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April 17, 2006
BYR 2006-032

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555-001

References: (a) License No. DPR-3 (Docket No. 50-29)

(b) BYR 2004-133, Submittal of Revision 1 to the Yankee Nuclear Power Station's License Termination Plan

(c) Yankee Nuclear Power Station – Issuance of Amendment 158 Re: License Termination Plan

Subject: Submittal of YNPS-FSS-WST01-00, Final Status Survey Report for Survey Area WST-01

Dear Madam/Sir:

This letter submits YNPS-FSS-WST01-00, Final Status Survey Report for WST-01. YNPS-FSS-WST01-00 was written in accordance with Section 5 of the YNPS License Termination Plan, "Final Status Survey Plan," and is consistent with the guidance provided in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM).

We trust that this information is satisfactory; however if you should have any questions or require any additional information, please contact Alice Carson at (301) 916-3995 or the undersigned at (413)-424-2261.

Very truly yours,

YANKEE ATOMIC ELECTRIC COMPANY

Joseph Lynch
Regulatory Affairs Manager

Enclosure: YNPS-FSS-WST01-00 (2 hard copies plus CD)

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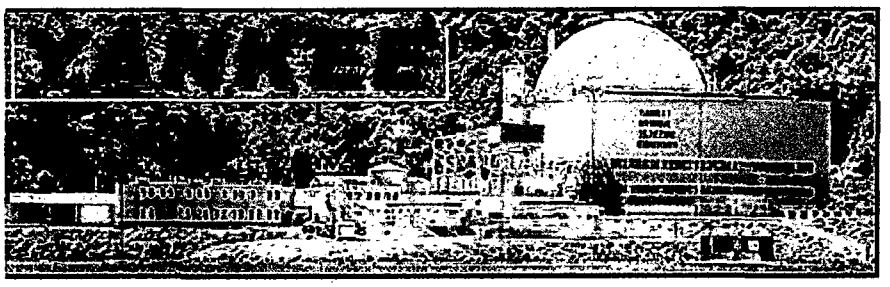
Yankee Nuclear Plant Station
Final Status Survey Report
For WST-01



Yankee Atomic Electric Company

YANKEE NUCLEAR POWER STATION
FINAL STATUS SURVEY REPORT

REPORT NO.: YNPS-FSS-WST-01-00

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(In the electronic version, every Table of Contents, Figures, Appendices and Attachments, as well as every mention of a Figure, Appendix or Attachment is a hyperlink to the actual location or document.)

List of Abbreviations and Acronyms

AL ..... Action Level
ALARA ..... As Low As Reasonably Achievable
c/d ..... Counts per Disintegration
DCGL ..... Derived Concentration Guideline Level
$DCGL_{EMC}$ ..... DCGL for small areas of elevated activity
$DCGL_W$ ..... DCGL for average concentration over a wide area, used with statistical tests
DQO ..... Data Quality Objectives
EMC ..... Elevated Measurement Comparison
ETD ..... Easy-to-Detect
FSS ..... Final Status Survey
FSSP ..... Final Status Survey Plan
GPS ..... Global Positioning System
H_o ..... Null Hypothesis
HSA ..... Historical Site Assessment
HTD ..... Hard-to-Detect
ISOCS ..... *In-situ* Object Counting System®
LBGR ..... Lower Bound of the Grey Region
LTP ..... License Termination Plan
MARSSIM ..... Multi-Agency Radiation Survey and Site Investigation Manual
MDA ..... Minimum Detectable Activity
MDC ..... Minimum Detectable Concentration
PAB ..... Primary Auxiliary Building
QAPP ..... Quality Assurance Project Plan
QC ..... Quality Control
RCA ..... Radiological Controlled Area
RP ..... Radiation Protection
RSS ..... Reactor Support Structure
SFP ..... Spent Fuel Pool
VC ..... Vapor Container
VCC ..... Vertical Concrete Cask
VSP ..... Visual Sample Plan
YNPS ..... Yankee Nuclear Power Station

1.0 EXECUTIVE SUMMARY

1.1 Identification of Survey Area and Units

A Final Status Survey (FSS) was performed of Survey Area WST-01 in accordance with Yankee Nuclear Power Station's (YNPS) License Termination Plan (LTP). This FSS was conducted as a structure surface FSS with building occupancy Derived Concentration Guideline Levels (DCGLs) even though the WST-01 structure will be subsurface at license termination. This practice conservatively implements LTP criteria that subsurface structure surfaces be evaluated for the presence of contamination.

Survey Area WST-01 consists of a single survey unit, WST-01-02, which is comprised of the reinforced concrete foundation of the 'Old Potentially Contaminated Area (PCA) Storage Building' as well as the remaining concrete partial walls exposed during the excavation of Survey Unit NOL-05-02. WST-01-02 encompasses a 61.3 m^2 footprint having a total surface area of 153.5 m^2. WST-01 was used, during plant operation, as a decontamination facility and as a storage area for heavily contaminated items. WST-01 is located within the Radiological Controlled Area (RCA) and has been classified as a MARSSIM Class 1 area.

1.2 Dates(s) of Survey

The FSS of the WST-01 survey area was performed from December 27, 2005, to January 19, 2005.

1.3 Number and Types of Measurements Collected

Final Status Survey Plan (FSSP) was developed for this survey unit in accordance with YNPS LTP and FSS procedures using the MARSSIM protocol. The planning and design of the survey plan employed the Data Quality Objective (DQO) process, ensuring that the type, quantity and quality of data gathered was appropriate for the decision-making process and that the resultant decisions were technically sound and defensible. A total of 24 fixed-point measurements were taken, providing data for the non-parametric testing of the survey area. In addition to the fixed-point samples, a total of 97 In-Situ Object Counting System (ISOCS) scans, supplemented by hand-held survey instrument scans, were performed to provide 100 percent coverage of the survey area.

1.4 Summary of Survey Results

Following the survey, the data were reviewed against the survey design to confirm completeness and consistency, to verify that the results were valid, to ensure that the survey plan objectives were met and to verify survey unit classification. The boundaries of areas of elevated activity were identified based upon the results of a 100 percent surface scan, and areas identified as exceeding $DCGL_{EMC}$ were remediated and resurveyed. Fixed point surveys indicated two of the measurements exceeded the $DCGL_W$ but were less than the $DCGL_{EMC}$, therefore the Sign Test was used to evaluate the survey unit. The survey unit passed the Sign Test, depicted in Attachment B. Retrospective power curves were generated and demonstrated that adequate power was achieved. Therefore, the null hypothesis (H_o) (that the survey unit exceeds the release criteria) is rejected.

1.5 Conclusions

Based upon the evaluation of the data acquired for the FSS, WST-01 meets the release requirements set forth in the YNPS LTP. The Total Effective Dose Equivalent (TEDE) to the average member of the critical group does not exceed 25 mrem/yr, including that from groundwater. 10CFR20 Subpart E ALARA requirements have been met as well as the site release criteria for the administrative level DCGLs that ensure that the Massachusetts Department of Public Health's 10 mrem/yr limit will also be met.

2.0 FSS PROGRAM OVERVIEW

2.1 Survey Planning

The YNPS FSS Program employs a strategic planning approach for conducting final status surveys with the ultimate objective to demonstrate compliance with the DCGLs, in accordance with the YNPS LTP. The DQO process is used as a planning technique to ensure that the type, quantity, and quality of data gathered is appropriate for the decision-making process and that the resultant decisions are technically sound and defensible. Other key planning measures are the review of historical data for the survey unit and the use of peer review for plan development.

2.2 Survey Design

In designing the FSS, the questions to be answered are: "Does the residual radioactivity, if present in the survey unit, exceed the LTP release criteria?" and "Is the potential dose from this radioactivity ALARA?" In order to answer these questions, the radionuclides present in the survey units must be identified, and the survey units classified. Survey units are classified with respect to the potential for contamination: the greater the potential for contamination, the more stringent the classification and the more rigorous the survey.

The survey design additionally includes the number, type and locations of fixed measurements/samples (as well as any judgmental assessments required), scanning requirements, and instrumentation selection with the required sensitivities or detection levels. DCGLs are developed relative to the surface/material of the survey unit and are used to determine the minimum sensitivity required for the survey. Determining the acceptable decision error rates, the lower bound of the gray region (LBGR), statistical test selection and the calculation of the standard deviation and relative shift allows for the development of a prospective power curve plotting the probability of the survey unit passing FSS.

