FINAL STATUS SURVEY PLAN

THE WARD CENTER FOR NUCLEAR STUDIES
CORNELL UNIVERSITY, ITHACA, NEW YORK
U.S. NUCLEAR REGULATORY COMMISSION
FACILITY OPERATING LICENSE NOS. R-80 AND R-89

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ACRONYMS AND ABBREVIATIONS

ALARA	as low as reasonably achievable
ANSI	American National Standards Institute
Bq	Becquerel
CEDE	committed effective dose equivalent
CFR	Code of Federal Regulations
Ci	curies
cpm	counts per minute
DCGL	derived concentration guideline level
D&D	decontamination and decommissioning
dpm/100cm^2	disintegrations per minute per 100 square centimeters
DQO	data quality objective
FSS	final status survey
FSSP	Final Status Survey Plan
HPGe	high purity germanium
ISO	International Organization for Standardization
kg	kilogram
LSC	liquid scintillation counter
m^3	cubic meters
MARSSIM	*Multi-Agency Radiation Survey and Site Investigation Manual*
MDC	minimum detectable concentration
mCi	millicuries
ml	milliliters
mR/hr	milliroentgen per hour
mrem/hr	millirem per hour
mrem/yr	millirem per year
NaI	sodium iodide
NRC	U.S. Nuclear Regulatory Commission
NUREG	NRC technical report designation (Nuclear Regulatory Commission)
pCi/g	picoCuries per gram
QA/QC	quality assurance and quality control
QAPP	quality assurance project plan
RSO	Radiation Safety Officer
SHSO	Site Health and Safety Officer
TRIGA	Teaching Research Isotope General Atomic
University	Cornell University
WRS	Wilcoxon Rank Sum
ZPR	Zero Power Reactor

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1.0 INTRODUCTION

As part of the decontamination and decommissioning (D&D) project at Cornell University's (University) Ward Center for Nuclear Studies (Ward Center), Energy*Solutions*, LLC will conduct a final status survey (FSS) to demonstrate compliance with facility release criteria approved by the U.S. Nuclear Regulatory Commission (NRC) as provided in the final site Decommissioning Plan[1]. The FSS will support the termination of the two NRC licenses held by the University: License R-80 for the Teaching Research Isotope General Atomic (TRIGA) reactor and License R-89 for the Zero Power Reactor (ZPR).

All FSS activities and tasks will be conducted in accordance with this FSS Plan (FSSP) and other applicable Energy*Solutions* standard operating manuals, procedures, and project-specific plans. Changes to this FSSP, including the deletion or addition of tasks that have an adverse impact on scheduling, must be approved and documented according to Energy*Solutions* Document 82A8001, *"Document Control."* [2]

The FSS was developed following the guidance provided in NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)"[3] to demonstrate compliance with the end point release criteria discussed in Section 2.2. The MARSSIM process emphasizes the use of data quality objectives (DQO), proper classification of survey units, a statistically-based survey and sampling approach, and an adequate quality assurance/quality control (QA/QC) program.

The FSS will be performed in accordance with this FSSP by trained and experienced technicians. The technicians will follow written procedures covering surveys and sampling, sample collection and handling, chain-of-custody, and recordkeeping. This FSSP defines survey and sampling locations, survey types, and analyses required.

1.1 SITE DESCRIPTION

The Ward Center is situated in the southwestern area of the Cornell campus off College Avenue just north of Cascadilla Creek. The facility was constructed between 1959 and 1962. The land area is not well defined, as there are no physical barriers between the Ward Center and other nearby engineering buildings.

The footprint of the three-level Ward Center building is about 10,000 square feet with about 26,000 square feet of floor space. The building contains the Reactor Complex (TRIGA reactor, the ZPR cell/pit, the gamma irradiation facilities, fuel and isotope storage, etc.) and the Office and Laboratory Wing (mechanical and electrical rooms, laboratories, offices, etc.).

1.1.1 Reactor Complex

The primary purpose of the Reactor Complex was to house the TRIGA reactor and ZPR. The Reactor Complex is a relatively airtight, reinforced concrete structure. Access to the Reactor Complex is through doors from the Office and Laboratory Wing on the north side of the Complex on each of the three levels. Access on the basement level is also provided via a large rolling door on the western side of the Reactor Complex.

The Reactor Complex contains three levels totaling about 6,000 square feet: the basement, the first floor, and the second floor. The TRIGA and ZPR pit occupy the basement along with the Reactor Equipment Room, the Isotope and Fuel Storage Room, and the Gamma Cell. The first floor of the Reactor Complex contains the ZPR Cell and the ZPR Control Room. The second floor contains the Isotope Handling Room, the TRIGA Control Room, the Observation Room, a small laboratory, a work area on top of the reactor bioshield, and a catwalk around the area open to the basement. The reactor bay is open on all three levels (about 45 feet from floor to ceiling).

1.1.2 Office and Laboratory Wing

The Ward Center Office and Laboratory Wing surround the Reactor Complex on the northern, eastern, and western sides.. The eastern and western sections consist of a basement and first floor, while the northern section also has a second floor. The basement of the Office and Laboratory Wing contains the Gamma Irradiation Facility, mechanical and electrical rooms, a transformer vault, a liquid waste storage tank room, a machine shop, and laboratory space. The first floor of the Office and Laboratory Wing contains eight office or laboratory spaces, including the ZPR Laboratory, several storage areas, a conference room, lobby, and restrooms. The second floor of the Office and Laboratory Wing contains only six office/laboratory spaces.

1.2 SUMMARY OF D&D ACTIVITIES

D&D activities are performed in accordance with an approved Work Plan. The Work Plan[4] provides details on the effective removal of contaminated and potentially contaminated materials from the Ward Center to facilitate license termination. In support of the Work Plan, Task Plans are also utilized to provide implementation-level direction for field operations to ensure the safe removal of contaminated components and concrete. Each Task Plan includes a description of proposed cutting, alteration or excavation work which may affect the existing facility. It addresses the following items: anticipated impacts on utility or other mechanical/electrical systems including utility interruptions; partial or complete abandonment; any temporary re-routing of piping or exhaust ductwork; and other facility modifications. For more information on the details of the site activities please refer to the project Work Plan[4].

2.0 FINAL STATUS SURVEY PROCESS

2.1 SUMMARY OF FINAL STATUS SURVEY PROCESS

The final status survey provides data and supporting information to demonstrate that the established end point criteria are satisfied. The process consists of four basic phases: planning, design, implementation, and assessment. Survey planning includes a review of historical information and characterization data to determine the contaminants of concern and establish area classifications. Planning also includes establishing reference areas for the determination of the response of survey instruments to background radiation. During planning the survey units should be established. The survey unit is the basic entity for evaluation of compliance with radiological end point criteria. Areas are then classified based on known or potential residual contamination levels. A reference coordinate system is established to document survey measurements and allow replication of measurements if necessary.

The survey design is intended to ensure data of sufficient quantity and quality is obtained to determine the status of survey units with regard to the end point criteria. The product of the design phase is the survey work package which directs the collection of survey measurements in accordance with established implementing procedures. Details on the survey planning and design are provided in Section 2.4.

The survey measurement process includes scanned and fixed point measurements and is detailed further in Section 2.5.

Assessment includes data verification, review of survey design basis and data analysis. The data is validated and it is determined if the residual radioactivity levels meet the end point criteria per Section 3.0.

2.2 END POINT CRITERIA

For the Ward Center decommissioning, the end point criteria are broken into two categories: Administrative Limits desired by the University, and the NRC screening levels designed to ensure dose is maintained at less than 25 mrem/yr after license termination. If the Administrative Limits cannot be met in any area, approval will be obtained from the University to determine acceptable limits not to exceed the NRC screening levels. These end point criteria are broken down as follows with additional detail provided in the following sections:

- Administrative Limits
  - 0.05 millirem per hour (mrem/hr) above background at 1 centimeter (cm) from any surface
  - Removable surface contamination levels less than 100 disintegrations per minute per 100 square centimeters (dpm/100 cm^2) (β-γ)
  - Total surface contamination (fixed plus removal) less than established minimum detectable concentration (MDC)

- NRC License Termination Rule (LTR)
  - Residual radioactivity distinguishable from background radiation resulting in a total effective dose equivalent (TEDE) to an average member of the critical group that does not exceed 25 millirem per year (mrem/yr) and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA)
  - The NRC-published License Termination Screening Values for isotopes of concern

2.2.1 Administrative Limits

While the NRC allows dose-based release criteria, the University has chosen to use non-detect, or less than MDC, as a total surface activity (fixed plus removable contamination) release criterion. MDC levels are highly variable due to changes in background, instrument efficiency, and surface efficiency. Even though scanning and direct measurements are performed with the same instruments, the MDCs for these activities are very different. Scanning MDCs are much higher than static count MDCs and also differ depending on scanning speed, distance of the probe to the surface, and the surveyor. As the MDCs will change daily and will be different for each instrument and surface surveyed, an MDC of **5,000 dpm/100 cm^2** fixed plus removable contamination has been set for the project (consistent with IE Circular No. 81-07). This value is less than the contamination levels allowed under the NRC LTR, discussed below.

In addition, the University has also established removable contamination guidelines for release equal to **100 dpm/100 cm^2** removable contamination with an alternative case-by-case limit of 1,000 dpm/100 cm^2. No removable contamination in excess of 100 dpm/100 cm^2 will be left without approval from Cornell and under no circumstances will removable contamination in excess of 1,000 dpm/100 cm^2 remain (an exception may be granted for tritium).

