-06
TH-228	9.79E-03
RA-224	1.36E-04
PO-216	8.52E-09
PB-212	1.02E-04
BI-212	1.07E-04
TL-208	6.39E-04
PO-212	0.00E+00
U-238	9.25E-03
TH-234	3.84E-06
PA-234M	3.38E-10
PA-234	3.18E-10
U-234	1.03E-02
TH-230	1.29E-02
RA-226	5.10E-04
PO-218	1.49E-09
PB-214	4.53E-08
BI-214	5.72E-08
PO-214	0.00E+00
PB-210	1.12E-03
BI-210	8.41E-06
PO-210	5.21E-04
TOTAL	6.31E-02

CANCER RISK SUMMARY

Cancer	Selected Individual Total Lifetime Fatal Cancer Risk
LEUKEMIA	2.66E-08
BONE	1.60E-08
THYROID	4.82E-10
BREAST	4.25E-09
LUNG	6.54E-07
STOMACH	2.73E-09
BOWEL	1.54E-09
LIVER	1.08E-08
PANCREAS	1.83E-09
URINARY	3.67E-09
OTHER	2.24E-09
TOTAL	7.25E-07

PATHWAY RISK SUMMARY

Pathway	Selected Individual Total Lifetime Fatal Cancer Risk
INGESTION	8.11E-09
INHALATION	6.96E-07
AIR IMMERSION	2.69E-12
GROUND SURFACE	2.09E-08
INTERNAL	7.04E-07
EXTERNAL	2.09E-08
TOTAL	7.25E-07

NUCLIDE RISK SUMMARY

Nuclide	Selected Individual Total Lifetime Fatal Cancer Risk
U-235	6.22E-09
TH-231	1.08E-13
PA-231	1.00E-08
AC-227	2.05E-08
TH-227	1.17E-09
RA-223	7.63E-10

PO-215	0.00E+00
PB-211	6.52E-13
BI-211	2.71E-14
TL-207	8.74E-16
FR-223	1.38E-15
PO-211	0.00E+00
TH-232	7.31E-08
RA-228	1.84E-09
AC-228	6.27E-11
TH-228	1.97E-07
RA-224	3.09E-09
PO-216	2.04E-13
PB-212	2.34E-09
BI-212	2.55E-09
TL-208	1.56E-08
PO-212	0.00E+00
U-238	1.23E-07
TH-234	1.73E-10
PA-234M	8.61E-15
PA-234	8.17E-15
U-234	1.36E-07
TH-230	1.06E-07
RA-226	9.23E-09
PO-218	1.06E-12
PB-214	7.73E-12
BI-214	6.63E-12
PO-214	0.00E+00
PB-210	7.99E-09
BI-210	2.26E-10
PO-210	8.03E-09
TOTAL	7.25E-07

Jul 3, 2002 08:11 am

SUMMARY
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INDIVIDUAL EFFECTIVE DOSE EQUIVALENT RATE (mrem/y)
(All Radionuclides and Pathways)

	Distance (m)			
Direction	275	595	1475	3050
N	3.9E-02	1.1E-02	2.9E-03	1.6E-03
NNW	2.1E-02	4.0E-03	1.6E-03	1.2E-03
NW	2.4E-02	6.4E-03	2.1E-03	1.3E-03
WNW	3.4E-02	8.0E-03	2.4E-03	1.4E-03
W	4.7E-02	1.3E-02	3.4E-03	1.7E-03
WSW	3.6E-02	8.1E-03	2.4E-03	1.4E-03
SW	3.0E-02	8.2E-03	2.4E-03	1.4E-03
SSW	2.5E-02	5.7E-03	1.9E-03	1.3E-03
S	3.2E-02	8.7E-03	2.5E-03	1.4E-03
SSE	3.4E-02	7.8E-03	2.3E-03	1.4E-03
SE	4.4E-02	1.2E-02	3.1E-03	1.6E-03
ESE	4.5E-02	1.1E-02	2.9E-03	1.6E-03
E	4.9E-02	1.3E-02	3.3E-03	1.7E-03
ENE	5.2E-02	1.2E-02	3.2E-03	1.6E-03
NE	6.3E-02	1.7E-02	4.2E-03	1.9E-03
NNE	5.0E-02	1.2E-02	3.1E-03	1.6E-03

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SUMMARY
Page 6

INDIVIDUAL LIFETIME RISK (deaths)
(All Radionuclides and Pathways)

	Distance (m)			
Direction	275	595	1475	3050
N	4.4E-07	1.2E-07	2.8E-08	1.2E-08
NNW	2.3E-07	4.0E-08	1.3E-08	7.8E-09
NW	2.7E-07	6.9E-08	1.8E-08	9.4E-09
WNW	3.9E-07	8.7E-08	2.2E-08	1.0E-08
W	5.4E-07	1.5E-07	3.3E-08	1.4E-08
WSW	4.1E-07	8.8E-08	2.2E-08	1.1E-08
SW	3.4E-07	8.9E-08	2.2E-08	1.1E-08
SSW	2.8E-07	6.0E-08	1.6E-08	8.9E-09
S	3.6E-07	9.5E-08	2.3E-08	1.1E-08
SSE	3.9E-07	8.4E-08	2.1E-08	1.0E-08
SE	5.0E-07	1.3E-07	3.0E-08	1.3E-08
ESE	5.2E-07	1.2E-07	2.8E-08	1.2E-08
E	5.7E-07	1.4E-07	3.2E-08	1.4E-08
ENE	6.0E-07	1.3E-07	3.1E-08	1.3E-08
NE	7.2E-07	1.9E-07	4.3E-08	1.7E-08
NNE	5.7E-07	1.3E-07	3.0E-08	1.3E-08