2.3 Survey Implementation

Once the planning and development has been completed, the implementation phase of the FSS program begins. Upon completion of remediation and final characterization activities, a final walk down of the survey unit is performed. If the unit is determined to be acceptable (i.e. physical condition of the unit is suitable for FSS), it is turned over to the FSS team, and FSS isolation and control measures are established. After the survey unit isolation and controls are in place, grid points are identified for the fixed measurements/samples, using Global Positioning System (GPS) coordinates whenever possible, consistent with the Massachusetts State Plane System, and the area scan grid is identified. Data is collected and any required investigations are performed.

2.4 Survey Data Assessment

The final stage of the FSS program involves assessment of the data collected to ensure the validity of the results, to demonstrate achievement of the survey plan objectives, and to validate survey unit classification. During this phase, the DQOs and survey design are reviewed for consistency between DQO output, sampling design and other data collection documents. A preliminary data review is conducted to include: checking for problems or anomalies, calculation of statistical quantities and preparation of graphical representations for data comparison. Statistical tests are performed, if required, and the assumptions for the tests are verified. Conclusions are then drawn from the data, and any deficiencies or recommendations for improvement are documented.

2.5 Quality Assurance and Quality Control Measures

YNPS FSS activities are implemented and performed under approved procedures, and the YNPS Quality Assurance Project Plan (QAPP) assures plans, procedures and instructions have been followed during the course of FSS, as well as providing guidance for implementing quality control measures specified in the YNPS LTP.

3.0 SURVEY AREA INFORMATION

3.1 Survey Area Descriptions and HSA Information

Survey Area WST-01 consists of the reinforced concrete foundation of the "Old PCA Storage Building" as well as the remaining concrete partial walls exposed during the excavation of Survey Unit NOL-05-02. WST-01 encompasses a 61.3 m^2 footprint having a total surface area of 153.5 m^2. WST-01 was used, during plant operation, as a decontamination facility and as a storage area for heavily contaminated items. WST-01 is located within the RCA and has been classified as a MARSSIM Class 1 area.

3.2 History of Survey Area

WST-01 was a concrete block structure constructed on a reinforced concrete foundation. It contained a reinforced concrete tank/tub fitted with a drain that connects to the floor drain and continued to the Waste Disposal Building ash de-watering sump. It also had a locally-controlled ventilation system located in the northeast corner of the structure. WST-01 was constructed for use as an equipment decontamination and storage facility. It was subsequently converted to a contaminated area used for radioactive material storage only. It was later decontaminated and used as a hazardous and mixed waste storage location. The decontamination tub was generally used for items considered heavily contaminated. These include control rod dash-pots and other components of moderate size from the primary systems. The glue in the joints of the drain line from this tub failed to hold over time and the use of the tub was discontinued. This drain line was partially remediated in 1984 during construction of the Radioactive Waste Warehouse. The area directly under the tub was further remediated prior to FSS.

Table 1Survey Area WST-01 Events/Conditions

Date	Event/Condition
1979	Drain Line Leak
1984	Drain Line Initial Excavation/Remediation
Various	Facility was used to store heavily contaminated items
Post-HSA	Additional Drain Line Excavation/Remediation

3.3 Division of WST-01 into Survey Units

WST-01 consists of a single survey unit, WST-01-02. WST-01-02 is the remnants of WST-01-01 which was the Old PCA Storage Building that has been demolished.

3.4 Survey Unit Description

WST-01-02 is located within the RCA yard area and consists of the reinforced concrete foundation of the old PCA storage building, as well as the remaining concrete partial walls exposed during the excavation of survey unit NOL-05-02. WST-01-02 is bounded by NOL-03 on the east, AUX-01 and AUX-02 on the north, NOL-04 on the south, and by NOL-05-02 on the west. The resultant total area of this unit is approximately 153.5 m^2. In addition to the afore mentioned areas, the underside area of the concrete pad, exposed during the demolition, was 100% scanned as part of this survey plan. No fixed-measurements were required on the underside of the concrete pad. The same investigative values applied to WST-01-02 were applied to this area.

4.0 SURVEY UNIT WST-01-02 INFORMATION

4.1 Summary of Radiological Data Since Historical Site Assessment (HSA)

4.1.1 Chronology and Description of Surveys Since HSA

Characterization of Survey Unit WST-01-02 is based upon the characterization of Survey Unit NOL-05-02 performed from November 17, 2005 to November 18, 2005 and the operational RP survey of WST-01 performed on May 2nd, 2005. The characterization survey was comprised of 455 ISOCS assays.

Upon completion of the characterization effort, isolation and control measures were implemented for the FSS. The condition of WST-01-02 at the time of FSS was smooth to heavily remediated steel reinforced concrete.

4.1.2 Radionuclide Selection and Basis

During the initial DQO process, Co-60 was identified as the radiological nuclide of concern due to its more restrictive DCGL value when compared to Cs-137 (sampling of soil adjacent to the concrete indicated a relationship of approximately 80% Co-60 to 20% Cs-137). Adjacent soil characterization and survey data indicate no other LTP-specified radionuclides warrant consideration in these survey units.

4.1.3 Summary of Scoping/Characterization Survey Data

Table 2 summarizes the characterization surveys for Survey Unit WST-01-02.

Table 2 Survey Unit WST-01-02

Parameter	Characterization
	05/02/05
Number of measurements	11
Mean	993 dpm/100cm2
Standard Deviation	571 dpm/100cm2

4.2 Basis for Classification

Based upon the historical use of the facility as a storage area for highly contaminated materials, and the known drain line leak, Survey Unit WST-01-02 was designated as MARSSIM Class 1.

4.3 Remedial Actions and Further Investigations

The majority of ISOCS measurements taken facing the southern wall were affected by radiation associated with the ISFSI. These locations were investigated using SPA-3 gamma scan. SPA-3 background on the southern end of the survey unit was also affected by the ISFSI. To shield the area from shine originating from the ISFSI, a 4' x 8' sheet of 1" plate steel was used. Background unshielded at the location was 25k cpm to 45k cpm, background shielded was 15k cpm to 19k cpm.

The SPA-3 scans of the high background ISOCS measurements yielded two locations of elevated activity in the soil, in survey unit NOL-05-02. These locations were not discovered during initial remediation due to the elevated background in the area. Those locations were further investigated and will be discussed in the Remedial Actions and Further Investigations portion of the Final Status Survey Report covering NOL-05-02.

4.4 Unique Features of Survey Unit

Survey Unit WST-01-02 exhibited surface characteristics ranging from smooth surfaces to heavily remediated irregular surfaces. Most of the pits and irregularities increased the source-to-detector distance by approximately ¼ - ½ inch, although some increase it as much as 1 - 2 inches. These types of irregularities in the concrete surfaces were taken into account through the efficiency factor applied to the measurements collected with the HP-100. Technical report YA-REPT-00-015-04 (Attachment B) provides instrument efficiency factors (ε_i) for various source-to-detector distances. The ε_i value for a source-to-detector distance of 1 inch was

selected as a representative efficiency for data collected with the HP-100 from the irregular surfaces because it accounts for the ½ inch stand-off and the most common depth of pits and surface irregularities (¼ - ½ inch). In contrast to the irregular surfaces, the vertical walls of the structures are relatively smooth. Table 3.2 of the YA-REPT-00-015-04 (Attachment B) provides instrument efficiency factors (ε_i) for various source-to-detector distances. Detector efficiencies (HP-100C) were applied as follows: smooth surface 0.0603 c/d, irregular surface 0.0373 c/d.

4.5 ALARA Practices and Evaluations

An ALARA evaluation was developed for the survey unit which concluded that additional remediation was not warranted. This evaluation is found in Appendix D.