Final status survey activities will also show that the administrative dose rate criterion of **0.05 mrem/hr** (50 µrem/hr) above background at 1 centimeter from surfaces has been met. An alternative limit is 0.2 mrem/hr may be applied on a case-by-case basis. Unless otherwise noted, the end-point criteria noted in the document hereafter refers to the administrative limits described in this section.

2.2.2 Dose Based Criteria

Title 10 Part 20 of the Code of Federal Regulations (10 CFR 20), Subpart E, also know as the License Termination Rule, requires that, in order for license termination, residual radioactive contamination be ALARA and result in a dose to the critical population of not more than 25 mrem/yr. To apply these criteria, derived concentration guideline levels (DCGL) that would result in a dose of 25 mrem/yr are established for contaminants of concern.

The NRC has developed screening levels that can be used as DCGLs in place of site-specific criteria[5]. The screening values are equivalent to 25 mrem/yr as derived using the NRC's DandD screening methodology in NUREG-5512, "Residual Radioactive Contamination for Decommissioning[6]. They were derived based on the 90th percentile of the output dose distribution for each specific radionuclide. Behavioral parameters in the NRC's DandD dose modeling computer program were set at "Standard Man" or at the mean of the distribution for an average human. Table 2-1 lists radionuclides of concern and their total activity screening criteria. The removable contamination criteria are 10% of the total activity screening level criteria.

TABLE 2-1
LICENSE TERMINATION SCREENING CRITERIA FOR BUILDING SURFACE CONTAMINATION ISOTOPES OF CONCERN

Radionuclide	Total Activity Screening Criteria (dpm/100cm^2)	Decay Mode (Average Beta Decay Energy in keV)
Tritium[a]	1.20E+08	Beta (5.7)
Carbon-14[a]	3.70E+06	Beta (49.5)
Manganese-54[a]	3.15E+04	EC w/ gamma (NA)
Iron-55[a]	4.50E+06	EC (NA)
Nickel-59[a]	4.30E+06	EC (NA)
Nickel-63[a]	1.80E+06	Beta (17.1)
Cobalt-60	7.10E+03	Beta-gamma (95.8)
Strontium-90/Yttrium-90	8.70E+03	Beta (195/935)
Niobium-94	8.30E+03	Beta-gamma (146)
Cesium-137	2.80E+04	Beta-gamma (156)
Europium-152	1.27E+04	Beta-gamma (301)
Europium-154	1.15E+04	Beta-gamma (225)

Note: [a] Hard to detect isotope using standard beta-gamma survey instruments; these isotopes have a very low beta decay energy, decay by electron capture (EC) and emit no beta or alpha radiation.

The following assessment demonstrates that application of the 5,000 dpm/100cm^2 detectable activity administrative criteria conforms with the NRC's 25 mrem/yr dose limit.

Dose Limit Verification

As demonstrated in Table 2-1, not all isotopes of concern are detectable using standard beta-gamma survey instruments. However, the 5,000 dpm/100cm^2 release criteria applies to the detectable isotopes. Since the survey instruments are not isotope specific, the 5,000 dpm/100cm^2 criteria applies to each individual or any combination or the detectable isotopes. To simplify the verification that the 25 mrem/yr dose limit is not exceeded by detectable isotopes when applying the release criteria, it can be conservatively assumed that all measurable activity is from cobalt-60. Therefore, the maximum dose at 5,000 dpm/100cm^2 total beta activity would be 17.6 mrem/yr (5,000 / 7,100).

Cobalt-60 has the lowest average beta decay energy which makes it the least efficient to measure and it has the lowest screening criteria (Table 2-1). If a different detectable isotope of concern was present by itself or any combination of isotopes was present at a reported 5,000 dpm/100cm^2, the resulting dose would be less than 17.6 mrem/yr based on two factors. First the true activity would be less because a lower than optimum detector efficiency would be used, and second, the actual activity screening criteria would be greater than the cobalt-60 screening criteria.

It is also important to note that the removable fraction assumed in determining the dose-based screening criteria was 10%. The administrative release limit is 100 dpm/100cm^2, far less than 10% of any of the criteria. That is 7,100 dpm/100 cm^2 total **plus** 710 dpm/100 cm^2 removable cobalt-60 results in a dose of 25 mrem/yr. The FSS release criteria are 5,000 dpm/100 cm^2 total **plus** 100 dpm/100 cm^2 removable. Therefore the true maximum dose impact from detectable activity is actually less than 17.6 mrem/yr.

Assuming a maximum of 17.6 mrem/yr from the detectable isotopes leaves 7.4 mrem/yr that can come from hard to detect isotopes. To meet this criterion, the sum of the fractions of the hard to detect isotopes to their respective screening criteria times 25 mrem/yr cannot exceed 7.4 mrem/yr. The expected mix of hard to detect isotopes and the resulting dose impact is provided in Table 2-2. The derivation of the "Fraction of Cobalt-60 Activity" is provided in the paragraphs following the table.

TABLE 2-2
EXPECTED MIX OF HARD TO DETECT ISOTOPES OF CONCERN

Radionuclide	Fraction of Cobalt-60 Activity	Expected Activity[a] (dpm/100cm^2)	Dose[b] (mrem/yr)
Tritium	2.28	11,400	< 0.001
Carbon-14	1.12	5,600	0.002
Manganese-54	0.03	150	0.005
Iron-55	1.77	8,850	0.002
Nickel-59	0.87	4,350	0.001
Nickel-63	0.91	4,550	0.003
Total expected dose from hard to detect isotopes at 5,000 dpm/100cm^2 total beta activity			**~ 0.013**

Notes: [a] Fraction of Cobalt-60 Activity time 5,000 dpm/100cm^2
[b] Expected Activity divided by Screening Criteria (Table 2-1)

Fraction of Cobalt-60 Activity

As shown in Table 2-2, the expected dose impact from the hard to detect isotopes is extremely small. However, this dose is highly dependent on the values presented in the second column of the table, "Fraction of Cobalt-60 Activity." These values are based on analytical results of pre-demolition and post-demolition samples taken as representative of any remaining residual contamination present in the reactor areas at the time of the FSS. The primary sources of residual contamination at the time of the FSS are expected to be reactor coolant water and/or activated concrete dust from reactor demolition. Table 2-3 provides a summary of the data used to determine these fractions. These fractions do not necessarily apply to the laboratory or storage areas of the Ward Center.

TABLE 2-3
HARD TO DETECT ISOTOPE CONCENTRATION ASSESSMENT

Radionuclide	Contamination (pCi/g)	Average MDC	Maximum Value or Average MDC	Fraction of Cobalt-60 Activity
Contamination Samples[a]				
Tritium	<MDC	78.5	78.5	2.28
Carbon-14	<MDC	38.6	38.6	1.12
Iron-55	61	35	61	1.77
Nickel-59	<MDC	30	30	0.87
Nickel-63	<MDC	31.1	31.1	0.91
Cobalt-60	< MDC	34.5	34.5	1.00
Activated Concrete[b]				
Manganese-54	15[b]	2.6	15	0.03
Cobalt-60	544	3.4	544	1.00

Notes:

[a] Evaluated from two pre-demolitions samples; one from a sink drain and one from the reactor water drain tank sump. These are considered representative of the pre-demolition conditions.

[b] Activated concrete sample from the inside surface of the reactor pool at the reactor center line.

As shown in Table 2-2, a cobalt-60 concentration of 34.5 pCi/g was used for the 2 reactor water contamination samples. This was the average of the sample MDAs. Co-60 was identified in one sample, but below the MDA. A cobalt -60 concentration of 544 pCi/g was used for the mangamese-54 fraction because manganese-54 was only identified in the activated concrete sample which had 544 pCi/g cobalt-60.

After the completion of the reactor demolition and cleanup and prior to completing the FSS, at least six concrete samples will be taken from the reactor room floor. These samples will be analyzed at an off-site laboratory for the hard to detect isotopes of concern and by gamma spectroscopy. The data will be used to verify that the fractions present in Table 2-2 are acceptable or conservative. Isotopes of concern not detected will be reported as present at the method MDA. Should large amounts of a hard to detect isotopes be detected, additional sampling will likely be required to verify that the dose rate from the residual contamination will not exceed 25 mrem/yr. The off-site laboratory will be contacted in advance to verify the sample volume, container, and preservative needs.

Soil Screening Criteria

The NRC also provides screening criteria for soil contamination[5] that will be applied to soil and around below the facility. These criteria for the isotopes of concern are provided in Table 2-3.