APPENDIX D

CAP88-PC REPORTS – POPULATION

C A P 8 8 - P C

Version 2.00

Clean Air Act Assessment Package - 1988

D O S E   A N D   R I S K   E Q U I V A L E N T   S U M M A R I E S

Non-Radon Population Assessment
Jul 9, 2002 10:40 am

Facility: Niagara Falls Storage Site
Address:
City: Lewiston
State: NY   Zip:

Source Category: Area
Source Type: Area
Emission Year: 2001

Comments: Air emissions NFSS CY2001 population

Dataset Name: NFSS 2001 pop2
Dataset Date: Jul 9, 2002 10:40 am
Wind File: C:\CAP88PC2\WNDFILES\IAG0905.WND
Population File: C:\CAP88PC2\POPFILES\NFSS.POP

Jul 9, 2002 10:40 am   SUMMARY
Page 1

ORGAN DOSE EQUIVALENT SUMMARY

Organ	Selected Individual (mrem/y)	Collective Population (person-rem/y)
GONADS	1.66E-03	1.66E-03
BREAST	1.40E-03	1.48E-03
R MAR	3.17E-02	2.20E-02
LUNGS	4.61E-01	2.74E-01
THYROID	1.36E-03	1.45E-03
ENDOST	3.85E-01	2.68E-01
RMNDR	3.61E-03	5.72E-03
EFFEC	7.25E-02	4.60E-02

PATHWAY EFFECTIVE DOSE EQUIVALENT SUMMARY

Pathway	Selected Individual (mrem/y)	Collective Population (person-rem/y)
INGESTION	1.29E-04	2.73E-03
INHALATION	7.13E-02	4.23E-02
AIR IMMERSION	1.31E-07	5.11E-08
GROUND SURFACE	1.00E-03	9.31E-04
INTERNAL	7.15E-02	4.50E-02
EXTERNAL	1.00E-03	9.31E-04
TOTAL	7.25E-02	4.60E-02

NUCLIDE EFFECTIVE DOSE EQUIVALENT SUMMARY

Nuclides	Selected Individual (mrem/y)	Collective Population (person-rem/y)
U-235	5.33E-04	3.37E-04
TH-231	4.33E-09	2.36E-09
PA-231	2.07E-03	1.29E-03
AC-227	2.73E-03	1.67E-03
TH-227	4.97E-05	2.95E-05
RA-223	3.56E-05	2.32E-05
PO-215	0.00E+00	0.00E+00
PB-211	3.98E-08	8.92E-09
BI-211	2.79E-09	2.57E-10
TL-207	3.21E-11	3.71E-12
FR-223	1.54E-10	2.91E-11
PO-211	4.20E-38	0.00E+00
TH-232	1.51E-02	9.02E-03
RA-228	1.07E-04	1.69E-04
AC-228	3.64E-06	1.58E-06
TH-228	1.15E-02	6.82E-03
RA-224	1.59E-04	9.28E-05
PO-216	9.94E-09	9.18E-09
PB-212	1.19E-04	1.08E-04
BI-212	1.24E-04	1.15E-04
TL-208	7.46E-04	6.91E-04
PO-212	0.00E+00	0.00E+00
U-238	1.07E-02	6.67E-03
TH-234	3.39E-06	3.80E-06
PA-234M	4.22E-10	3.30E-11
PA-234	3.72E-10	1.85E-10
U-234	1.19E-02	7.41E-03
TH-230	1.50E-02	9.01E-03
RA-226	4.63E-04	5.22E-04
PO-218	1.81E-09	1.83E-10
PB-214	5.33E-08	1.08E-08
BI-214	6.75E-08	1.24E-08
PO-214	0.00E+00	0.00E+00
PB-210	7.44E-04	1.42E-03
BI-210	9.82E-06	5.75E-06

PO-210	4.50E-04	5.46E-04
TOTAL	7.25E-02	4.60E-02

CANCER RISK SUMMARY

Cancer	Selected Individual Total Lifetime Fatal Cancer Risk	Total Collective Population Fatal Cancer Risk (Deaths/y)
LEUKEMIA	2.94E-08	3.04E-07
BONE	1.76E-08	1.77E-07
THYROID	5.37E-10	7.46E-09
BREAST	4.75E-09	6.58E-08
LUNG	7.66E-07	6.45E-06
STOMACH	3.01E-09	4.24E-08
BOWEL	1.62E-09	2.42E-08
LIVER	9.99E-09	1.63E-07
PANCREAS	2.01E-09	2.85E-08
URINARY	2.34E-09	7.52E-08
OTHER	2.46E-09	3.49E-08
TOTAL	8.40E-07	7.37E-06

PATHWAY RISK SUMMARY

Pathway	Selected Individual Total Lifetime Fatal Cancer Risk	Total Collective Population Fatal Cancer Risk (Deaths/y)
INGESTION	7.50E-10	2.25E-07
INHALATION	8.15E-07	6.83E-06
AIR IMMERSION	3.16E-12	1.75E-11
GROUND SURFACE	2.43E-08	3.19E-07
INTERNAL	8.16E-07	7.05E-06
EXTERNAL	2.43E-08	3.19E-07
TOTAL	8.40E-07	7.37E-06

PATHWAY GENETIC RISK SUMMARY
(Collective Population)

Pathway	Genetic Risk (person-rem/y)

INGESTION	3.33E-05
INHALATION	2.26E-05
AIR IMMERSION	4.96E-08
GROUND SURFACE	8.97E-04
INTERNAL	5.59E-05
EXTERNAL	8.97E-04
TOTAL	9.53E-04

Jul 9, 2002 10:40 am SUMMARY
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NUCLIDE RISK SUMMARY