5.0 SURVEY UNIT WST-01-02 FINAL STATUS SURVEY

5.1 Survey Planning

5.1.1 Final Status Survey Plan and Associated DQOs

The FSS for WST-01-02 (YNPS-FSSP-WST01-02-00) was planned and developed in accordance with the LTP using the DQO process. Form DPF-8856.1, found in YNPS Procedure 8856, "*Preparation of Survey Plans*," was used to provide guidance and consistency during development of the FSS Plan. The FSS Plan can be found in Appendix A. The DQO process allows for systematic planning and is specifically designed to address problems that require a decision to be made in a complex survey design and, in turn, provides alternative actions.

The DQO process was used to develop an integrated survey plan providing the survey unit identification, sample size, selected analytical techniques, survey instrumentation, and scan coverage. The Sign Test was specified for non-parametric statistical testing for this survey unit, if required. The design parameters developed are presented in Table 3.

Table 3 Survey Unit WST-01-02 Design Parameters

Survey Unit	Design Parameter	Value	Basis
WST-01-02	Area	153.5 m^2	Class 1, ≤1000 m^2
	Number of Direct Measurements	15 plus 9 added	Based on an adjusted LBGR of 5159.7, sigma of 571and an adjusted relative shift of 2 α= 0.05, β= 0.05
	Sample Area	6.4 m^2	153.5 m^2 / 24 = 6.4 m^2
	Sample Grid Spacing, triangular pitch	2.7 m	$(153.5/(0.866*24))^{1/2}$
	Scan Grid Area	ISOCS scans at 2 meters	2.6 m on center
	Scan area	153.5 m^2	Class 1 Area – 100%
	Scan Investigation Level	Co-60: 2.9E3 dpm/100cm^2 Cs-137: 1.1E4 dpm/100cm^2	See Appendix C

5.1.2 Deviations from the FSS Plan as Written in the LTP

The null hypothesis (H_o) is stated and tested in the negative form: "Residual licensed radioactive materials in Survey Unit WST-01-02 exceed the release criterion." This null hypothesis is designed to protect the health of the public as well as to demonstrate compliance with the requirements set forth in the Yankee Rowe LTP. The tolerable limits established for this survey plan set the probability of Type I errors (*a*) at 0.05 and the probability of Type II errors (β) at 0.05. Investigation levels for the fixed measurements were set at a greater than three sigma from the mean and >$DCGL_W$ or >$DCGL_{EMC}$. The scan MDCs for the ISOCS measurements were set at the $DCGL_{EMC}$. All MDCs for the surveys of WST-01-02 were met in accordance with YNPS LTP. DCGL values and the associated MDC values can be found in Table 4.

Table 4 DCGLW, DCGLEMC and Investigation Level for ISOCS measurements

	DCGLw	$DCGL_{EMC}$ (ISOCS based on source area = 1m^2)	Investigation Level (ISOCS Based on source area = 1m^2, 2m 90d collimated)
Nuclide	Bldg Surface (dpm/100 cm^2) at 8.73 mrem/y	Bldg Surface (dpm/100 cm^2)	Bldg Surface (dpm/100 cm^2)
Co-60	6.3E+03 (Smooth=379 cpm) (Irregular=232 cpm)	4.6E+04	2.9E+03
Cs-137	2.2E+04	1.7E+05	1.1E+04

The FSSP design was performed to the criteria of the LTP; therefore, no subsequent LTP deviations with potential impact to this survey unit need to be evaluated.

5.1.3 DCGL Selection and Use

It must be noted that for the final evaluation of the WST-01-02 survey unit and throughout this report, the acceptance criteria of Building Surface LTP-listed DCGL values has been applied. However, given that all of the remaining slab and foundation structure will be at least a few feet subsurface before site grading is complete and will be in such a state at license termination, the LTP, section 5.6.3.1.2, "Exterior Surfaces of Building Foundations," establishes the applicable guidance, as it addresses methods that may be applied to determine if subsurface structure surfaces will be acceptable by meeting LTP-required concrete volumetric DCGLs.

With the established LTP guidance, given that Co-60 and Cs-137 have been found to be the only radionuclides of significance in the area of concern, and given the ISOCS ability to readily detect either constituent to acceptable levels and conventional hand-held instrument survey criteria techniques being conservatively based on Co-60 beta emissions, performing a Class 1 survey applying Building Surface DCGLs has led to a very conservative approach in determining the final status of the survey unit. However, in applying this approach, in addition to evaluating subsurface conditions, there is no unanswered concern should the question of future subsurface structure occupancy arise.

5.1.4 Measurements

Error tolerances and characterization sample population statistics drove the selection of fifteen samples. Professional judgment was exercised adding nine additional fixed-point measurements despite the use of ISOCS scanning to achieve a tighter sampling grid building conservatism into the sampling design.

The fixed-point sampling grid was developed as a systematic grid with spacing consisting of a triangular pitch pattern with a random starting point. With the aid of a GPS and AutoCAD-generated survey unit map, the systematic random start grid was developed using Visual Sample Plan software. Sample measurement locations are provided in Attachment D Figures 2 and 3.

A total of 97 ISOCS scans were performed in Survey Unit WST-01-02 providing 100 percent coverage of the survey area. The ISOCS scan grid used a 2.6-m point-to-point grid with no perimeter points farther than 1.3

m from the survey unit boundary. The ISOCS scan grid did not require a random start. ISOCS scans were performed at a height of 2 m from the surface positioned perpendicular to the scan point using a 90-degree collimator. The adjusted investigation levels, referenced in Table 3, for the ISOCS were derived by multiplying the $DCGL_{EMC}$ ($DCGL_W$ * AF for a 1-m^2 elevated area) by the ratio of MDCs obtained from the 12.6-m^2 field of view relative to the MDC obtained for a 1-m^2 area at the edge of the 12.6-m^2 field of view, as this leads to a conservative model. The values developed for the 1-m^2 elevated area at the edge of the field of view used for the ISOCS scan investigative levels are sensitive enough to detect the elevated comparison values for the 12.6-m^2 area. MDC values for the Portable ISOCS scans were set at the $DCGL_{EMC}$ for the individual radionuclides. The technical basis for the use of the ISOCS is documented in Technical Report YA-REPT-00-018-05, "*Use of In-situ Gamma Spectrum Analysis to Perform Elevated Measurement Comparison in Support of Final Status Surveys.*" (Appendix C).

5.2 Survey Implementation Activities

Table 5 provides a summary of daily activities performed during the Final Status Survey of Survey Unit WST-01-02.

Table 5 FSS Activity Summary for Survey Unit WST-01-02

Date	Activity
December 21, 2005	Performed walk-down of Survey Unit WST-01-02, established Isolation and Controls
December 27, 2005	Gridded Survey Units. Commenced ISOCS scans
January 3, 2006	Commenced fixed-point measurements.
January 9, 2006	Performed investigations, and further remediation.
January 19, 2006	ISOCS Scans, fixed point measurements, and investigations complete
January 20, 2006	FSS Complete

5.3 Surveillance Surveys

5.3.1 Periodic Surveillance Surveys

Upon completion of the FSS of Survey Unit WST-01-02, the unit was placed into the program for periodic surveillance surveys on a quarterly basis in accordance with YNPS procedure DP-8860, "*Area Surveillance Following Final Status Survey.*" These surveys provide assurance that

areas with successful FSS remain unchanged until license termination. Survey Unit WST-01-02 is unique in the fact that after the successful FSS, and verification by ORISE, the survey unit was backfilled with clean fill, thus protecting the survey unit.

5.3.2 Resurveys

No resurveys were required for this survey unit due to surveillance surveys.

5.3.3 Investigations

No additional investigations were required for this survey unit due to surveillance surveys.

5.4 Survey Results

A total of 24 fixed-point readings were taken in Survey Unit WST-01-02. Two of the fixed-point measurements used in the statistical analysis of the Survey Unit exceeded the $DCGL_W$ but were less than the $DCGL_{EMC}$, therefore the Sign Test was used to evaluate the survey unit. The survey unit passed the Sign Test. Table 6 includes the fixed-point readings that were gathered for Survey Unit WST-01-02. These measurements were not background adjusted.