TABLE 2-4
LICENSE TERMINATION SCREENING CRITERIA FOR SOIL CONTAMINATION

Radionuclide	Soil Screening Criteria (pCi/g)
Tritium	1.1 E+02
Carbon-14	1.2 E+01
Manganese-54	1.5E+01
Iron-55	1.0E+04
Nickel-59	5.5E+05
Nickel-63	2.1E+03
Cobalt-60	3.8E+00
Strontium-90/Yttrium-90	1.7E+03
Niobium-94	5.8E+00
Cesium-137	1.1E+01
Europium-152	8.7E+00
Europium-154	8.0E+00

2.2.3 Isotopes of Concern

Tables 2-1 and 2-4 list the isotopes of concern for the Ward Center. This list has been shortened from the list provided in the Decommissioning Plan. The following isotopes were removed from the list for the reasons provided:

- Cobalt-57: Cobalt-57 has a half-life of 0.74 years and was not reported as an activation product in Ward Center Activation Study (Hertel 2002[7]).
- Cobalt-58: Cobalt-57 has a half-life of 0.19 years, it is only a minor activation product (Hertel 2002), and it was identified only in resins that have been removed from the facility.
- Zinc-65: Zinc-65 has a short half-life of 0.67 years, its highest concentrations are in activated aluminum in the reactor components, and it was not identified in activated concrete samples.
- Technicium-99: Technicium-99 was not reported as an activation product (Hertel 2002) and all characterization results were less than the minimum detectable activity (MDA). If present, its beta activity will be detectable with an efficiency approximately equal to cobalt-60.

- Antimony-124: Antimony-124 has a short half-life of 0.16 years and was only previously identified in resins.
- Antimony-125: Antimony-125 is listed as a minor activation product in lead (Hertel 2002) and it was not identified in the characterization data or in activated concrete samples.
- Iodine-129: Iodine-129 is not an activation product (Hertel 2002) and was not identified in the characterization data. If present, it will be identified in the carbon-14 channel of the LSC.
- Cesium-134: Cesium-134 has a relatively short half-life of 2.07 years, it was reported in low concentrations in activated graphite which was removed, and, if present, its beta activity will be measured with an efficiency greater than cobalt-60.
- Europium-155: Europium-155 is only present along with europium-154 and in much lower concentrations than europium-154, it was reported in low concentrations in activated graphite which was removed, and it is hard to detect.
- Lead-210: Lead-210 was reported in the Characterization Report as present at high levels in activated graphite. However, the Ward Center Activation Study (Hertel 2002) does not report lead-210 as an activation product in graphite. It is possible that the lead-210 gamma emission (at 45 keV) was incorrectly identified by gamma spectroscopy. Europium-154, which should be present in the levels reported for lead-210, has a lot of low energy x-rays in the same energy range.
- Thorium-230: Thorium-230 was reported only in very low concentrations in graphite and resins at approximately equal to what would be expected in background soils. The resins and graphite have been removed. If present, it will be detectable with the alpha/beta survey probes.

2.3 DATA QUALITY OBJECTIVES

The Data Quality Objective (DQO) process is used to establish criteria which act as the basis for final status survey design to ensure data collection is of sufficient quality and quantity to support endpoint criteria. DQOs enable a rational decision making process for conducting FSSs and need to be developed prior to survey planning and design. The seven step DQO process and the DQOs for the Cornell FSS are as follows:

<u>State the Problem</u>

Cornell University wishes to decontaminate and decommission the TRIGA reactor and ZPR in a manner that protects human health and the environment. In order to achieve this objective, a final status survey must be performed of the building and surrounding soil areas to demonstrate compliance with release criteria.

<u>Identify the Decision</u>

Following contaminated equipment, building surface and soil remediation, it must be determined if the release limits have been met or if further decontamination or remediation is required. The resulting positive decision can be stated: "The building surfaces and soils that remain exceed the established release limits." This statement is referred to as the null hypothesis for statistical comparison tests.

Identify Inputs to the Decision

Inputs to the decision include the type, quality and quantity of data that will allow the decision to be made. 'Type' refers to the radiological data needed for the survey unit or area. 'Quality' refers to precision, accuracy, representativeness, comparability and completeness. 'Quantity' refers to the amount of data necessary to confirm compliance with the established release criteria and is determined as part of the design process. Inputs involve developing estimates of the median residual radioactivity concentrations and maximum residual radioactivity concentrations.

Define the Study Boundaries

The study is to be performed within and surrounding the Ward Center for Nuclear Studies.

Develop Decision Rule

If data indicate a survey unit or area meets or exceeds the survey objectives, decontamination and remediation efforts are complete and the null hypothesis is rejected.

Limits on Decision Errors

The Type I and Type II decision errors have been established as 0.05. The Type I error results when the null hypothesis is rejected when in fact it is true. The Type II error results when the null hypothesis is accepted when in fact it is false.

Optimize Design

Optimizing the data collection process and meeting the release criteria ensure optimal survey design. Operational details and theoretical assumptions of the survey design are used to ensure optimum design during survey activities.

Key parameters that will affect the overall FSS quality will be determined by the Project Health Physicist. These include:

- The number of sample points for each survey unit.
- The standard deviation of survey unit measurements and the relative shift.

2.4 SURVEY PLANNING & DESIGN

2.4.1 Establishing Survey Units

Survey units are established to facilitate the survey process and statistical analysis of survey data. Survey units will be established by dividing the building interior surfaces. A survey unit is a physical area consisting of structural surfaces of a specified size and physical characteristic for which a determination is made as to whether or not the applicable end point criteria are satisfied. Survey units have been determined based mainly on the physical room boundaries for the Ward Center. In addition, survey units can not have areas with different classifications and therefore it is likely that individual rooms will be broken up into more than one survey unit based on classification. These survey units can be modified as necessary based on survey results and confirmation of room dimensions from site plans and drawings.

Survey units are limited in size based on area classification, site-specific conditions and data management considerations. The area for each survey unit for Class 1 and 2 areas are limited to ensure that each area has the correct number of data points selected to meet statistical tests. Guidance for surface area limits used to establish the initial surveys are provided in Table 2-5.

TABLE 2-5
SURVEY UNIT AREA LIMITS

Classification	Type	Area Limit (m^2)
1	Building & Structures	< 100
1	Soil	< 2,000
2	Building & Structures	100 to 1,000
2	Soil	2,000 to 10,000
3	Building & Structures	no limit
3	Soil	no limit

2.4.2 Reference Coordinate System and the Number of Measurements

A reference coordinate system is used to provide a standardized basis for locating survey units and determining locations within a survey unit. The coordinate system serves as a tool for documenting survey efforts and other information pertaining to a given survey unit. The reference coordinate system also provides a means to specify the general locations for measurements or samples.

The Sign Test will be used to assess surface activity levels. The Sign Test is the chosen non-parametric test because:

- Contaminants are not present in significant quantities in background
- The building areas consist of a number of different surface materials

- Surface activity measurements can be corrected for background

For Class 1 building and structures, the number of data points is found by the following equation:

$$N = \left[\frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{4\left(sign\ p - 0.5\right)^2} \right]$$

Where:

N	number of data points
$Z_{1-\alpha}$	decision error percentile (MARSSIM Table 5.2)
$Z_{1-\beta}$	decision error percentile (MARSSIM Table 5.2)
sign p	probability that a random measurement will be less than Δ (MARSSIM Table 5.4)

Once N is calculated, it is increased by 20% and rounded up to the nearest integer value to provide the actual number of survey points required within the survey unit (*n*). The 20% increase is to allow for possible lost or rejected data.

N is highly dependent on the standard deviation of the expected data within the survey unit. For the purpose of calculating N, the standard deviation of actual impacted areas (σ_{su}) was determined to be 20.3 cpm. This value, and those that follow, correspond to the results of site measurements taken with the Ludlum 2360 with a 43-93 probe, which is the principal fixed-point measurement instrument to be used during the Cornell FSS.

Because the Sign Test will compare the *net* surface activity to the DCGL, the background rate will be subtracted from the *gross* field measurement. As such, the variation in the background (σ_{bkgnd}) must also be accounted for in the calculation on N. The standard deviation of the *net* activity (σ_{net}) is calculated as follows:

$$\sigma_{net} = \sqrt{\left(\sigma_{su}\right)^2 + \left(\sigma_{bkgnd}\right)^2}$$

In order to derive a conservative *a priori* value for calculate σ_{net}, background measurements were taken on all expected FSS survey unit surface types and σ_{bkgnd} was calculated. Since all surface types were included in the calculation of σ_{bkgnd}, 79.2 cpm, it is considered a very conservative value. Using the equation above and the stated values for σ_{su} and σ_{bkgnd}, σ_{net} is 82 cpm. Using an appropriate instrument efficiency, this correlates to about 712 dpm/100 cm^2.

The net standard deviation is used to determine the *sign p* value. Using half the DCGL (5,000 dpm/100cm^2) as the lower bound of the grey region (LBGR), *sign p* is determined from Table 5.4 from MARSSIM by calculating the relative shift (Δ/σ_{net}) (where Δ = DCGL – LBGR).

$$N = \left[\frac{(1.645 + 1.645)^2}{4(1 - 0.5)^2} \right] = 10.82$$

$$n = 10.82 + (10.82 \times 20\%) = 13$$

This calculation is supported by the Building Surface Survey Plan Summary provided using the Compass Version 1.0.0 software. Appendix A provides the Survey Plan Summary.

Survey locations will be placed on a random-start triangular grid. The random start location will be determined on-site using the random number generator in Excel®. To facilitate the survey process, the grid pattern from an adjacent survey unit (with its random starting point) may be used. The horizontal spacing (L) of the grid points (survey locations) is calculated as follows:

$$L = \sqrt{\frac{A_{su}}{0.866\, n}}$$

Where:

L the horizontal distance between measurement locations in meters
A_{su} the area of the survey unit
n number of required data points

The vertical spacing of the rows of grid points (R) is calculated as follows:

$$R = 0.866 \times L$$

In some circumstances, the resulting number of accessible grid points (survey locations) may be less than n because a point may fall outside the survey unit or it may not be accessible due to the presence of an immovable object. In either case, additional sample locations will need to be selected either randomly using the Excel® random number generator or by selecting a point as close as possible to the intended grid point. If required by the geometry of specific survey units, it is acceptable to have a number of data points which is greater than n.