Nuclide	Selected Individual Total Lifetime Fatal Cancer Risk	Total Collective Population Fatal Cancer Risk (Deaths/y)
U-235	7.24E-09	6.32E-08
TH-231	1.26E-13	9.68E-13
PA-231	1.17E-08	1.00E-07
AC-227	2.38E-08	2.04E-07
TH-227	1.37E-09	1.14E-08
RA-223	8.86E-10	7.54E-09
PO-215	0.00E+00	0.00E+00
PB-211	7.67E-13	2.43E-12
BI-211	3.32E-14	4.31E-14
TL-207	1.05E-15	1.72E-15
FR-223	1.63E-15	4.34E-15
PO-211	1.00E-42	7.06E-43
TH-232	8.55E-08	7.19E-07
RA-228	1.74E-09	2.52E-08
AC-228	7.35E-11	4.51E-10
TH-228	2.30E-07	1.93E-06
RA-224	3.61E-09	2.94E-08
PO-216	2.38E-13	3.11E-12
PB-212	2.73E-09	3.52E-08
BI-212	2.97E-09	3.89E-08
TL-208	1.82E-08	2.39E-07
PO-212	0.00E+00	0.00E+00
U-238	1.43E-07	1.23E-06
TH-234	1.91E-10	1.88E-09
PA-234M	1.07E-14	1.19E-14
PA-234	9.57E-15	6.66E-14
U-234	1.58E-07	1.35E-06
TH-230	1.24E-07	1.05E-06
RA-226	1.01E-08	1.03E-07
PO-218	1.28E-12	1.84E-12
PB-214	9.11E-12	2.61E-11
BI-214	7.82E-12	2.03E-11
PO-214	0.00E+00	0.00E+00
PB-210	5.32E-09	1.43E-07
BI-210	2.65E-10	2.18E-09
PO-210	8.58E-09	9.24E-08
TOTAL	8.40E-07	7.37E-06

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INDIVIDUAL EFFECTIVE DOSE EQUIVALENT RATE (mrem/y)
(All Radionuclides and Pathways)

	Distance (m)						
Direction	250	750	1500	2500	3500	4500	7500
N	4.4E-02	6.2E-03	1.8E-03	7.7E-04	4.4E-04	3.0E-04	1.4E-04
NNW	2.5E-02	1.9E-03	5.6E-04	2.4E-04	1.4E-04	9.3E-05	4.2E-05
NW	2.7E-02	3.5E-03	1.0E-03	4.3E-04	2.4E-04	1.7E-04	7.4E-05
WNW	4.0E-02	4.5E-03	1.3E-03	5.5E-04	3.2E-04	2.1E-04	9.6E-05
W	5.3E-02	7.9E-03	2.3E-03	9.7E-04	5.6E-04	3.8E-04	1.7E-04
WSW	4.2E-02	4.6E-03	1.3E-03	5.6E-04	3.3E-04	2.2E-04	1.0E-04
SW	3.4E-02	4.6E-03	1.3E-03	5.7E-04	3.3E-04	2.2E-04	1.0E-04
SSW	3.0E-02	3.0E-03	8.8E-04	3.7E-04	2.1E-04	1.4E-04	6.5E-05
S	3.6E-02	5.0E-03	1.4E-03	6.1E-04	3.5E-04	2.4E-04	1.1E-04
SSE	4.0E-02	4.4E-03	1.3E-03	5.4E-04	3.1E-04	2.1E-04	9.5E-05
SE	5.1E-02	7.0E-03	2.0E-03	8.5E-04	4.9E-04	3.3E-04	1.5E-04
ESE	5.3E-02	6.3E-03	1.8E-03	7.8E-04	4.5E-04	3.1E-04	1.4E-04
E	5.7E-02	7.6E-03	2.2E-03	9.4E-04	5.4E-04	3.7E-04	1.7E-04
ENE	6.2E-02	7.1E-03	2.1E-03	8.8E-04	5.1E-04	3.5E-04	1.6E-04
NE	7.2E-02	1.0E-02	3.1E-03	1.3E-03	7.5E-04	5.1E-04	2.3E-04
NNE	5.9E-02	6.9E-03	2.0E-03	8.5E-04	4.9E-04	3.4E-04	1.5E-04

	Distance (m)						
Direction	15000	25000	35000	45000	55000	65000	75000
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.9E-06
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.8E-06	1.5E-06
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.6E-06	2.1E-06
WNW	3.5E-05	1.6E-05	0.0E+00	0.0E+00	0.0E+00	3.1E-06	2.5E-06
W	6.3E-05	2.8E-05	1.7E-05	1.2E-05	8.0E-06	5.5E-06	4.3E-06
WSW	3.7E-05	1.7E-05	1.1E-05	7.3E-06	5.1E-06	3.6E-06	2.9E-06
SW	3.7E-05	1.7E-05	1.1E-05	7.2E-06	5.1E-06	3.6E-06	0.0E+00
SSW	2.4E-05	1.1E-05	6.9E-06	4.8E-06	0.0E+00	0.0E+00	2.1E-06
S	3.9E-05	1.8E-05	1.1E-05	7.6E-06	5.4E-06	3.8E-06	3.1E-06
SSE	3.5E-05	1.6E-05	1.0E-05	6.9E-06	4.9E-06	3.6E-06	2.9E-06
SE	5.5E-05	2.5E-05	1.6E-05	1.1E-05	7.5E-06	5.3E-06	4.3E-06
ESE	5.1E-05	2.3E-05	1.4E-05	9.9E-06	7.0E-06	5.0E-06	4.0E-06
E	6.2E-05	2.8E-05	1.8E-05	1.2E-05	8.5E-06	6.0E-06	4.8E-06
ENE	5.8E-05	2.7E-05	1.7E-05	1.2E-05	8.3E-06	6.0E-06	4.8E-06
NE	8.6E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