Table 6 Survey Unit WST-01-02 Fixed-point Measurements

Location	Surface	Results (cpm)	Results (dpm/100cm2)
WST-01-02-001-F-FM	Smooth	240	3980
WST-01-02-002-F-FM	Smooth	228	3781
WST-01-02-003-F-FM	Rough	199	5335
WST-01-02-004-F-FM	Smooth	217	3599
WST-01-02-005-F-FM	Smooth	182	3018
WST-01-02-006-F-FM	Rough	218	5845
WST-01-02-007-F-FM	Smooth	261	4328
WST-01-02-008-F-FM	Smooth	246	4080
WST-01-02-009-F-FM	Smooth	239	3964
WST-01-02-010-F-FM	Smooth	267	4428
WST-01-02-011-F-FM	Smooth	207	3433
WST-01-02-012-F-FM	Smooth	265	4395
WST-01-02-013-F-FM	Smooth	269	4461
WST-01-02-014-F-FM	Smooth	268	4444
WST-01-02-015-F-FM	Smooth	271	4494
WST-01-02-016-F-FM	Smooth	255	4229
WST-01-02-017-F-FM	Smooth	342	5672
WST-01-02-018-F-FM	Smooth	387	6418
WST-01-02-019-F-FM	Rough	318	8525
WST-01-02-020-F-FM	Smooth	258	4279

Location	Surface	Results (cpm)	Results (dpm/100cm2)
WST-01-02-021-F-FM	Smooth	283	4693
WST-01-02-022-F-FM	Smooth	252	4179
WST-01-02-023-F-FM	Smooth	313	5191
WST-01-02-024-F-FM	Smooth	300	4975

Ninety-seven ISOCS scans were performed and the results compared to the respective Investigation Levels (Table 4) and where multiple nuclides were positively identified a fractional $DCGL_{EMC}$ sum-of-fractions (Unity) was performed. A summary of the ISOCS scans is provided in Table 7.

Table 7 Summary of ISOCS Scan Results for Survey Unit WST-01-02

Unit Number	Number of Scans	Action Levels Exceeded	Sum of Fractions ≥ 1
WST-01-02	96	No	No

5.5 Data Quality Assessment

The Data Quality Assessment phase is the part of the FSS where survey design and data are reviewed for completeness and consistency, ensuring the validity of the results, verifying that the survey plan objectives were met, and validating the classification of the survey unit.

The sample design and the data acquired were reviewed and found to be in accordance with applicable YNPS procedures DP-8861, "*Data Quality Assessment*"; DP-8856, "*Preparation of Survey Plans*"; DP-8853, "*Determination of the Number and Locations of FSS Samples and Measurements*"; DP-8857, "*Statistical Tests*"; DP-8865, "*Computer Determination of the Number of FSS Samples and Measurements*" and DP-8852, "*Final Status Survey Quality Assurance Project Plan*".

WST-01-02

A data review was performed and statistical quantities were calculated. The average concentrations from Table 6 are smaller than the respective characterization data from Table 2 and the standard deviation is higher. However, the retrospective power curve maintained sufficient power to pass the survey unit. The data range for the unit was less than two standard deviations. The frequency plot exhibits a normal Poisson distribution. The scatter plot graphically illustrates that the data varies about the arithmetic mean. The data posting plot does not clearly reveal any systematic spatial trends.

Copies of the power curves, scatter plots and posting plots are found in Attachment B.

The actual level of residual activity was lower than the estimated level (i.e., values derived from characterization data) used for the survey design and the survey demonstrated sufficient power to indicate that the survey unit null hypothesis should be rejected.

6.0 QUALITY ASSURANCE AND QUALITY CONTROL

6.1 Instrument QC Checks

Operation of the portable ISOCS was in accordance with DP-8871,"*Operation of the Canberra Portable ISOCS System,*" with QC checks performed in accordance with DP-8869,"*In-situ (ISOCS) Gamma Spectrum Assay System Calibration Procedure*" and DP-8871, "*Operation of the Canberra Portable ISOCS System.*" Operation of the E-600 w/SPA-3 was in accordance with DP-8535,"*Setup and Operation of the Eberline E-600 Digital Survey Instrument,*" with QC checks preformed in accordance with DP-8540, "*Operation and Source Checks of Portable Friskers.*" Instrument response checks were performed prior to and after use for the E-600 w/SPA-3 and once per shift for the Portable ISOCS. Any flags (i.e. anomalies in the QC results) encountered during the ISOCS QC Source Count were corrected/ resolved prior to surveying. All instrumentation involved with the FSS of WST-01 satisfied the above criteria for the survey. QC records are found in Attachment C.

6.2 Split Samples and Recounts

DP-8864,"*Split Sample Assessment for Final Status Survey*" deals strictly with samples and provides no criteria for fixed-point measurements therefore no measurement comparison were made.

6.3 Self-Assessments

No self-assessments were performed during the FSS of WST-01.

7.0 CONCLUSION

The FSS of WST-01 has been performed in accordance with YNPS LTP and applicable FSS procedures. Evaluation of the fixed-point data has shown two of the fixed-point measurements exceeded the $DCGL_W$ but were less than the $DCGL_{EMC}$, therefore the Sign Test was used to evaluate the survey unit. The survey unit passed the Sign Test, depicted in Attachment B. Retrospective power curves were generated and demonstrated that adequate power was achieved. Therefore, the null hypothesis (H_o) is rejected.

WST-01 meets the objectives of the Final Status Survey.

Based upon the evaluation of the data acquired for the FSS, WST-01 meets the release requirements set forth in the YNPS LTP. The Total Effective Dose Equivalent (TEDE) to the average member of the critical group does not exceed 25 mrem/yr, including that from groundwater. 10CFR20 Subpart E ALARA requirements have been met as well as the site release criteria for the administrative level DCGLs that ensure that the Massachusetts Department of Public Health's 10 mrem/yr limit will also be met.

List of Appendices

Appendix A – YNPS-FSSP-WST-01, *"Final Status Survey Planning Worksheet, Survey Area WST-01, Unit 2*

Appendix B – YA-REPT-00-015-04, *"Instrument Efficiency Determination for Use in Minimum Detectable Concentration Calculations in Support of the Final Status Survey at Yankee Rowe"*

Appendix C –YA-REPT-00-018-05, "Use of In-situ Gamma Spectrum Analysis to Perform Elevated Measurement Comparison in Support of Final Status Surveys"

Appendix D – ALARA Evaluation WST-01 Unit 2

List of Attachments

Attachment A – ISOCS Results

Attachment B – Data Quality Assessment Plots and Curves

Attachment C – Instrument QC Records

Attachment D – Maps

(In the electronic version, every Table of Contents, Figures, Appendices and Attachments, as well as every mention of a Figure, Appendix or Attachment is a hyperlink to the actual location or document.)

The following files have been provided on the enclosed CD:

Attachment A – ISOCS Results

Attachment B – Data Quality Assessment Plots and Curves

Attachment C – Instrument QC Records

Attachment D - Maps

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FIGURE 3 ISOCS SCAN LOCATIONS....4