2.4.3 Radiological Classification of Areas

Classification is the process by which an area or survey unit is categorized based on its potential for residual contamination. Survey measurement requirements, including the survey intensity, are based on the classification. In classifying areas, those that have no reasonable potential for residual contamination are classified as non-impacted areas. These areas have no radiological impact from site operations and are typically identified early in the decommissioning. At the Ward Center, ceilings and upper walls (above 1 meter) in areas where there is a low probability of contamination on floor and lower wall (below 1 meter) surfaces will be considered non-impacted.

Areas with some potential for residual radioactivity or areas with known contamination are classified as impacted areas. Impacted areas are subdivided into one of three classifications. To properly perform and document the final status survey, the entire area of interest must be partitioned into properly classified survey units of appropriate physical area.

The Ward Center will be divided into multiple survey units, each with a class designation of Class 1, 2, or 3. The classification will be conducted according to MARSSIM protocols based on characterization surveys[8], historical routine contamination surveys, and scoping surveys performed by Energy*Solutions,* which indicate the potential for residual radioactive contamination to be present in the survey unit following D&D activities.

Appendix B provides the layout of the basement,. first, and second floors of the Ward Center with Class, 1, 2, and 3 areas delineated. The classification in the figures corresponds to the highest designation for the room/area. Walls and ceiling may have a lower class designation.

Table 2-6, 2-7, and 2-8 provide lists of the individual survey units and their classifications for the second floor, first floor, and basement respectively. Some Class 1 and Class 2 survey units may need to be divided into smaller areas to meet the maximum size restrictions as provided in Table 2-5. These sub-divided areas are not shown in the figures in Appendix B.

<u>Initial Classification</u>

Class 1 is assigned to areas which currently have or have had a potential for radioactive contamination above the release criteria prior to remediation. These assignments are based on site operating history or results from previous radiological surveys. Examples of Class 1 areas include:

- Site areas subjected to remedial actions to remove contamination or contaminated materials
- Locations where leaks or spill are known to have occurred
- Waste storage areas
- Radioactive material storage areas

Class 2 areas will be assigned to surfaces for which survey data indicates that residual radioactivity levels may be present but is expected to be below the release criteria or there is a higher probability of elevated activity based on its proximity or association with a Class 1 area. Typically Class 2 areas are adjacent to Class 1 areas such as the upper walls in a room where the floor and lower walls are classified as Class 1. Several Class 2 areas are corridors connecting Class 1 and Class 3 areas.

Class 3 areas are impacted areas not expected to contain any residual radioactivity. Examples of areas that might be classified as Class 3 include the 2nd Floor Lab Offices or Staff Offices on the 1st Floor. Ceilings in rooms that only include Class 2 or Class 3 survey units are generally considered as non-impacted.

Characterization Information

There are multiple data sets which contributed to the delineation of the initial survey units and their classification. These data sets are available on-site for review.

- *Characterization Survey Report for the Ward Center for Nuclear Studies at Cornell University,* May 2003. Duratek, Inc.
- Initial characterization data collected by Energy*Solutions* upon mobilization for the reactor decontamination and decommissioning project in February 2006.
- Routine quarterly contamination survey data collected by Cornell EH&S.

The information provided in the data sets listed above indicates that the Ward Center is relatively free of residual contamination that exceeds the release criteria. Much of the contamination identified in the *Characterization Survey Report* was associated with equipment or material removed during decontamination and decommissioning activities. The Energy*Solutions* characterization data only identified a few locations of residual activity in the reactor bay and reactor equipment room. Therefore, survey unit classification for reactor support areas, laboratories, classrooms, offices, and so forth relied on the historical use of the area or rooms and professional judgment of the Cornell staff and the Energy*Solutions* health physics personnel experienced in reactor characterization and decommissioning.

Reclassification

If newly acquired data suggest that the potential for contamination above the release criteria is higher than previously thought, the classification of the survey unit may change based on the MARSSIM definitions of the Class 1, 2, and 3 survey units. If a survey unit is misclassified (e.g., Class 2 instead of Class 1), then the potential for residual radioactivity in the unit is underestimated and it is possible that insufficient data will be gathered to support an appropriate decision and that small areas of elevated radioactivity may be missed.

If survey results from a Class 2 unit indicate residual activity in excess of the end-point criteria, the survey unit will be reclassified as Class 1. If the survey unit is subdivided, the portion of the unit containing the elevated activity will be assigned the more restrictive classification, while the remainder of the unit may retain its original classification.

TABLE 2-6
INITIAL SURVEY UNITS FOR THE WARD CENTER 2ND FLOOR

Rooms/Area	Description	Survey Unit(s)	Classification
201 202 203 204 205 206 Hallway	Lab Office #4 Lab Office #3 Lab Office #5 Lab Office #2 Lab Office #6 Lab Office #1 Hallway connecting rooms	1. Floors only	3
Corridor	Between Reactor Complex and Lab Complex hallway	2. Floor	2
Stairway	Main Stairway	3. Steps, landings, railings	3
Elevator	Elevator car and shaft	4. Floors	3
2R01	Laboratory	5. Floor, Walls, and Ceiling	1
2R02	Isotope Handling Room	6. Floor, Walls, and Ceiling	1
2R03	Observation Room	7. Floor and Lower Walls 8. Upper Walls 9. Ceiling	1 2 3
2R05	TRIGA Control Room	10. Floor and Lower Walls 11. Upper Walls - Ceiling (w/ 2R03 ceiling)	1 2 3
200CB	Top of ZPR Room	12. Floor and Lower Walls	1
Catwalk	Reactor Bay Catwalk	13. Floor (railings scanned)	1

Notes:

Lower Walls – up to 1 meter from the floor.
Stairway survey includes all levels.
Adjacent Class 3 ceilings can be combined into larger survey units (e.g., 2R03 and 2R05).

TABLE 2-7
INITIAL AREA CLASSIFICATIONS FOR THE WARD CENTER 1ST FLOOR

Room/ Area	Description	Survey Unit(s)	Classification
	Vestibule		
100	Lobby		
101	Health Physicist's Office		
102	Supervisor's Office		
103	Stock & Storage Room #2		
104	Stock & Storage Room #1	1. Floors only	3
105	Staff Lab Office No. 1		
106	Staff Office		
107	Men's Toilet		
108	Women's Toilet		
Hallway	Hallway connecting rooms		
109	Reading/Conference Room	2. Floor	3
112	Staff Lab Office No. 2		
114	Pantry		
116	Staff Lab Office No. 3	3. Floors	3
118	Class Room		
Hallway	Hallway connecting rooms		
110	Janitor's Closet	5. Floor/Walls/Ceiling	2
Corridor	Corridor outside Rooms 109 and 111	6. Floor	2
111	ZPR Laboratory	7. Floor and Lower Walls 8. Upper walls 9. Ceiling	1 2 3
1R01/113	ZPR Control Room	10. Floor and Lower Walls 11. Upper walls 12. Ceiling	1 2 3
1R03/117	ZPR Tank Room	13. Floor/Walls/Ceiling	1
1R07	Top of Gamma Cell	14. Floor and Lower Walls	1

Notes:

Lower Walls – up to 1 meter from the floor.

TABLE 2-8
INITIAL AREA CLASSIFICATIONS FOR THE WARD BASEMENT

Room/ Area	Description	Survey Unit(s)	Classification
B01 B03 B04 Hallway	Introductory Lab No. 2 Dark Room Introductory Lab No. 1 Hallway connecting rooms	1. Floors and Lower Walls	2
B06 B06A B06B B06C B06D Hallway	Machine Shop Misc. rooms Hallway connecting rooms	2. Floor	3
B07	Laboratory	3. Floor and Lower Walls	2
B09 B11 B17 Hallway	Electrical Room Mechanical Equipment Room Transformer Room Hallway connecting rooms	4. Floor	3
B05	Counting Room	5. Floor/Walls/Ceiling	2
Corridor	Corridor from Reactor Bay to B13 (Men's Room) and hallway	6. Floor	2
B15	Waste Storage Tank Room	7. Floor/Walls/Ceiling	1
B08	Chemistry Laboratory	8. Floor/Walls/Ceiling	1
B08A	Chemistry Laboratory Storage	9. Floor/Walls/Ceiling	1
BR01	Isotope and Fuel Storage	10. Floor/Walls/Ceiling	1
BR03	Reactor Equipment Room	11. Floor/Walls/Ceiling	1
BR05	ZPR Pit	12. Floor and walls	1
BR02A	Cold Work Area	13 Floor/Walls/Ceiling	1
BR02B	Set-Up Room	14. Floor/Walls/Ceiling	1
BR02C	Gamma Cell	15. Floor/Walls/Ceiling	1
BR10	Reactor Bay	16. Floor and Lower Walls 17. Upper walls 18. Ceiling	1 2 3

Notes:

Lower Walls – up to 1 meter from the floor.