COLLECTIVE EFFECTIVE DOSE EQUIVALENT (person rem/y)
(All Radionuclides and Pathways)

Direction	250	750	1500	2500	3500	4500	7500
	Distance (m)						
N	3.5E-04	1.5E-04	1.8E-04	1.2E-04	1.0E-04	8.7E-05	1.1E-04
NNW	2.0E-04	4.6E-05	5.4E-05	3.8E-05	3.1E-05	2.7E-05	3.4E-05
NW	2.2E-04	8.4E-05	9.8E-05	6.8E-05	5.5E-05	4.8E-05	8.9E-05
WNW	3.2E-04	1.1E-04	1.3E-04	8.8E-05	7.1E-05	6.2E-05	3.5E-05
W	4.3E-04	1.9E-04	2.2E-04	1.5E-04	1.2E-04	1.1E-04	1.7E-05
WSW	3.4E-04	1.1E-04	1.3E-04	9.0E-05	7.3E-05	6.4E-05	3.9E-05
SW	2.8E-04	1.1E-04	1.3E-04	9.1E-05	7.3E-05	6.4E-05	2.6E-03
SSW	2.4E-04	7.2E-05	8.4E-05	5.9E-05	4.8E-05	4.2E-05	1.6E-04
S	2.9E-04	1.2E-04	1.4E-04	9.7E-05	7.8E-05	6.8E-05	2.6E-04
SSE	3.2E-04	1.0E-04	1.2E-04	8.6E-05	6.9E-05	6.0E-05	2.3E-04
SE	4.0E-04	1.7E-04	2.0E-04	1.4E-04	1.1E-04	9.6E-05	3.6E-04
ESE	4.3E-04	1.5E-04	1.8E-04	1.2E-04	1.0E-04	8.8E-05	3.3E-04
E	4.6E-04	1.8E-04	2.1E-04	1.5E-04	1.2E-04	1.1E-04	4.0E-04
ENE	5.0E-04	1.7E-04	2.0E-04	1.4E-04	1.1E-04	1.0E-04	3.8E-04
NE	5.8E-04	2.5E-04	3.0E-04	2.1E-04	1.7E-04	1.5E-04	5.6E-04
NNE	4.8E-04	1.6E-04	1.9E-04	1.4E-04	1.1E-04	9.7E-05	2.8E-04

Distance (m)

Direction	15000	25000	35000	45000	55000	65000	75000
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E-03
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.7E-03	9.2E-04
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E-03	3.3E-04
WNW	1.2E-05	1.7E-06	0.0E+00	0.0E+00	0.0E+00	2.7E-04	1.1E-04
W	3.3E-05	2.2E-05	1.7E-03	4.7E-06	7.8E-06	1.2E-03	4.7E-04
WSW	2.0E-05	1.5E-05	3.6E-04	1.2E-05	1.0E-05	8.3E-06	7.2E-06
SW	9.4E-04	1.5E-05	1.3E-05	1.0E-05	5.0E-06	2.1E-06	0.0E+00
SSW	6.6E-04	1.4E-05	8.5E-06	1.5E-06	0.0E+00	0.0E+00	7.4E-06
S	3.3E-04	3.0E-04	1.9E-04	1.6E-04	2.1E-04	3.0E-04	2.5E-04
SSE	3.2E-04	4.7E-04	4.9E-04	4.3E-04	3.8E-04	3.3E-04	2.9E-04
SE	5.3E-04	7.7E-04	7.7E-04	6.7E-04	4.2E-04	1.5E-04	4.8E-05
ESE	4.9E-04	4.0E-04	5.2E-04	3.5E-04	7.1E-05	6.0E-05	5.3E-05
E	5.9E-04	4.5E-04	3.9E-04	1.4E-04	7.7E-05	6.5E-05	6.0E-05
ENE	5.6E-04	2.9E-04	1.9E-04	8.4E-05	2.8E-05	2.4E-05	1.5E-05
NE	1.0E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

INDIVIDUAL LIFETIME RISK (deaths)
(All Radionuclides and Pathways)

Distance (m)

Direction	250	750	1500	2500	3500	4500	7500

N	5.1E-07	7.2E-08	2.1E-08	8.9E-09	5.2E-09	3.5E-09	1.6E-09
NNW	2.9E-07	2.2E-08	6.5E-09	2.7E-09	1.6E-09	1.1E-09	4.9E-10
NW	3.2E-07	4.1E-08	1.2E-08	4.9E-09	2.8E-09	1.9E-09	8.6E-10
WNW	4.7E-07	5.2E-08	1.5E-08	6.4E-09	3.7E-09	2.5E-09	1.1E-09
W	6.2E-07	9.2E-08	2.7E-08	1.1E-08	6.5E-09	4.4E-09	2.0E-09
WSW	4.9E-07	5.3E-08	1.6E-08	6.6E-09	3.8E-09	2.6E-09	1.2E-09
SW	4.0E-07	5.3E-08	1.6E-08	6.6E-09	3.8E-09	2.6E-09	1.2E-09
SSW	3.4E-07	3.5E-08	1.0E-08	4.3E-09	2.5E-09	1.7E-09	7.6E-10
S	4.2E-07	5.8E-08	1.7E-08	7.0E-09	4.1E-09	2.8E-09	1.2E-09
SSE	4.6E-07	5.1E-08	1.5E-08	6.2E-09	3.6E-09	2.4E-09	1.1E-09
SE	5.9E-07	8.1E-08	2.4E-08	9.9E-09	5.7E-09	3.9E-09	1.8E-09
ESE	6.2E-07	7.3E-08	2.1E-08	9.0E-09	5.2E-09	3.6E-09	1.6E-09
E	6.7E-07	8.8E-08	2.6E-08	1.1E-08	6.3E-09	4.3E-09	2.0E-09
ENE	7.2E-07	8.2E-08	2.4E-08	1.0E-08	5.9E-09	4.1E-09	1.9E-09
NE	8.4E-07	1.2E-07	3.6E-08	1.5E-08	8.8E-09	6.0E-09	2.7E-09
NNE	6.9E-07	8.0E-08	2.3E-08	9.9E-09	5.7E-09	3.9E-09	1.8E-09