Figure 1 Map of Survey Unit Relative to Structures

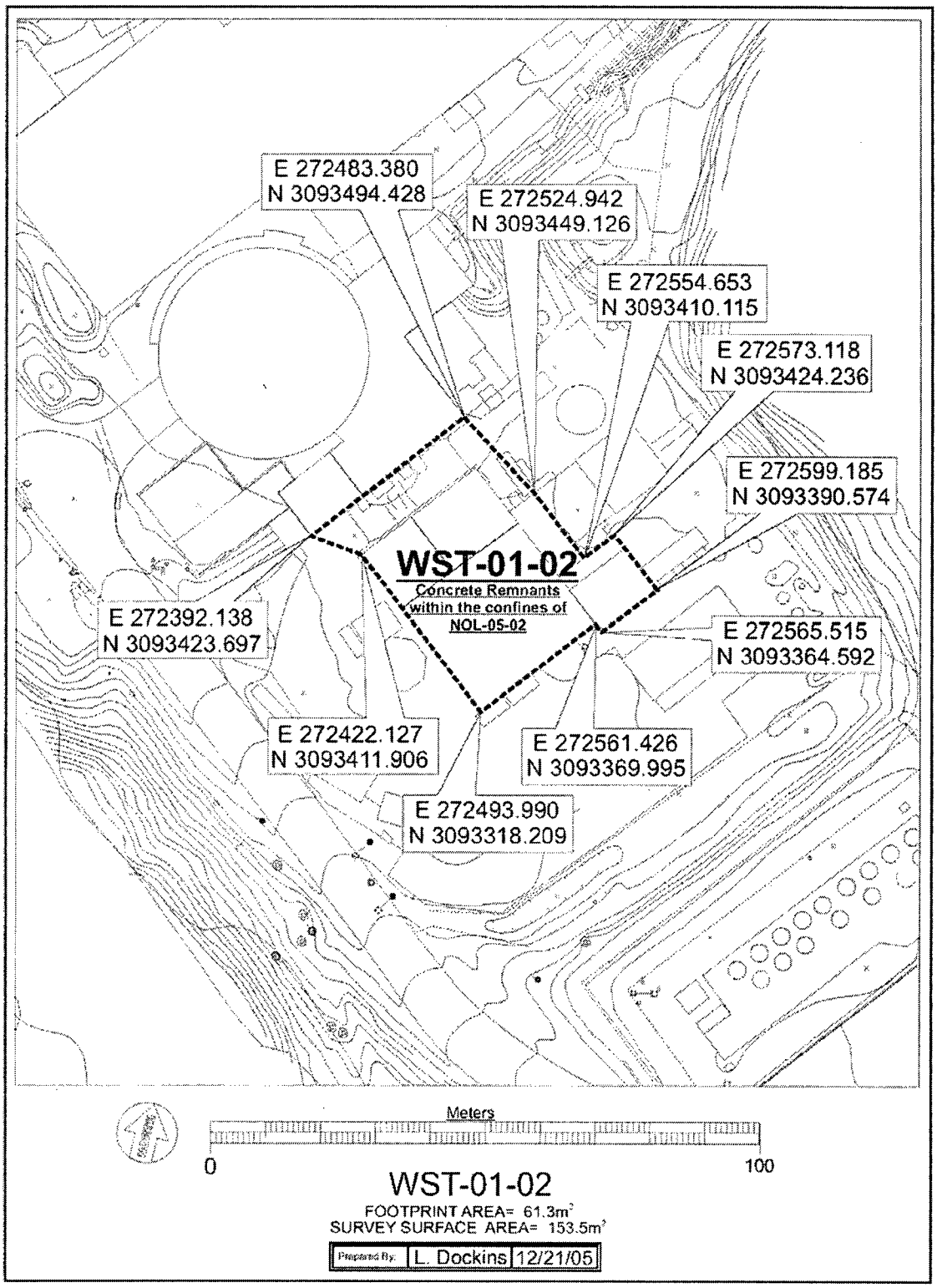


Figure 2 Direct Measurement Locations

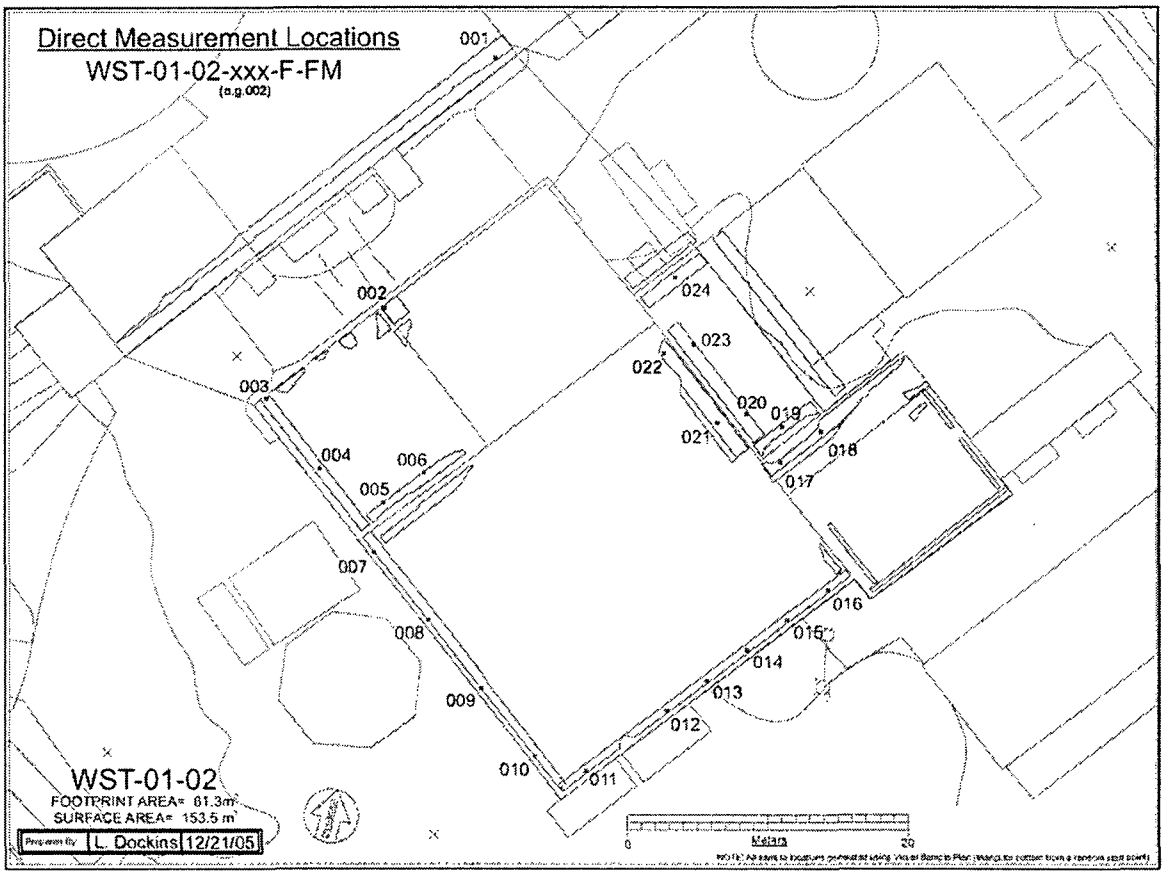
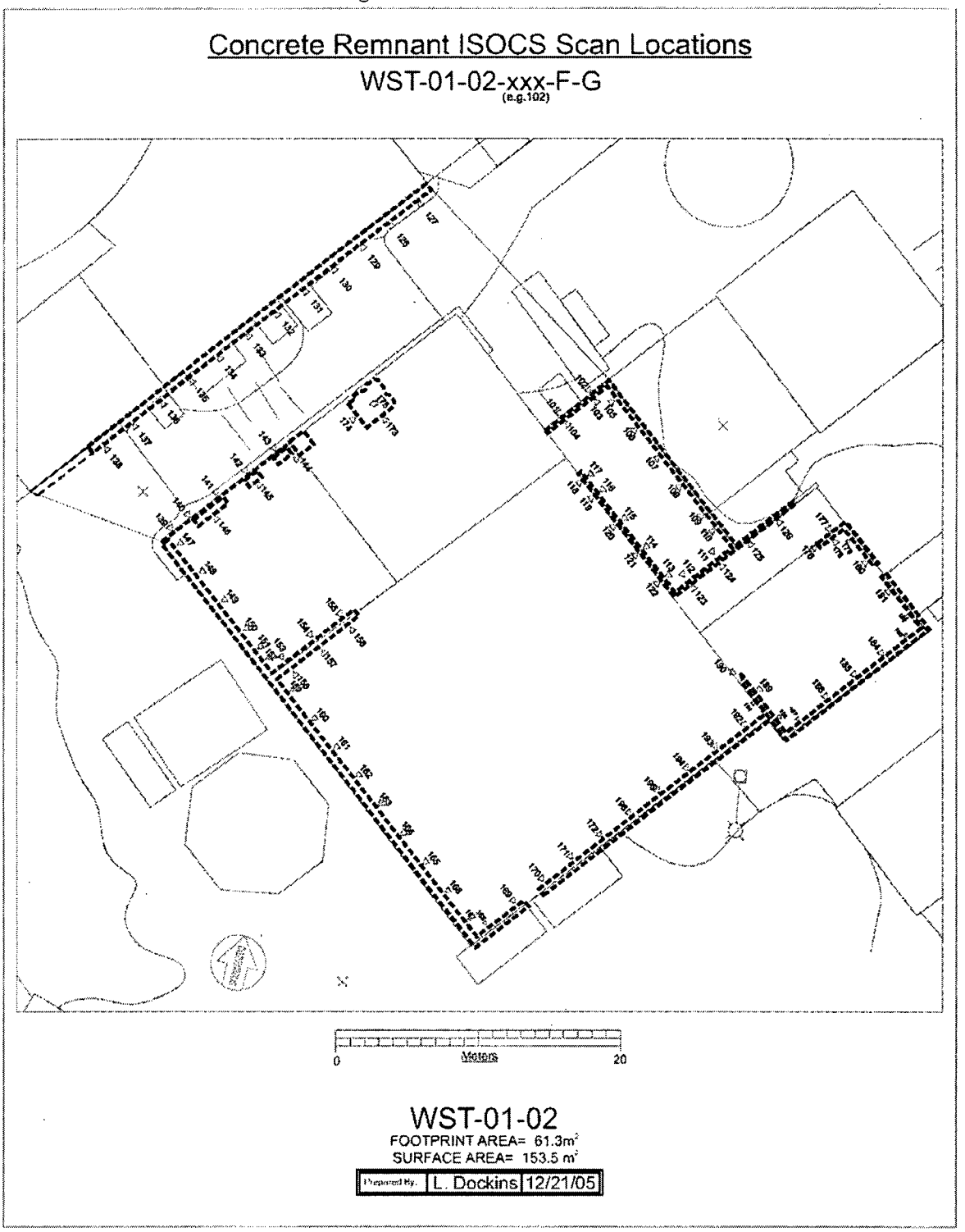