2.4.4 Survey Coverage

Survey units designated as **Class 1** will be no greater than 100 m^2 in area. Class 1 survey units require a **100%** surface scan and direct measurements at survey points located on a systematic random-start grid. The number and location of direct measurements will be made determined according to Section 2.4.2. A removable contamination smear will be taken at each direct measurement location for total alpha, total beta, and tritium (if a concern).

Survey units designated as **Class 2** survey units will be no greater than 1,000 m^2 in area. Class 2 survey units typically require at least a 10% surface scan and direct measurements at survey points located on a systematic random-start grid. However, the Decommissioning Plan for the Ward Center has established a minimum survey coverage for Class 2 areas of **50%**. The number and location of direct measurements will be determined according to Section 2.4.2. A removable contamination smear will be taken at each direct measurement location for total alpha and total beta.

For those Class 2 survey units in which 100% of the area is not surveyed, it is important to consider performing judgmental assessments to augment any regimented measurements made in accordance with the above guidance. Such assessments may consist of biased sampling or measurements performed in locations selected on the basis of site knowledge and professional judgment. Judgmental assessments serve to provide added assurance that residual radioactivity at the site has been adequately located and characterized.

Survey units designated as **Class 3** can be unlimited in size. The Decommissioning Plan for the Ward Center[1] has established minimum scan survey coverage for Class 3 areas of **25%**. The number of direct measurements will be determined according to Section 2.4.2. The locations of the survey points in Class 3 survey units may be systematic, biased or a combination thereof. This will be determined by the survey technicians.

If a survey unit is reclassified (in whole or in part), or if remediation is performed within a unit, then the areas affected are subject to re-survey. Any re-surveys will be designed and performed as specified in this Plan based on the appropriate classification of the survey unit.

2.4.5 Survey Unit Controls

Before final status survey activities can begin, an area needs to be verified "ready" and isolation and control measures need to be determined. Following this assessment, isolation and control measures are implemented to ensure that no radioactive material is introduced into the area prior to, during or after final survey activities. Isolation and control measures are implemented for logical areas to prevent any impact from ongoing decommissioning activities.

Prior to transitioning an area from decontamination activities to isolation and control, a walkdown will be performed to identify access requirements and to specify the required isolation and control measures. The physical condition of the area will also be assessed to identify and address conditions that could interfere with final survey activities. The following criteria should be met for a survey unit to be designated as ready for isolation and control:

- All planned decontamination activities in the survey unit are complete;
- Items that could interfere with final survey activities are removed from the area to the extent practical;

- Planned decontamination activities in areas adjacent to the area to be isolated, or that could otherwise affect it, are complete or the area is isolated to eliminate the impact;
- All transit paths to or through the area, except those required to support final survey activities, are eliminated or rerouted.

Once the area meets the isolation and control criteria, isolation and control will be achieved through:

- Personnel training, physical barriers and postings, as appropriate, to prevent unauthorized access to an isolated area,
- Measures to prevent the introduction of radioactive or other material by persons authorized to enter the area, and
- Routine surveys to ensure the effectiveness of controls for areas adjacent to unreleased areas.

Measures to prevent the introduction of radioactive material by persons entering an isolated area may include personnel frisking stations at the entry point, the use of "sticky pads," or other methods.

Once an area has completed final status survey activities the area should be sealed or secured in such a way to prevent inadvertent entry by unauthorized persons. Where effective, isolation of completed areas can be by posting only.

2.4.6 Reference Area Background

The one-sample statistical test (Sign Test) described in Section 5.5.2.3 of MARSSIM will be used to evaluate survey units at the Ward Center. The Sign Test does not require that background reference areas be established. If a measurement's net activity is greater than the MDA (> MDA) using the background measured during the daily instrument check, the net activity will be adjusted using a surface-specific background measured in a non-impacted campus building.

2.5 SURVEY IMPLEMENTATION AND DATA COLLECTION

2.5.1 Survey Methods

Direct Measurements

As described in Section 2.4.2, each Class 1, 2, and 3 survey unit will receive a minimum of 13 direct gross activity measurements. Direct measurements are made by placing the detector in a fixed position and integrating its response over a sufficient time interval to accurately assess contamination at the end-point criterion. For Class 1 and 2 survey units, data is collected at predetermined locations identified on a systematic grid. Direct measurements with hand-held instruments may also be used as a method to investigate elevated or anomalous readings observed during the use of other survey methods.

MARSSIM makes a distinction between a DCGL that applies to wide areas of contamination, the $DCGL_W$, and a DCGL that can be applied to elevated measurements, the $DCGL_{EMC}$. Because the overall goal of the decontamination and demolition project is to remove contamination to "background" or "less than MDC levels," the $DCGL_{EMC}$ will not be used and only the acronym DCGL is used in this document. However, the DCGLs (Table 2-1 screening criteria values) will not be applied unless the administrative release criteria of less than MDC (less than 5,000 dpm/100 cm^2) can not be met. In this case, the DCGLs will be applied on a case-by-case basis and their use must be approved by Cornell project management personnel.

It is expected that direct measurements will be made using Ludlum Model 2360 data logging rate meters with Model 43-93 probes. When coupled with the Ludlum 2360, the Ludlum 43-93 100-cm^2 α/β phoswich scintillator probes can record both total alpha and beta activity. While there are no alpha-emitting radionuclides of concern, both the alpha and beta measurements will be recorded by the 2360 rate meter and reported in the FSSR. The 43-93 probes have a thin mylar film window and care should be give to protect the window from tears and punctures. If necessary, pancake GM detectors will be used for direct measurements if the 100cm^2 43-93 probe cannot be accommodated. Both of these instruments are capable of meeting the 5,000 dpm/100 cm^2 MDC requirement with standard 1 to 2 minute count times. The MDC formula is shown in Table 2-10.

Because surface-specific background count rates will be subtracted from the gross measurements, the surface on which a direct measurement is made must be noted on the survey form.

Scanning

Scanning is the process of passing a radiation detector over a surface at some rate and at some source-to-detector distance. Scanning affords one the ability to survey all or a fraction of an area for the presence of radioactivity. The ability of a scan survey to detect non-background radioactivity depends on its sensitivity to the radiation of interest, the scan rate, and the ability of an observer to distinguish a change in instrument response. Indications of elevated activity observed when scanning will generally require verification via some sort of direct measurement.

The Ward Center Decommissioning Plan requires that Class 1, Class 2, and Class 3 survey units be scanned for radiations of concern. The percentage of the scan area is based on the survey unit classification. A Class 1 survey unit will receive a 100% scan. Class 2 survey units will receive a 50% scan. Class 3 areas receive a 25% scan. The ScanMDC is calculated as described in Table 2-10 and will not be greater than the 5,000 dpm/100 cm^2, the surface contamination screening criteria for cobalt-60 provided in Table 2-1.

Floor surfaces will be scanned using a Ludlum Model 239-1F floor monitor with a 400 cm^2 gas proportional detector to the extent practical. The detector will measure β–γ surface activity in cpm. Scans on non-floor surfaces will be made using Ludlum Model 2360 data logging rate meters with Model 43-93 probes or equivalent. The internal memory of the Model 2360 is insufficient to efficiently log scan data; therefore, it will not be logged by the detector. Large-area gas proportional detectors, similar to the floor monitor probe, may also be used for scanning wall and ceiling surfaces.

If necessary, pancake GM detectors will be used for scanning measurements if the 100cm^2 43-93 probe cannot be accommodated.

Removable Contamination Measurements

Surveys to demonstrate compliance with removable contamination will be based on 100 cm^2 swipe surveys. At least one removable contamination smear will be collected at each direct measurement survey location. The smears will be collected using moderate pressure while wiping an area of approximately 100 cm^2. Cloth smears (e.g., Mohawk brand) area acceptable for removable gross beta contamination.

Cloth smears may be counted on a Ludlum Model 2929 sample counter. This is an ZnS(Ag) scintillator that provides both alpha and beta count rates. Count times are typically one minute but will be adjusted as necessary to meet MDC requirements. The MDC for removable beta contamination should be less than 100 dpm, which is the administrative criterion for removable contamination. An LSC may also be used to analyze smears for removable beta contamination.

Sample and background count times will be appropriate to obtain 90% of the MDC, or 90 dpm. For example, the expected background count time and sample count time are 10 and 3 minutes respectively if the average instrument background of 60 cpm beta and a 4-pi efficiency of 40%.

In Class 1 survey units, tritium smears will also be collected at each direct survey point. If an LSC is used to analyze smears for removable beta contamination, an additional tritium smear is not necessary. Instead, a separate tritium analysis will be performed on the LSC. The smears are small round filter papers used dry or wet (with water, glycol, or glycerol). Wet smears are more efficient in removing tritium, and the results are more reproducible, although the papers are usually more fragile when wet. Therefore, wet smears are preferred on smooth surfaces while dry smears are acceptable on rough surfaces. An area of 100 cm^2 of the surface is wiped with the smear paper and quickly placed in a vial with about 10 mL of liquid scintillation cocktail, or 1 or 2 mL of water with the cocktail added later. The paper must be placed in liquid immediately after wiping because losses from evaporation can be considerable, especially if the paper is dry.

Dose Rate Measurements

One of the administrative release criteria is that the gamma dose rate at 1 cm from any surface shall not exceed 0.05 mrem/hr (50 μrem/hr) effective dose equivalent (EDE) above background. Energy*Solutions* will verify compliance with this criterion by measuring gamma external dose rates at each direct measurement location at 1 cm from the survey unit surface. For the purpose of the dose rate evaluation, an exposure rate of 1 milliroentgen per hour (mR/hr) is equivalent to dose rate of 1 mrem/hr.