	Distance (m)						
Direction	15000	25000	35000	45000	55000	65000	75000
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.3E-11
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.8E-11	1.5E-11
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.8E-11	2.2E-11
WNW	4.1E-10	1.8E-10	0.0E+00	0.0E+00	0.0E+00	3.3E-11	2.6E-11
W	7.3E-10	3.3E-10	2.0E-10	1.3E-10	9.1E-11	6.1E-11	4.7E-11
WSW	4.3E-10	2.0E-10	1.2E-10	8.2E-11	5.7E-11	3.9E-11	3.1E-11
SW	4.3E-10	1.9E-10	1.2E-10	8.1E-11	5.7E-11	4.0E-11	0.0E+00
SSW	2.8E-10	1.3E-10	7.8E-11	5.3E-11	0.0E+00	0.0E+00	2.1E-11
S	4.5E-10	2.1E-10	1.3E-10	8.6E-11	6.0E-11	4.2E-11	3.3E-11
SSE	4.0E-10	1.8E-10	1.1E-10	7.8E-11	5.5E-11	3.9E-11	3.1E-11
SE	6.4E-10	2.9E-10	1.8E-10	1.2E-10	8.5E-11	6.0E-11	4.7E-11
ESE	5.9E-10	2.7E-10	1.7E-10	1.1E-10	8.0E-11	5.6E-11	4.4E-11
E	7.2E-10	3.3E-10	2.0E-10	1.4E-10	9.7E-11	6.8E-11	5.3E-11
ENE	6.8E-10	3.2E-10	2.0E-10	1.3E-10	9.5E-11	6.8E-11	5.4E-11
NE	1.0E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

COLLECTIVE FATAL CANCER RATE (deaths/y)
(All Radionuclides and Pathways)

	Distance (m)						
Direction	250	750	1500	2500	3500	4500	7500
N	5.8E-08	2.5E-08	2.9E-08	2.0E-08	1.6E-08	1.4E-08	1.8E-08
NNW	3.2E-08	7.6E-09	8.9E-09	6.2E-09	5.0E-09	4.4E-09	5.5E-09
NW	3.6E-08	1.4E-08	1.6E-08	1.1E-08	9.0E-09	7.8E-09	1.5E-08
WNW	5.3E-08	1.8E-08	2.1E-08	1.4E-08	1.2E-08	1.0E-08	5.8E-09
W	7.0E-08	3.1E-08	3.6E-08	2.5E-08	2.1E-08	1.8E-08	2.8E-09
WSW	5.5E-08	1.8E-08	2.1E-08	1.5E-08	1.2E-08	1.1E-08	6.4E-09

SW	4.5E-08	1.8E-08	2.1E-08	1.5E-08	1.2E-08	1.1E-08	4.3E-07
SSW	3.9E-08	1.2E-08	1.4E-08	9.7E-09	7.8E-09	6.8E-09	2.6E-08
S	4.7E-08	2.0E-08	2.3E-08	1.6E-08	1.3E-08	1.1E-08	4.2E-08
SSE	5.2E-08	1.7E-08	2.0E-08	1.4E-08	1.1E-08	9.9E-09	3.7E-08
SE	6.6E-08	2.7E-08	3.2E-08	2.2E-08	1.8E-08	1.6E-08	6.0E-08
ESE	7.0E-08	2.5E-08	2.9E-08	2.0E-08	1.7E-08	1.4E-08	5.5E-08
E	7.5E-08	3.0E-08	3.5E-08	2.5E-08	2.0E-08	1.7E-08	6.6E-08
ENE	8.2E-08	2.8E-08	3.3E-08	2.3E-08	1.9E-08	1.6E-08	6.3E-08
NE	9.5E-08	4.1E-08	4.9E-08	3.4E-08	2.8E-08	2.4E-08	9.3E-08
NNE	7.8E-08	2.7E-08	3.2E-08	2.2E-08	1.8E-08	1.6E-08	4.5E-08

	Distance (m)						
Direction	15000	25000	35000	45000	55000	65000	75000
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E-07
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E-07	1.3E-07
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.8E-07	4.8E-08
WNW	2.0E-09	2.8E-10	0.0E+00	0.0E+00	0.0E+00	4.2E-08	1.7E-08
W	5.4E-09	3.6E-09	2.8E-07	7.5E-10	1.3E-09	1.8E-07	7.3E-08
WSW	3.2E-09	2.4E-09	5.7E-08	1.8E-09	1.6E-09	1.3E-09	1.1E-09
SW	1.5E-07	2.4E-09	2.1E-09	1.6E-09	7.8E-10	3.2E-10	0.0E+00
SSW	1.1E-07	2.2E-09	1.4E-09	2.4E-10	0.0E+00	0.0E+00	1.1E-09
S	5.4E-08	4.9E-08	3.0E-08	2.6E-08	3.3E-08	4.7E-08	3.8E-08
SSE	5.3E-08	7.6E-08	7.9E-08	6.9E-08	6.0E-08	5.0E-08	4.5E-08
SE	8.7E-08	1.3E-07	1.3E-07	1.1E-07	6.7E-08	2.4E-08	7.5E-09
ESE	8.0E-08	6.6E-08	8.4E-08	5.6E-08	1.1E-08	9.5E-09	8.2E-09
E	9.7E-08	7.4E-08	6.4E-08	2.2E-08	1.2E-08	1.0E-08	9.5E-09
ENE	9.2E-08	4.8E-08	3.1E-08	1.4E-08	4.5E-09	3.8E-09	2.3E-09
NE	1.7E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