Figure 3 ISOCS Scan Locations



Final Status Survey Planning Worksheet

GENERAL SECTION

Survey Area #: WST-01	Survey Unit #: 02
Survey Unit Name: Old PCA-1 slab foundation and remaining partial concrete structures	
FSSP Number: YNPS-FSSP-WST01-02-00	

PREPARATION FOR FSS ACTIVITIES

Check marks in the boxes below signify affirmative responses and completion of the action.

1.1 Files have been established for survey unit FSS records. ☑

1.2 ALARA review has been completed for the survey unit. ☑

1.3 The survey unit has been turned over for final status survey. ☑

1.4 An initial DP-8854 walkdown has been performed and a copy of the completed Survey Unit Walkdown Evaluation is in the survey area file. ☑

1.5 Activities conducted within area since turnover for FSS have been reviewed. ☑

Based on reviewed information, subsequent walkdown: ☑ not warranted ☐ warranted

If warranted, subsequent walkdown has been performed and documented per DP-8854. ☐

OR

The basis has been provided to and accepted by the FSS Project Manager for not performing a subsequent walkdown. ☐

1.6 A final classification has been performed. ☑

Classification: CLASS 1 ☑ CLASS 2 ☐ CLASS 3 ☐

DATA QUALITY OBJECTIVES (DQO)

1.0 Statement of problem:

Survey Unit WST-01-02 consists of the reinforced concrete foundation of the Old PCA Storage Building as well as the remaining concrete partial walls exposed during the excavation of Survey Unit NOL-05-02. WST-01-02 encompasses a 61.3 m^2 footprint having a total surface area of 153.5 m^2. WST-01 was used, during plant operation, as a decontamination facility and as a storage area for heavily contaminated items. WST-01-02 is located within the RCA and has been classified as a MARSSIM Class 1 area.

The data collected under this plan will be used to determine whether or not residual plant-related radioactivity on the exposed concrete surfaces of Survey Unit WST01-02 meet LTP release criteria.

The planning team for this effort consists of the FSS Project Manager, FSS Radiological Engineer, FSS Field Supervisor, and FSS Technicians. The FSS Radiological Engineer will make primary decisions with the concurrence of the FSS Project Manager.

2.0 Identify the decision:

Does residual plant-related radioactivity, if present in the survey unit, exceed LTP release criteria? Alternative actions that may be implemented in this effort are investigations and remediation followed by re-surveying.

3.0 Identify the inputs to the decision:

Sample media: Concrete surfaces.

Types of measurements: Systematic measurements, scans and concrete sampling (if required for investigations).

Radionuclides-of-concern: All nuclides listed in Table 1 of this FSSP will be included in analysis with

the primary emphasis on Co-60. The following discussion of the data from the characterization turnover survey supports this assumption for this survey unit.

Characterization of Survey Unit WST-01-02 is based upon the characterization of Survey Unit NOL-05-02 performed from November 17, 2005 to November 18, 2005 and the Operational RP survey of WST-01 performed on 2 May 2005. The characterization of NOL-05-02 was designed to verify that remediation of the soil after removal of the tub and drain lines reduced the residual plant-related radioactivity to acceptable levels. The results from that characterization were used as turnover data demonstrating acceptability for FSS and are used to identify the radionuclides-of-concern for the FSS of WST-01-02. The characterization survey for the soil was used in this plan since the soil would have been the source of, or in direct communication with any wall contamination. The numbers of fixed-point measurements were derived from the statistical values calculated from the Operational RP turnover survey performed 2 May 2005. Characterization data has indicated a mixed isotopic concentration of approximately 80 percent Co-60 and 20 percent Cs-137. The DCGLs in this Survey Plan, however, were developed using Co-60 as the single isotope providing a conservative approach because of the more restrictive DCGL value.

Average radiation level: 993 dpm/100cm^2 (from the Operational RP turnover survey)

Standard deviation (σ): 571 dpm/100cm^2 (from the Operational RP turnover survey)

DCGLs:

(1) Applicable $DCGL_w$: 6.3E3 dpm/100cm^2 (Co-60 assumed as a conservative measure)

Note: the $DCGL_w$ value corresponds to 8.73 mrem/y.

Certain portions of the concrete structures in WST-01-02 contain pits and irregular surfaces, which will increase the source-to-detector distance for some localized areas under the 100cm^2 window of the detector. Most of the pits and irregularities increase the source-to-detector distance by approximately ¼ - ½ inch, although some increase it as much as 1 - 2 inches. These types of irregularities in the concrete surfaces will be taken into account through the efficiency factor applied to the measurements collected with the HP-100. Technical report YA-REPT-00-015-04 provides instrument efficiency factors (ε_i) for various source-to-detector distances. The ε_i value for a source-to-detector distance of 1 inch was selected as a representative efficiency for data collected with the HP-100 from the irregular surfaces because it accounts for the ½ inch stand-off and the most common depth of pits and surface irregularities (¼ - ½ inch). In contrast to the irregular surfaces, the vertical walls of the structures are relatively smooth. The ε_i value for a distance of ½ inch will be applied to HP-100 data collected from smooth concrete surfaces, such as the vertical walls. The efficiency factors provided in YA-REPT-00-015-04 are used below:

- ε_i = 0.2413 c/e for smooth concrete surfaces (reflects a source to detector distance = ½ inch), and
  = 0.149 c/e for pitted/irregular surfaces (reflects a source to detector distance = 1 inch)
- ε_s = 0.25 e/d (consistent with the Co-60 assumption)
- total efficiency for smooth surface = $\varepsilon_i \cdot \varepsilon_s$ = 0.2413 c/e · 0.25 e/d = 0.0603 c/d
- total efficiency for pitted/irregular surfaces = $\varepsilon_i \cdot \varepsilon_s$ = 0.149 c/e · 0.25 e/d = 0.0373 c/d

(2) Gross measurement $DCGL_w$ (for HP-100): 6.3E3 dpm/100cm^2

- for smooth concrete surface: 6.3E3 dpm/100cm^2 * 0.0603 c/d = 3.8E2 cpm/100cm^2
- for pitted/irregular surface: 6.3E3 dpm/100cm2 * 0.0373 c/d = 2.3E2 cpm/100cm^2

(3) Applicable $DCGL_{EMC}$ for fixed-point measurements: $DCGL_w$ * AF = 6.3E3 dpm/100cm^2 *1.6 = 1.0E4 dpm/100cm^2

- for smooth concrete surface: 1.0E4 dpm/100cm^2 * 0.0603 c/d = 6.1E2 cpm/100cm^2
- for pitted/irregular surface: 1.0E4 dpm/100cm2 * 0.0373 c/d = 3.7E2 cpm/100cm^2.