Dose rate measurements will be made using either a Ludlum Model 19 μR or Bicron μR exposure rate meter. It has been noted that these instruments may over respond at low energies; however, since Energy*Solutions'* primary goal is to remove all residual radioactivity, the fact that the microR instrument tends to over respond (at low energies), is not anticipated to be a problem. Bicron microR meters, which have a relatively flat energy response, may also be used.

Energy*Solutions* will use surface contamination activity measurements to further verify that the average radiation levels associated with surface contamination resulting from beta-gamma emitters do not exceed 0.05 mrem/hr at 1 cm.

The method used to empirically calculate the expected dose rate on contact with a uniformly contaminated infinite plane at the release limit of 5,000 dpm/100cm^2 through not more than 7 milligrams/cm^2 of absorber (dead skin layer thickness) was prepared by Kocher and Eckerman[9]. This document provides beta dose rates factors for various radionuclides through several thicknesses for uniformly deposited contamination on the skin. For the evaluation of the dose rate, strontium-90 and its decay daughter yttrium-90 are assumed to be the only surface contaminants as they have the highest combined dose rate conversion factor of the Ward Center isotopes of concern. The estimated dose rate is calculated as follows:

$$SkinDoseRate = \left(\frac{5000dpm}{100cm^2}\right)\left(\frac{3.7E^{-2}Sv-cm^2}{y-Bq}\right)\left(\frac{\min}{60\sec}\right)\left(\frac{Bq}{dps}\right)\left(\frac{100\,\text{Rem}}{Sv}\right)\left(\frac{y}{365d}\right)\left(\frac{d}{24hr}\right)$$

= 3.5E-4 rem/hr (0.35 mrem/hr) on contact with the surface.

Since the dose rate limit of 0.05 mrem/hr applies to the EDE, the skin dose rate is multiplied by the ICRP organ weighting factor of 0.01 for skin. Therefore, 5,000 dpm/100cm^2 of strontium/yttrium-90 on contact results in an EDE of 0.0035 mrem/hr at the surface. This is significantly less than the 0.05 mrem/hr dose rate limit at 1 cm.

<u>Gamma Surveys</u>

Energy*Solutions* will also conduct scanning surveys using 2x2 NaI gamma scintillation detectors to identify the presence of gamma-emitting isotopes that may be present below the surfaces scanned using the proportional or phoswich detectors. These surveys will include the floors in Class 1 areas and the paved area outside the reactor bay sliding exterior door. Special attention will be given to cracks in the floor, floor/wall joints, and other areas where contamination may likely accumulate. If the gamma count rate exceeds 1.5 times the background level, Energy*Solutions* will investigate the area further by taking direct beta-gamma measurements, removable contamination measurements, and possibly material samples. All gamma surveys will be documented on standard survey forms giving the instrument information, a diagram of the area, and the gamma count rates measurements.

2.5.2 Radiological Survey Instrumentation

The FSS will consist primarily of direct surface activity measurements, surface scans, and removable contamination smears. The instruments proposed for use during the FSS and their applications are provided in Table 2-9. If necessary, Energy*Solutions* may substitute comparable instruments should those listed in Table 2-9 not be available.

TABLE 2-9
FSS INSTRUMENTS

Application	Primary Instrument
Direct measurements and scanning	Ludlum 2360 data logging rate meter w/ 43-93 probe (100 cm^2 α/β phoswich scintillator)
Scanning floor surfaces	Ludlum 239-1F w/ 400 cm^2 gas proportional detector (floor monitor)
Total removable α and β (except tritium)	Ludlum 2929 sample counter α/β ZnS(Ag) scintillator
Scanning equipment and smaller items	Ludlum 2221/2220 rate meter w/ 99-4 probe (15 cm^2 GM pancake probe)
Removable tritium and other low-energy β activity	Wallac Model 1409 Liquid scintillation counter (LSC)
Gamma exposure/dose rates	Ludlum Model 19 uR exposure rate meter

All instrumentation used in the survey will be calibrated and maintained according to Energy*Solutions'* "Calibration and Maintenance of Survey Instruments Procedure."[10] Instruments will be calibrated for normal use under typical field conditions using source standards traceable to National Institute of Standards and Technology (NIST). Calibration records will be maintained per procedures.

Instrument efficiency will be determined in accordance with Energy*Solutions'* "Calibration and Maintenance of Survey Instruments Procedure"[10]. Efficiencies may require modifications to account for surface conditions or coverings. Such modifications will be established using the information in NUREG-1507[11] and pertinent site characterization data.

Detector minimum detectable concentration (MDC) will be determined using the protocols provided in Energy*Solutions*' "General Radiological Survey and Air Sampling Procedure."[12] Energy*Solutions* will use the true background standard deviation in its calculations rather than estimating the standard deviation using the square root of the mean background count rate. Equations for the ScanMDC and direct measurement MDC are provided in Table 2-10.

TABLE 2-10
MDC CALCULATION EQUATIONS[10]

Factors	Equations	Variables
Minimum Detectable Count Rate (MDCR)	$MDCR = d'\sqrt{b_i} \times (60/i)$ $b_i = b(i/60)$	b = Background count rate (cpm) i = observation interval = 1 sec. d' = detectability value = 1.38
ScanMDC	$ScanMDC = \frac{MDCR}{\sqrt{p} \times \varepsilon_S \times \varepsilon_i \times \frac{probe.area}{100cm^2}}$	p = surveyor efficiency (0.5) ε_s = surface efficiency (0.5 for clean beta smears) ε_i = intrinsic (4-pi) efficiency
MDC (direct counts)	$MDC = \frac{3 + 3.29\sqrt{R_B t_S (1 + t_S / t_B)}}{\varepsilon_S \times \varepsilon_i \times t_S \times \frac{probe.area}{100cm^2}}$	R_B = Background count rate (cpm) t_S = Sample count time (min) t_B = Background count time (min) ε_s = surface efficiency (0.5 for clean beta smears) ε_i = intrinsic (4-pi) efficiency
MDC (100 cm^2 smears)	$MDC = \frac{3 + 3.29\sqrt{R_B t_S (1 + t_S / t_B)}}{\varepsilon_S \times \varepsilon_i \times t_S}$	R_B = Background count rate (cpm) t_S = Sample count time (min) t_B = Background count time (min) ε_s = surface efficiency (0.5 for clean beta smears) ε_i = intrinsic (4-pi) efficiency

Soil samples will be collected from below the reactor floor and in unpaved areas around the Ward Center. Soil samples will be analyzed for radionuclides of concern using various analytical methods. Additional information on soil sampling is provided in Section 4.1.

2.5.3 Daily Instrument and Background Measurements

Daily instrument checks will be made according to Energy*Solutions*' "General Radiological Survey and Air Sampling Procedure."[12] These measurements will be made in non-impacted areas using radioactive check sources. These measurements will be recorded for the purpose of assuring that instruments are operating properly. A response check form or instrument control log will be used for each instrument to keep track of background counts and response checks. The logs will be routinely checked to identify any negative trends in instrument response. The acceptable response range is determined *a priori* according to Energy*Solutions*' "General Radiological Survey and Air Sampling Procedure."[12]

Daily background measurements will also be made according to Energy*Solutions* procedures. These measurements will be made in a designated Class 3 room where it has been shown that the background levels are consistent with known non-impacted areas. Single background measurements used to estimate the mean background will be made for a minimum of 10 minutes. Background measurements will be made on all surface types that will be included in FSS work for that day.

2.6 SURVEYS OF BUILDING FIXTURES AND SYSTEMS

As part of the FSS, Energy*Solutions* will also perform surveys and sample building fixtures and systems such as fume hood; ventilation ducts; exhaust stacks; floor, sink, and shower drains; drain lines; and sumps. To the extent practical, site personnel will take direct measurements and collect removable contamination samples from accessible areas. Accessible areas may be enclosed areas than can be reached for survey or sampling without destructive measures. For example, a vent or drain cover will be removed and surveys will be made or smears taken to the limit that the surveyor can reach by hand. This is typically a couple of feet into a duct access point and a foot or less for drains. Destructive measures include actions such as removing concrete, removing dry wall, or cutting into pipes or ducts. The data from the accessible areas will be used to extrapolated information on inaccessible areas. Areas where contamination exceeds the release criteria for surface contamination and areas where contamination is suspected will be remediated or the contaminated components will be removed and disposed of as LLRW.

Surveys will be performed with instruments such as those described in Table 2-9. Additionally, surveys may also be performed through pipe and duct walls (such as the outside of accessible sink traps) with NaI gamma scintillation detectors which are sensitive to gamma radiation. While the NaI surveys cannot determine the surface contamination levels in dpm/100cm^2, they can provide an indication of the presence of gamma-emitting radionuclides such as cobalt-60.

The reactor bay ceiling is designated as a Class 3 survey unit because the potential for any residual contamination on the ceiling to be above the release criteria is very small. Similarly, systems and fixtures associated with the overhead areas of the reactor bay (light fixtures, overhead crane, support beams, etc.) are not suspected to contain residual contamination above the release criteria following demolition activities. Therefore, these items will be surveyed like a Class 3 survey unit with partial scans and direct measurements in biased locations. All surveys and survey results will be documented on standard survey forms. The forms will include diagrams of photographs of the surveyed areas.