APPENDIX E

CY2001 RADON-222 FLUX MEASUREMENTS

2001 Radon Flux Monitoring Results[a]
Niagara Falls Storage Site

NFSS Sample ID	Radon-222 Flux ($pCi/m^2/s$)	NFSS Sample ID	Radon-222 Flux ($pCi/m^2/s$)	NFSS Sample ID	Radon-222 Flux ($pCi/m^2/s$)
1	0.095 ± 0.043	41	0.049 ± 0.034	81	0.105 ± 0.072
2	0.141 ± 0.030	42	0.084 ± 0.057	82	0.047 ± 0.031
3	0.163 ± 0.080	43	0.065 ± 0.038	83	0.036 ± 0.045
4	0.118 ± 0.026	44	0.074 ± 0.043	84	0.061 ± 0.034
5	0.068 ± 0.054	45	0.126 ± 0.056	85	0.049 ± 0.044
6	0.090 ± 0.040	46	0.066 ± 0.063	86	0.052 ± 0.034
7	0.106 ± 0.035	47	0.118 ± 0.059	87	0.082 ± 0.047
8	0.079 ± 0.040	48	0.143 ± 0.067	88	0.043 ± 0.033
9	0.207 ± 0.081	49	0.069 ± 0.035	89	0.020 ± 0.038
10	0.110 ± 0.043	50	0.091 ± 0.046	90	0.140 ± 0.069
10 DUP	0.081 ± 0.038	50 DUP	0.083 ± 0.046	90 DUP	0.176 ± 0.078
11	0.139 ± 0.039	51	0.067 ± 0.041	91	0.121 ± 0.086
12	0.182 ± 0.075	52	0.063 ± 0.037	92	0.086 ± 0.066
13	0.002 ± 0.001	53	0.057 ± 0.050	93	0.084 ± 0.038
14	0.091 ± 0.057	54	0.109 ± 0.025	94	0.074 ± 0.039
15	0.069 ± 0.038	55	0.176 ± 0.075	95	0.074 ± 0.040
16	0.087 ± 0.049	56	0.103 ± 0.024	96	0.040 ± 0.024
17	0.083 ± 0.037	57	0.074 ± 0.061	97	0.046 ± 0.032
18	0.173 ± 0.080	58	0.042 ± 0.040	98	0.029 ± 0.038
19	0.077 ± 0.022	59	0.060 ± 0.034	99	0.044 ± 0.034
20	0.069 ± 0.057	60	0.117 ± 0.067	100	0.090 ± 0.068
20 DUP	0.108 ± 0.069	60 DUP	0.094 ± 0.049	100 DUP	0.034 ± 0.041
21	0.071 ± 0.022	61	0.135 ± 0.063	101	0.024 ± 0.028
22	0.067 ± 0.058	62	0.318 ± 0.066	102	0.074 ± 0.041
23	0.055 ± 0.028	63	0.107 ± 0.028	103	0.073 ± 0.049
24	0.080 ± 0.059	64	0.003 ± 0.048	104	0.145 ± 0.072
25	0.081 ± 0.046	65	0.128 ± 0.032	105	0.102 ± 0.026
26	0.001 ± 0.000	66	0.057 ± 0.047	106	0.009 ± 0.029
27	0.081 ± 0.043	67	0.049 ± 0.033	107	0.033 ± 0.035
28	0.093 ± 0.068	68	0.079 ± 0.055	108	0.097 ± 0.064
29	0.100 ± 0.045	69	0.057 ± 0.031	109	0.090 ± 0.044
30	0.101 ± 0.056	70	0.128 ± 0.037	110	0.161 ± 0.078
30 DUP	0.107 ± 0.077	70 DUP	0.107 ± 0.033	110 DUP	0.162 ± 0.074
31	0.098 ± 0.046	71	0.147 ± 0.072	111	0.137 ± 0.031
32	0.105 ± 0.027	72	0.088 ± 0.052	112	0.054 ± 0.033
33	0.085 ± 0.051	73	0.162 ± 0.071	113	0.083 ± 0.048
34	0.056 ± 0.032	74	0.112 ± 0.053	114	0.060 ± 0.046
35	0.044 ± 0.042	75	0.155 ± 0.047	115	0.010 ± 0.037
36	0.112 ± 0.033	76	0.085 ± 0.023	116	0.024 ± 0.028
37	0.217 ± 0.037	77	0.127 ± 0.059	117	0.038 ± 0.042
38	0.182 ± 0.074	78	0.109 ± 0.055	118	0.050 ± 0.036
39	0.046 ± 0.028	79	0.101 ± 0.071	119	0.096 ± 0.057
40	0.085 ± 0.053	80	0.077 ± 0.041	120	0.008 ± 0.022
40 DUP	0.079 ± 0.043	80 DUP	0.097 ± 0.049	120 DUP	0.051 ± 0.041