Note: the DCGL and $DCGL_{EMC}$ value refer to above-background radioactivity.

Investigation Level for fixed-point measurement:

- for smooth (i.e., vertical side) concrete surface: >6.1E2 cpm/100cm^2 above background
- for pitted/irregular (i.e., top) concrete surface: >3.7E2 cpm/100cm^2 above background

Investigation Level for HP-100 scan: Reproducible indication above background using an audible signal. Refer to Attachment 3 for HP-100 MDCR and MDC*f*($DCGL_{EMC}$) values.

Investigation Level for SPA-3 scan: Reproducible indication above background using an audible signal. A shielded SPA-3 probe should be used for these scans due to the close proximity to the ISFSI.

Note: If ISOCS scans are utilized then SPA-3 gamma scans are not applicable. If beta scans are used then the MDCR and *f*($DCGL_{EMC}$) developed for the SPA-3 scans will be implemented for those Spa-3 scans. (Refer to Attachment 2).

Investigation Level for ISOCS assays: 1m90d assays: 1.7E4 dpm/100cm^2 (Co-60)
2m90d assays: 2.91E3 dpm/100cm^2 (Co-60)

Note: The investigation levels for the ISOCS assays were derived by multiplying the $DCGL_{EMC}$ associated with a 1m^2 area by the ratio of the MDC for the full field of view (12.6m^2 for 2m90d assays and 3.14m^2 for 1m90d assays) to the MDC for a 1m^2 area at the edge of the full field of view. The investigation levels developed in this manner are sensitive enough to detect the Co-60 $DCGL_{EMC}$ value based on the grid area (1.0E4 dpm/100cm^2). If other LTP-listed gamma-emitting radionuclides are identified in the ISOCS assays, the investigation level will be evaluated using the same criteria applied in the development of the investigation level for Co-60.

MDCs for ISOCS measurements:

Table 1
MDC values for LTP ISOCS Measurements

Nuclide	MDC (dpm/100cm^2)	Nuclide	MDC (dpm/100cm^2)	Nuclide	MDC (dpm/100cm^2)
Co-60	1.0E3	Sb-125	5.6E3	Eu-152	2.1E3
Nb-94	1.5E3	Cs-134	1.6E3	Eu-154	1.9E3
Ag-108m	1.4E3	Cs-137	3.5E3	Eu-155	3.6E4

Note: The MDCs listed in the above table are 10% of the $DCGL_{EMC}$ values (based on concrete surface DCGLs & nuclide-specific AF value for 8m^2 from LTP, Appendix 6S). If the MDC values in the above table cannot be achieved in a reasonable count time, then an MDC no greater than 5X the table value must be achieved.

Scan coverage: ISOCS and/or HP-100/Spa-3 scan measurements providing 100% coverage of all WST-01-02 surfaces.

MDCR for HP-100: The accompanying table provides MDCR values by various background levels. The expected ambient background for the HP-100 range is 200 - 400 cpm.

Note: If the ambient background for the HP-100 exceeds 1000 cpm, notify the FSS Radiological Engineer before proceeding with the survey.

MDCf($DCGL_{EMC}$) for HP-100 scans: The accompanying table provides MDC*f*($DCGL_{EMC}$) values for various background levels.

QC checks and measurements: QC checks for the survey instruments will be performed in accordance with DP-8534. Pre- and post-use instrument QC checks will be performed. QC checks for the ISOCS will be in accordance with DP-8869 and DP-8871.

4.0 Define the boundaries of the survey:

WST-01-02 is located within the RCA yard area. WST-01-02 is bounded by NOL-03 on the north and east, NOL-04 on the south, and by NOL-05-02 on the west. In addition to the before mentioned areas, the underside area of the concrete pad, exposed during the demolition, will be 100% scanned as part of this survey plan. No fixed-measurements will be required on the underside of the concrete pad. The same investigative values applied to WST-01-02 will be applied to this area.

5.0 Develop a decision rule:

(a) If all the FSS data show that residual levels of plant-related radioactivity are below the $DCGL_w$, reject the null hypothesis (i.e., Survey Unit meets the release criteria).
(b) If the investigation level is exceeded, then perform an investigation.
(c) If the average of the FSS measurements is below the $DCGL_w$, but some individual measurements exceed the $DCGL_w$, then apply a statistical test as the basis for accepting or rejecting the null hypothesis.
(d) If the average of the FSS measurements exceeds the $DCGL_w$, then accept the null hypothesis (i.e., Survey Unit fails to meet the release criteria).

6.0 Specify tolerable limits on decision errors:

Null hypothesis: The null hypothesis (H_o), as required by MARSSIM, is stated and tested in the negative form: "Residual licensed radioactive materials in Survey Unit WST-01-02 exceeds the release criterion".

Probability of type I error: 0.05

Probability of type II error: 0.05

LBGR: 5.2E3 dpm/100 cm^2 (Adjusted LBGR from DP-8853.1)

7.0 Optimize Design:

Type of statistical test: WRS Test ☐ Sign Test ☑

Basis including background reference location (if WRS test is specified): N/A

Number samples (per DP-8853): 24. Refer to the completed DPF-8853.1 in the survey package file.

Biased Measurements: None

GENERAL INSTRUCTIONS

1. Survey instrument: Operation of the E-600 w/SPA-3 will be in accordance with DP-8535, with QC checks preformed in accordance with DP-8540. Operation and source checking of the E-600 w/HP-100 will be in accordance with DP-8534. The instrument response checks shall be performed before issue and after use

2. Collect ISOCS measurements in accordance with DP-8871.

3. The job hazards associated with the FSS in Survey Unit 02 are addressed in the accompanying JHA for WST-01-02.

4. All personnel participating in this survey shall be trained in accordance with DP-8868.

SPECIFIC INSTRUCTIONS

1. Grid WST-01-02 for 100% ISOCS scan coverage by placing parallel rows of markers forming a square pattern at a maximum distance of 2.6 meters apart and a maximum of 1.3 meters from the edge of each surface area (add additional scan points closer than 2.6 meters apart as necessary to achieve 100%

scan coverage). Sequentially number each scan location starting with number 101. Indicate the approximate ISOCS scan location and the sequence number (WST-01-02-xxx [sequential number starting at 101]-F-G) on the maps. Using the 90° collimator, position the ISOCS detector directly at each marker 2 meters from the surface to be scanned. Angle the detector as necessary perpendicular to the scan surface and perform an analysis in accordance with DP-8871 employing a preset count time sufficient to meet the MDAs referenced in this survey plan. Review the report to verify that the MDAs have been met for the nuclides. Identify radionuclides representing licensed radioactive material and compare their concentration to their respective $DCGL_{EMC}$ value.

Note: If multiple radionuclides are identified in any single ISOCS assay, then, in addition to comparing each individual nuclide to it's action (investigation) level; the assay will be compared to unity (SOF<1).

2. If any ISOCS scan measurement is equal to or greater than the action (investigation) level, or the SOF ≥1, then an investigation of that scan area footprint shall be performed as follows:

(a) Using the SPA-3 at a slow speed scan rate (approximately 5" per second), scan the entire ISOCS footprint. Scanning will be performed in the rate-meter mode with the audible feature "on".

Note: If the background level exceeds 19000 cpm, contact the FSS Engineer prior to continuing.

(b) Mark (outline on the surface) locations where detectable-above-background readings are found. Identify each outlined areas on a survey map.

(c) Measure the total area (square centimeters) of each outlined elevated area. Indicate on the map (and with black marker on the actual location) the location of the highest indicated activity spot. Record the highest SPA-3 reading observed for each outlined area.

(d) On the spot indicating the highest SPA-3 reading observed for each outlined area, perform and record a 1-minute scaler reading using the E600/SHP100.

Note: Should further investigative measures be required (i.e. concrete core sampling) a specific investigative sample plan will be developed.

Detailed descriptions of investigative actions will be recorded on form DPF-8856.2 and the location of the investigation analyses will be recorded on the survey map. The location description must provide ample detail to allow revisiting the spot at a later time.

3. If performing beta scans execute the following:

(a) Perform the HP-100 scans by moving the detector at a speed no greater than 2 inches per second, using a ½ inch standoff.