3.0 ASSESSMENT

3.1 DATA MANAGEMENT

Direct measurements are stored in the internal memory of the Ludlum Model 2360 data logging rate meters. To mark the beginning of a survey unit, a source check measurement will be recorded. The time and date of the survey should be recorded on the survey form/map along with the name of the survey technician and the serial numbers of the detector and probe. Data from the 2360 will be downloaded daily when final status surveys are collected and saved on a project computer. To ensure preservation and safekeeping of files they should be e-mailed to the Project Health Physicist daily.

While the alpha count rate data is also available from the Ludlum 2360s, only the beta activity survey data will be transcribed or copied into standard data sheets that Energy*Solutions* uses to present the final survey results. The alpha count rate data will be maintained in Excel® spreadsheets and it will be examined for anomalies. If alpha activity is detected, it will be reported separately.

The beta activity survey data will be presented in net dpm/100cm^2 total beta activity according to Energy*Solutions* procedures. Although all raw data will be provided, measurements that are less than the survey MDC will be reported as "<MDC." The MDC will be provided on the survey data sheet.

Scan measurements will be recorded as maximum and average count rates (in cpm) for a survey area. For Class 1 areas, scans will consist of 100% of the surface area. For Class 2 and 3 areas, the scan coverage will be 50% and 25% respectively. According to Energy*Solutions* procedures, average and maximum scan count rate data will be transferred onto survey data sheets and converted to net dpm/100 cm^2 total beta activity. Measurements that are less than the ScanMDC will be reported as "<MDC." The ScanMDC will be provided on the survey data sheet.

Smear count data, alpha and beta counts, from the Ludlum Model 2929 will be recorded on a survey form. The count rate data will be transcribed into a spreadsheet and converted to activity in dpm/100 cm^2 according to Energy*Solutions* Document No. 82A8008.[12]

While the alpha activity data is available from the Ludlum 2929, only the beta activity survey data will be transcribed or copied into standard data sheets that Energy*Solutions* uses to present the final results. The alpha count rate data will be maintained in Excel® spreadsheets and it will be examined for anomalies. If alpha activity is detected, it will be reported separately.

The beta activity survey data will be presented in net dpm/100cm^2 total beta activity. Measurements that are less than the survey MDC will be reported as "<MDC." The MDC will be provided on the survey data sheet. The LSC will report tritium, carbon-14, and total beta activity in cpm. The data will be converted to dpm using the LCS's efficiencies for the energy range and measured quench factor for the sample. The efficiency/quench relationship will be determined using a set of LSC quench standards. LSC reports (hard copies) will be filed on-site.

Dose/exposure rate measurements will be presented in units of μR/hr on the final survey data sheets along with the surface activity measurements.

3.2 QUALITY ASSURANCE

Quality Assurance activities shall be performed in compliance with the Decommissioning Plan and the project Quality Assurance Project Plan (QAPP).[13] Only instruments calibrated according to Energy*Solutions* Document No. 82A8034[8] will be used to collect FSS data. To ensure that instruments are operating properly and reporting precise data, QA measurements will be performed on a daily basis. Typically, QA measurements are made on surfaces within survey units or with smears that show some measurable activity. However, during the FSS at the Ward Center, most measurements are expected to be below the survey method MDC and, therefore, replicate measurements in a survey unit or of actual smears from a survey unit are not adequate tools for measuring instrument precision.

Instrument precision will be measured by collecting daily source check measurements in a low background area and ensuring that the measurements do not vary by more than two standard deviations from the mean source measurement determined early in the FSS process and tracked on a control chart to identify response trends. Daily precision measurements will be maintained in an instrument control log.

The LSC will be properly calibrated using NIST-traceable tritium standards. The calibration consists of generating a quench/efficiency curve using the set of quench standards.

To ensure that all radionuclides-of-concern are properly evaluated, six biased samples will be collected from surveyed media in Class 1 areas. These samples will be subject to laboratory analyses for the radionuclides-of-concern listed in Table 2-2. The Project Health Physicist will evaluate the results of these analyses to determine if the relative concentrations are consistent with those presented in this plan.

All survey data will be reviewed and approved by the Project Health Physicist. If practical, reference area measurements and final status survey data will be transmitted to the Project Health Physicist on a daily basis.

3.3 FINAL STATUS SURVEY REPORT

The FSS data will be presented in the FSS Report. This will include all survey data and sample analysis data. The report will also contain survey forms, survey and sampling maps, instrument calibration information, and other information necessary to support the validity of the data. The Report will present the conclusions of the survey and the justification for license termination. The Report will also detail any deviations from the FSSP.

4.0 SOIL SAMPLING

Only two soil survey units are expected at the Ward Center. One will be within the Reactor Complex below the concrete floor, parts of which may be completely removed, and the other includes the exterior unpaved areas around the perimeter of the Ward Center. These areas will receive walkover gamma radiation surveys and discrete surface soil sampling.

4.1 SAMPLING SOIL BELOW THE REACTOR

Project plans call for the concrete slab below the reactor to be removed, exposing the underlying earth. Any contaminated soil encountered below the floor will also be remediated. However, there may or may not be a layer of soil between the bottom of the concrete slab and bedrock. If there is a soil layer, it will be surveyed and sampled as described in this section. Otherwise, exposed areas of bedrock will be surveyed using direct measurements.

In areas where all of the concrete has been removed, exposed soil will be scanned using 2" x 2" sodium iodide (2x2 NaI) gamma scintillation detectors. Since the area is expected to be rather small, only a few square meters, a maximum and average gamma count rate should be recorded for each square meter of surface area.

The exposed soil layer will be classified as a Class 1 survey unit and will be sampled using the MARSSIM approach to determine the number of samples and the sampling grid. Sampling procedures are described in Energy*Solutions* Document No. 82A8016, "Environmental Sample Collection Procedure."[14] As described in the procedure, a sufficient volume of soil determined by the off-site laboratory will be collected in appropriate sample containers using clean sampling tools such as a stainless steel trowel. Sampling equipment will be cleaned between each sample. Samples will be logged and given a unique sample identification number, packaged, and shipped according to Energy*Solutions* procedures for chain-of-custody and transportation.

Soil sample analysis should include, as a minimum, gamma spectroscopy, tritium, iron-55, nickel 63, and carbon-14.

For samples with multiple detectable contaminants of concern, the statistical tests must be performed with a normalized DCGL. This approach is not described in this FSSP because FSS soil samples are expected to be free of residual contamination. Should measurable levels of any of the contaminants of concern be identified, the Project Health Physicist will perform the data analysis as required for multiple contaminants.[15]

If the concrete slab is not removed to the point where soil is accessible, concrete cores will be removed to allow access to the underlying soil. Soil samples will be collected from the resulting holes in the concrete to the extent possible.

4.2 SAMPLING SOIL OUTSIDE THE WARD CENTER

Site characterization data does not indicate that the outside areas of the Ward Center are radiologically impacted.[8] Therefore, these areas will be designated as a Class 3 survey unit and only judgmental surface soil samples will be collected from the non-paved areas around the facility. To have a statistically valid data set, the number of samples will be equal to the number of samples determined using MARSSIM protocols. Judgmental surface scans using 2x2 NaI detectors may also be performed as part of the FSS.

All soil samples will be managed as described in Section 4.1 above and Energy*Solutions* Document No. 82A8016.[14] All survey data will be recorded on appropriate survey forms.

5.0 REFERENCES

1. Duratek, Inc., *Decommissioning Plan for the Ward Center for Nuclear Studies at Cornell University*, July 2003.
2. Energy*Solutions* Field Services, *Document Control*, 82A8001, current revision.
3. U.S. Nuclear Regulatory Commission, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM),* NUREG-1575, August 2000.
4. Energy*Solutions* Field Services, *Work Plan for the Ward Center for Nuclear Studies Decommissioning Project*, 82A9580, current revision.
5. U.S. Nuclear Regulatory Commission, *Supplemental Information on the Implementation of the Final Rule on Radiological Criteria for License Termination*, Federal Register, Vol. 63, No. 222. November 18, 1998.
6. U.S. Nuclear Regulatory Commission, *Residual Radioactive Contamination From Decommissioning,*NUREG/CR-5512, Volume 3, October 1999.
7. Hertel, Nolan E. 2002. "Activation Study of Components of the Cornell Research Reactor in Support Of Its Characterization." March 10.
8. Duratek, Inc., *Characterization Survey Report for the Ward Center for Nuclear Studies at Cornell University,* May 2003.
9. D.C. Kocher and K.F. Eckerman. "Electron Dose Rate Conversion Factors for External Exposures of the Skin from Uniformly Deposited Activity on the Body Surface." *Health Physics Journal.* Vol. 53, No. 2 (August), pp. 135-141. 1987.
10. Energy*Solutions* Field Services, *Calibration and Maintenance of Survey Instruments,* 82A8034, current revision.
11. U.S. Nuclear Regulatory Commission, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, NUREG-1507.
12. Energy*Solutions* Field Services, *General Radiological Survey and Air Sampling Procedure*, 82A8008, current revision.
13. Energy*Solutions*, *Quality Assurance Program Plan for the Ward Center for Nuclear Studies Decommissioning Project*, 82A9576, current revision.
14. Energy*Solutions* Field Services, *Environmental Sample Collection Procedure*, 82A8016, current revision.
15. Abelquist, E. W., *Decommissioning Health Physics, A Handbook for MARSSIM Users*, Institute of Physics Publishing 2001.