NOTE: The EPA Standard for Radon-222 Flux is 20 pCi/m2/sec

a. Radon-222 flux was performed in July 30-31, 2001

b. Every 10th canister is counted twice as a quality control (QC) duplicate to evaluate analytical precision

c. Background

2001 Radon Flux Monitoring Results[a]
Niagara Falls Storage Site

NFSS Sample ID	Radon-222 Flux ($pCi/m^2/s$)	NFSS Sample ID	Radon-222 Flux ($pCi/m^2/s$)	NFSS Sample ID	Radon-222 Flux ($pCi/m^2/s$)
121	0.063 ± 0.046	141	0.104 ± 0.046	161	0.104 ± 0.057
122	0.076 ± 0.044	142	0.096 ± 0.051	162	0.102 ± 0.050
123	0.073 ± 0.062	143	0.085 ± 0.040	163	0.132 ± 0.060
124	0.104 ± 0.027	144	0.107 ± 0.058	164	0.092 ± 0.047
125	0.098 ± 0.055	145	0.076 ± 0.047	165	0.088 ± 0.051
126	0.078 ± 0.038	146	0.088 ± 0.062	166	0.107 ± 0.055
127	0.106 ± 0.064	147	0.052 ± 0.033	167	0.081 ± 0.058
128	0.119 ± 0.053	148	0.026 ± 0.037	168	0.097 ± 0.027
129	0.148 ± 0.069	149	0.077 ± 0.036	169	0.103 ± 0.062
130	0.090 ± 0.047	150	0.026 ± 0.037	170	0.077 ± 0.045
130 DUP	0.099 ± 0.026	150 DUP	0.125 ± 0.059	170 DUP	0.075 ± 0.038
131	0.018 ± 0.033	151	0.118 ± 0.049	171	0.028 ± 0.031
132	0.096 ± 0.051	152	0.115 ± 0.048	172	0.133 ± 0.069
133	0.049 ± 0.035	153	0.087 ± 0.066	173	0.074 ± 0.038
134	0.043 ± 0.045	154	0.023 ± 0.031	174	0.084 ± 0.037
135	0.052 ± 0.033	155	0.079 ± 0.029	175	0.102 ± 0.045
136	0.091 ± 0.067	156	0.025 ± 0.031	176	0.126 ± 0.060
137	0.063 ± 0.041	157	0.085 ± 0.055	177	0.077 ± 0.038
138	0.046 ± 0.039	158	0.062 ± 0.038	178	0.174 ± 0.098
139	0.045 ± 0.028	159	0.114 ± 0.071	179	0.058 ± 0.020
140	0.084 ± 0.048	160	0.084 ± 0.047	180	0.185 ± 0.093
140 DUP	0.104 ± 0.070	160 DUP	0.107 ± 0.025	180 DUP	0.180 ± 0.084
				181[c]	0.070 ± 0.047
				182[c]	0.126 ± 0.087
				183[c]	0.086 ± 0.045

Maximum concentration found was 0.318 $pCi/m^2/s$
Minimum concentration found was 0.001 $pCi/m^2/s$
Average concentration found was 0.089 $pCi/m^2/s$
The EPA Standard for Radon-222 Flux is 20 $pCi/m^2/sec$

NOTE: The EPA Standard for Radon-222 Flux is 20 pCi/m2/sec
a. Radon-222 flux was performed in July 30-31, 2001
b. Every 10th canister is counted twice as a quality control (QC) duplicate to evaluate analytical precision
c. Background

APPENDIX F

NATIONAL CLIMATIC DATA CENTER, BUFFALO, NEW YORK

U.S. Department of Commerce
National Oceanic & Atmospheric Administration

National Climatic Data Center
Federal Building
151 Patton Avenue
Asheville, North Carolina 28801

ANNUAL CLIMATOLOGICAL SUMMARY
(2001)

Station: **305840/99999, NIAGARA FALLS INT'L AP, New York** Elev. 519 ft. above sea level Lat. 43°06'N, Lon. 78°57'W

Date	Temperature (° F)														Precipitation (inches)									
Elem->	MMXT	MMNT	MNTM	DPNT	HTDD	CLDD	EMXT		EMNP		DT90	DX32	DT32	DT00	TPCP	DPNP	EMXP		TSNW	MXSD		DP01	DP05	DP10
											Number of Days						Greatest Observed		Snow, Sleet			Number of Days		
2001 Month	Mean Max.	Mean Min.	Mean	Depart. from Normal	Heating Degree Days	Cooling Degree Days	Highest	High Date	Lowest	Low Date	Max >=90°	Max <=32°	Min <=32°	Min <=0°	Total	Depart. from Normal	Day	Date	Total Fall	Max Depth	Max Date	>=.10	>=.50	>=1.0
1	30.6	19.7	25.2		1224	0	39	15	1	2	0	19	31	0	1.49		0.46	30	13.2	13	6	5	0	0
2	35.9	20.0	28.0		1031	0	59	25	2	12	0	7	27	0	2.10		0.58	9	8.3	3	3	4	1	0
3	38.2	23.9	31.1		1044	0	51	23	11	12	0	7	26	0	2.75		0.45	17	31.9	9	6	12	0	0
4	58.6	35.4	47.0		533	2	83	24	25	19	0	0	11	0	1.61		0.52	12	1.3	0T	1	7	1	0
5	72.0	48.1	60.1		166	20	85	1	35	13	0	0	0	0	4.42		1.05	22	0.0	0		9	4	1
6	79.1	57.5	68.3		47	152	95	14	43	4	4	0	0	0	1.24		0.32	20	0.0	0		5	0	0
7	82.1	59.4	70.8		11	195	93	24	44	2	4	0	0	0	0.54		0.13	17	0.0	0		3	0	0
8	84.7	61.3	73.0		0	256	95	8	48	25	6	0	0	0	2.16		0.63	19	0.0	0		7	1	0
9	72.7	51.3	62.0		139	56	91	9	38	30	2	0	0	0	2.39		0.74	25	0.0	0		5	2	0
10	61.5	43.4	52.5		385	4	78	4	26	8	0	0	3	0	4.39		1.60	5	0.0T	0T	18	8	3	1
11	53.6	37.0	45.3		583	0	68	1	27	13	0	0	9	0	3.23		0.62	25	0.0	0		10	3	0
12	41.1	28.3	34.7		933	0	66	6	14	27	0	7	22	0	3.24		0.60	24	22.5	6	26	8	3	0
Annual	59.2	40.4	49.8		6096	685	95	Aug	1	Jan	16	40	129	0	29.56		1.60	Oct	77.2	13	Jan	83	18	2

Notes

(blank) Not reported.