APPENDIX A

COMPASS SITE REPORT AND BUILDING SURFACE SURVEY PLAN

Site Report

Site Summary

Site Name: Cornell University Ward Center

Planner(s): Kevin Taylor, CHP

Contaminant Summary

NOTE: Surface soil DCGLw units are pCi/g.
Building surface DCGLw units are dpm/100 cm².

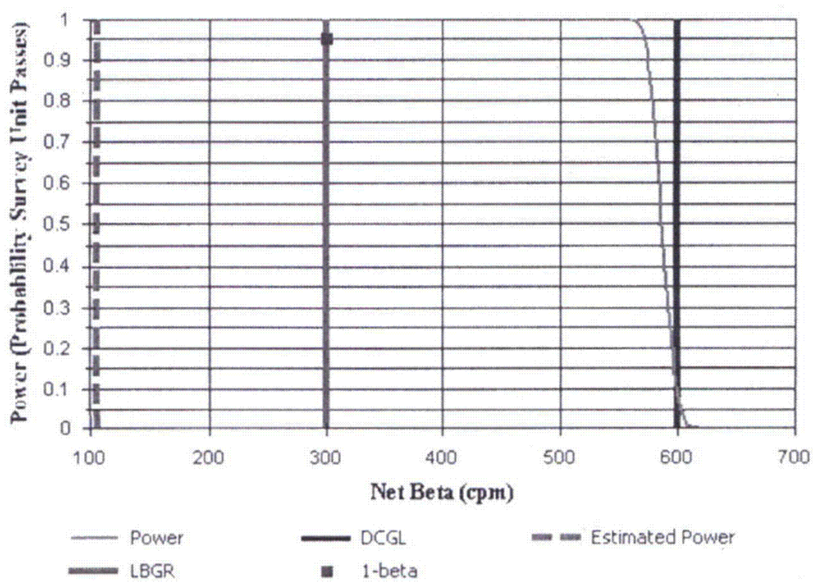
Contaminant	Type	DCGLw	Screening Value Used?	Area (m²)	Area Factor
Co-60	Building Surface	5,000	No	1	22.7
				4	5.5
				9	2.5
				16	1.6
				25	1.2
				36	1
Co-60	Surface Soil	3.80	No	1	9.81
				3	4.39
				10	2.12
				30	1.52
				100	1.23
				300	1.13
				1,000	1.06
				3,000	1.04
				10,000	1

Building Surface Survey Plan

Survey Plan Summary

Site:	Cornell University Ward Center		
Planner(s):	Kevin Taylor, CHP		
Survey Unit Name:	Generic		
Comments:	Generic survey unit for planning		
Area (m²):	100	Classification:	1
Selected Test:	Sign	Estimated Sigma (cpm):	26.9
DCGL (cpm):	600	Sample Size (N):	13
LBGR (cpm):	300	Estimated Conc. (cpm):	105
Alpha:	0.050	Estimated Power:	1.00
Beta:	0.050	EMC Sample Size (N):	13

Prospective Power Curve



Building Surface Survey Plan

Contaminant Summary

Contaminant	DCGLw (dpm/100 cm²)
Co-60	5,000

Beta Instrumentation Summary

Gross Beta DCGLw (dpm/100 cm²): 5,000
Total Efficiency: 0.12
Gross Beta DCGLw (cpm): 600

ID	Type	Mode	Area (cm²)
4	Ludlum 2360 w/ 43-93 (generic)	Beta	100

Contaminant	Energy[1]	Fraction[2]	Inst. Eff.	Surf. Eff.	Total Eff.
Co-60	96.09	1.0000	0.25	0.50	0.1250

[1] Average beta energy (keV) [N/A indicates alpha emission]
[2] Activity fraction

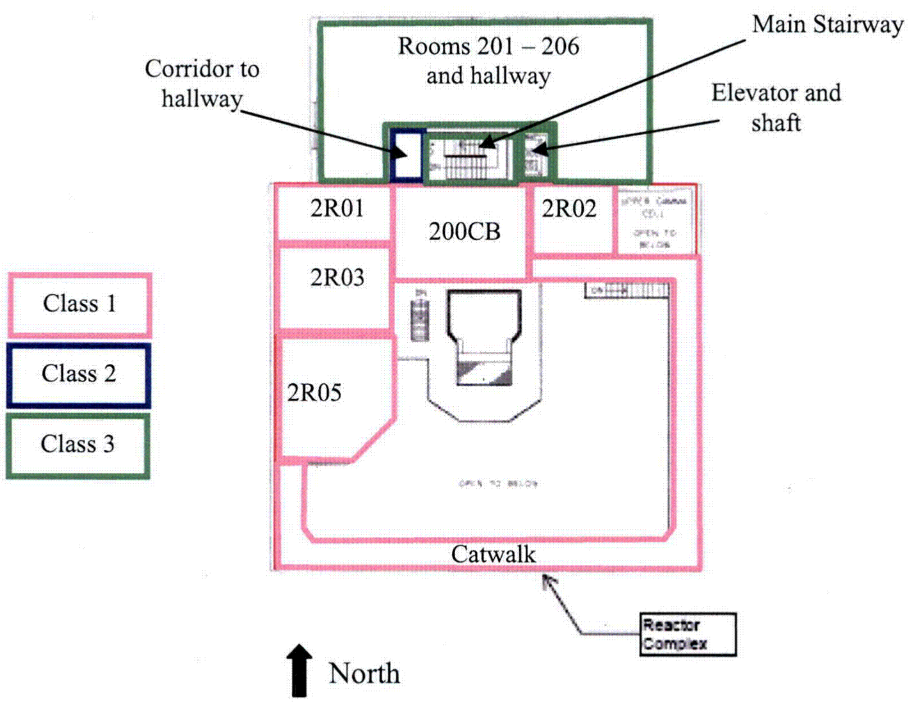
Gross Survey Unit Mean (cpm): 411 ± 20 (1-sigma)
Count Time (min): 1

Material	Number of BKG Counts	Average (cpm)	Standard Deviation (cpm)	MDC (dpm/100 cm²)
Concrete	10	305.2	17.7	702

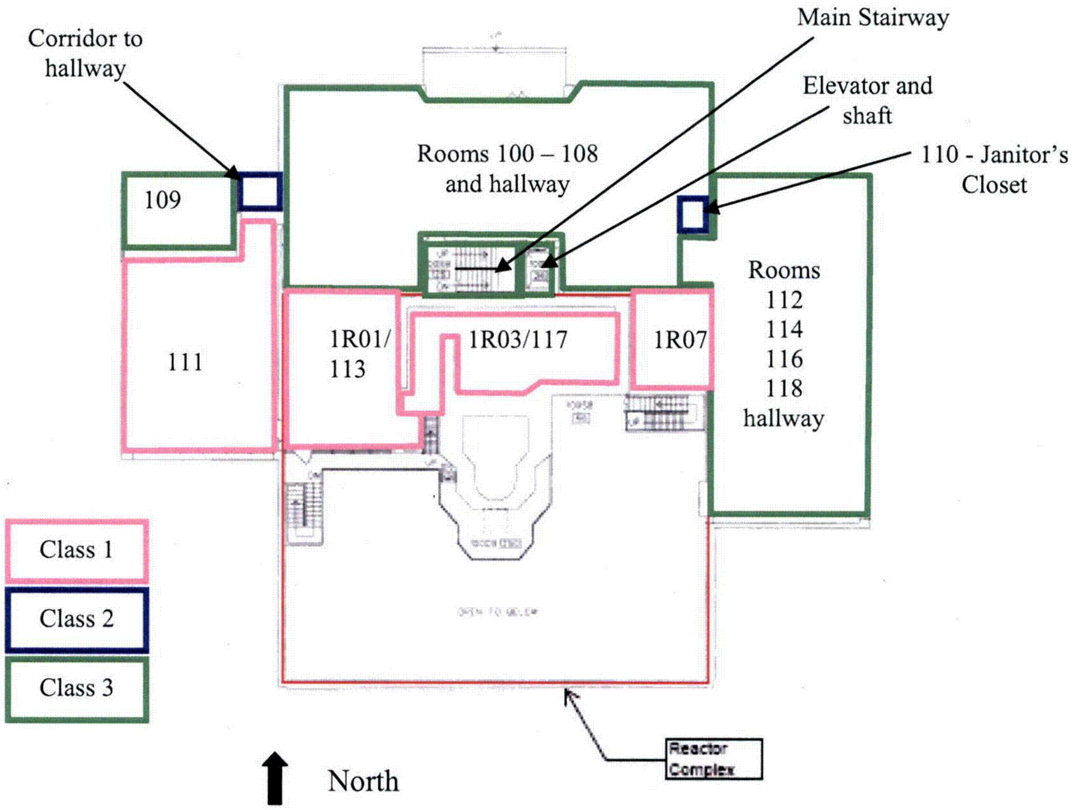
APPENDIX B

WARD CENTER FACILITY PLANS
WITH SURVEY UNIT CLASSIFICATIONS

Cornell University
Ward Center for Nuclear Studies
Second Floor Plan



Cornell University
Ward Center for Nuclear Studies
First Floor Plan



Cornell University
Ward Center for Nuclear Studies
Basement Plan