\+ Occurred on one or more previous dates during the month. The date in the Date field is the last day of occurrence. Used through December 1983 only.

A Accumulated amount. This value is a total that may include data from a previous month or months or year (for annual value).

B Adjusted Total. Monthly value totals based on proportional available data across the entire month.

E An estimated monthly or annual total.

X Monthly means or totals based on incomplete time series. 1 to 9 days are missing. Annual means or totals include one or more months which had 1 to 9 days that were missing.

M Used to indicate data element missing.

T Trace of precipitation, snowfall, or snowdepth. The precipitation data value will = zero.

Elem-> Element Types are included to provide cross-reference for users of the NCDC CDO System.

Station Station is identified by: CoopID/WBAN, Station Name, State.

S Precipitation amount is continuing to be accumulated. Total will be included in a subsequent monthly or yearly value. Example: Days 1-20 had 1.35 inches of precipitation, then a period of accumulation began. The element TPCP would then be 00135S and the total accumulated amount value appears in a subsequent monthly value. If TPCP = "M" there was no precipitation measured during the month. Flag is set to "S" and the total accumulated amount appears in a subsequent monthly value.

Dynamically generated Mon Jul 01 14:20:25 EDT 2002 via http://lwf.ncdc.noaa.gov/servlets/ACS
Data provided from the NCDC CDO System
Additional documentation can be found at http://www5.ncdc.noaa.gov/cdo/3220doc.txt

STATION: NIAGARA FALLS IN TL, NY STA-NUM: 7 2528 ANNUAL PERIOD OF RECORD : 1991- 2000

UNITS — H O URLY OBSERVATIONS OF WIND SPEEDS — AVERAGE SPEED

UNITS														
MPS	0- 2	3-3	4-5	6-8	9-11	12-14	15-17	18-21	22&GR					
MPH	0- 3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47&GR					
KNOTS	0- 3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41&GR	TOTAL	PCT	KNOTS	MPH	MPS
DIRECTION														
1	33	273	407	144	4					861	1.2	7.9	9.1	4.1
2	28	281	406	155	1					871	1.2	7.8	9	4
3	50	269	427	169	8					923	1.3	8	9.2	4.1
4	72	364	480	241	5					1162	1.7	7.9	9.1	4.1
5	69	502	643	398	29	4	1			1646	2.3	8.4	9.7	4.3
6	93	601	728	458	38	9				1927	2.7	8.4	9.7	4.3
7	89	664	679	452	48	7				1939	2.8	8.3	9.6	4.3
8	85	577	706	338	32	3				1741	2.5	8.1	9.3	4.2
9	89	518	676	238	20					1541	2.2	7.7	8.9	4
10	81	401	349	90	3					924	1.3	6.8	7.8	3.5
11	87	478	298	60						923	1.3	6.3	7.2	3.2
12	83	470	276	38						867	1.2	6.1	7	3.1
13	88	356	208	45	2					699	1	6.1	7	3.1
14	63	313	204	35	1					616	0.9	6.2	7.2	3.2
15	72	380	215	54	6	1				728	1	6.4	7.4	3.3
16	84	532	425	145	17	8				1211	1.7	7.2	8.3	3.7
17	100	543	590	315	38	6	1			1593	2.3	8.1	9.3	4.2
18	107	630	847	470	45	4				2103	3	8.4	9.7	4.3
19	74	739	1112	623	55	11				2614	3.7	8.6	10	4.4
20	70	675	1154	863	96	13				2871	4.1	9.3	10.7	4.8
21	79	560	1296	1256	233	26	2	1		3453	4.9	10.3	11.8	5.3
22	72	529	1490	1776	360	88	12	1	1	4329	6.2	11.1	12.8	5.7
23	63	490	1475	1748	498	141	14	3		4432	6.3	11.7	13.5	6
24	72	489	1088	1468	444	102	29	2		3694	5.3	11.7	13.5	6
25	58	455	960	1232	369	82	8	4		3168	4.5	11.5	13.2	5.9
26	45	458	1042	1202	310	41	2			3100	4.4	11	12.7	5.7
27	43	395	852	989	240	46				2565	3.7	11	12.6	5.7
28	37	319	610	674	166	25	1			1832	2.6	10.6	12.3	5.5
29	34	330	691	788	170	22	3			2038	2.9	10.7	12.3	5.5
30	53	375	863	762	152	22				2227	3.2	10.3	11.8	5.3
31	40	294	771	616	72	13				1806	2.6	9.9	11.4	5.1
32	46	307	693	496	74	5				1621	2.3	9.6	11.1	5
33	45	344	587	333	22	2				1333	1.9	8.8	10.1	4.5
34	55	468	544	222	7		1			1297	1.8	7.7	8.8	4
35	52	434	466	140	5					1097	1.6	7.4	8.5	3.8
36	64	361	377	132						934	1.3	7.3	8.5	3.8
CALM	3580									3580	5.1			
TOTAL	5955	16174	24635	19165	3570	681	74	11	1	70266	100	9	10.4	4.6
PERCENT	8.5	23	35.1	27.3	5.1	1	0.1	0	0		100			
PCT ALL OBS	7.6	20.7	31.5	24.5	4.6	0.9	0.1	0	0	78244	* 89.8			

CEIL/VIS : CEIL > 1000 FT. AND VIS. >= 3.0 0 MI.
PRES WEA : ALL
HOURS: ALL
DISKETTE FILE NAM E: AN725 28B.PRN
* THIS TOTAL MAY BE LESS THAN THE "ALL WE ATHER" T OTAL DU E TO STN OBSERVI NG PRAC' ICES AND /OR MIS SING CE IL, VIS, O R PRES W A DAT A