(b) FSS Technicians will wear headphones while scanning and the survey instrument will be in the rate-meter mode. Surveyors will listen for upscale readings and respond to readings that exceed the investigation level.

Note: Contact FSS Engineer if HP-100 background levels exceed 1000 cpm prior to or during scans.

(c) If the HP-100 scan investigation level is exceeded:

(1) Confirm that the above background indication is reproducible and cannot be attributed to a nearby source.

(2) If a nearby source is identified, have it removed or shielded, document the finding on DP-8856.2, and repeat the scan,

(3) If reproducible and not caused by a nearby source, collect a fixed-point measurement at the location of the highest reading observed during the scan,

(4) The designation for a fixed-point measurement collected during a first-level investigation will continue in sequence beginning with WST-01-02-025-F-FM-I. Record all investigation fixed-point measurements "as read" (in units of cpm) on the attached Form 1 (even if the measurement was

logged).

(5) Clearly mark the location of any fixed-point measurement collected during this level of investigation. The FSS Radiological Engineer is responsible for assessing the need for further investigation. If further investigation is required, it will be conducted under a separate survey plan.

Note: The FSS Field Supervisor will record information relevant to the HP-100 scans on DPF-8856.2 accompanied by a survey map of the area scanned.

4. If beta scans are performed then gamma scans will be performed on irregular surfaces and cracks in the concrete as follows:

(a) Perform SPA-3 scans on the irregular surfaces and over cracks by moving the detector slowly (no greater than 0.13m/s) and keeping it < 3 inches from the surface.

Note: If background levels exceed 19000 cpm contact the Radiological Engineer prior to starting the scan or continuing scans.

Note: When performing Spa-3 scans, (investigations not included) no less than 50% of the time will be monitored and timed by the FSS Field Supervisor.

(b) FSS Technicians will wear headphones while scanning with the survey instrument in the rate-meter mode. Surveyors will listen for upscale readings and respond to readings that exceed the SPA-3 investigation level.

(c) If a SPA-3 reading exceeds the investigation level:

(1) Confirm that the above-background indication is reproducible and cannot be attributed to a nearby source,

(2) If a nearby source is identified, have it removed or shielded, document the finding on DP-8856.2, and repeat the scan,

(3) If the reading is reproducible and not caused by a nearby source, collect a fixed-point measurement with the HP-100 at the highest reading observed during the scan and clearly mark that location. Designate the investigation fixed-point measurement as describe in step 3(c)(4) above. Record all investigation fixed-point measurements "as read" (in units of cpm) on the attached Form 1 (even if the measurement was logged). The FSS Radiological Engineer is responsible for assessing the need for further investigation. If further investigation is required, it will be conducted under a separate survey plan.

5. For the statistical fixed-point measurements perform the following:

(a.) Locate and mark the measurement points at the locations shown in the attached map using small, but readily visible marks. Use the distances (from edge of survey unit footprint) shown on Map 2 to locate the fixed-point measurements on the vertical walls.

Note: If a measurement location is obstructed such that a measurement cannot be collected, select the nearest suitable location within one meter in accordance with DP-8856.

(b.) Collect and record the ~~20~~ 24 measurements with the E-600/SHP-100 in accordance with DP-8534 and DP-8535 using the scalar mode (1 minute). Record each fixed-point measurement "as read" (in units of cpm) on the Form 1 indicating whether the concrete surface was smooth (S) or irregular (I). 1/4/06

(c.) Designation for fixed-point measurements: WST-01-02-001-F-FM through WST-01-02-024-F-FM corresponding to FSS measurement locations 001 through 024. 1/4/06

6. Perform a background survey as follows:

(a) Cover the detector with 1/8-inch Lucite shield, or equivalent, and collect a series of one-minute background readings according to the following plan:

(1) At each corner location of WST-01-02 as indicated on the attached map, determine a location that is 1 meter from any wall present and 1 meter above the floor as nearly as possible. Take 4 readings: one each facing plant north, south, east and west and one reading facing the floor.

(2) At the approximate center of the room, as indicated on the attached map, take a set of readings as follows: one each facing plant north, south, east and west and one facing the floor

(3) Record each background measurement "as read" (in units of cpm) on the background survey map attached to this survey plan.

NOTIFICATION POINTS

FSI point(s) (y/n) n_ Specify: _____

Prepared by _____ Date 12/22/05
FSS Radiological Engineer

Reviewed by _____ Date 12/22/05
FSS Radiological Engineer

Approved by _____ Date 12/22/05
FSS Project Manager

Appendix B
YA-REPT-00-015-04
Instrument Efficiency Determination for Use in Minimum Detectable Concentrations Calculations in Support of the Final Status Survey at Yankee Rowe

TECHNICAL REPORT TITLE PAGE

COPY

Instrument Efficiency Determination for Use in Minimum Detectable Concentration Calculations in Support of the Final Status Survey at Yankee Rowe

Title

YA-REPT-00-015-04
REV. 0

Technical Report Number

Approvals	(Print & Sign Name)	
Preparer:		Date: 10-7-04
Reviewer:	James R. Hummer	Date: 10/7/04
Approver (Cognizant Manager):		Date: 10/7/04

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1.0 Executive Summary:

The minimum detectable concentration (MDC) of the field survey instrumentation is an important factor affecting the quality of the final status survey (FSS). The efficiency of an instrument inversely impacts the MDC value. The objective of this report is to determine the instrument and source efficiency values used to calculate MDC. Several factors were considered when determining these efficiencies and are discussed in the body of this report. Instrument efficiencies (ε_i), and source efficiencies (ε_s), for alpha beta detection equipment under various field conditions, and instrument conversion factors (E_s), for gamma scanning detectors were determined and the results are provided herein.

2.0 Introduction:

Before performing Final Status Surveys of building surfaces and land areas, the minimum detectable concentration (MDC) must be calculated to establish the instrument sensitivity. Table 5.4 of the License Termination Plan (LTP) [8.6] lists the available instrumentation and nominal detection sensitivities; however for the purposes of this basis document, efficiencies for the 100cm^2 gas proportional and the 2"x2" NaI (Tl) detectors will be determined. Efficiencies for the other instrumentation listed in the LTP shall be determined on an as needed basis. The 100 cm^2 gas proportional probe will be used to perform surveys (i.e. fixed point measurements). A 2" x2" NaI (Tl) detector will be used to perform gamma surveys (i.e., surface scans) of portions of land areas and possibly supplemental structural scans at the Yankee Rowe site. Although surface scans and fixed point measurements can be performed using the same instrumentation, the calculated MDCs will be quite different. MDC is dependent on many factors and may include but is not limited to:

- instrument efficiency
- background
- integration time
- surface type
- source to detector geometry
- source efficiency

A significant factor in determining an instrument MDC is the total efficiency, which is dependent on the instrument efficiency, the source efficiency and the type and energy of the radiation. MDC values are inversely affected by efficiency, as efficiencies increase, MDC values will decrease. Accounting for both the instrument and source components of the total efficiency provides for a more accurate assessment of surface activity.

3.0 Calibration Sources:

For accurate measurement of surface activity it is desirable that the field instrumentation be calibrated with source standards similar to the type and energy of the anticipated contamination. The nuclides listed in Table 3.1 illustrate the nuclides found in soil and building surface area DCGL results that are listed in the LTP.

Instrument response varies with incident radiations and energies; therefore, instrumentation selection for field surveys must be modeled on the expected surface activity. For the purposes of this report, isotopes with max beta energies less than that of C-14 (0.158 MeV) will be considered difficult to detect (reference table 3.1). The detectability of radionuclides with max beta energies less than 0.158 MeV, utilizing gas proportional detectors, will be negligible at typical source to detector distances of approximately 0.5

inches. The source to detector distance of 1.27 cm (0.5 inches) is the distance to the detector with the attached standoff (DP-8534 "Operation and Source Checks of Proportional Friskers")[8.5]. Table 3.1 provides a summary of the LTP radionuclides and their detectability using Radiological Health Handbook [8.4] data.

Table 3.1

Nuclides and Major Radiations: Approximate Energies (Reference 8.4)

Nuclide	α Energy (MeV)	$E_{\beta max}$ (MeV)	Average E_β (MeV)	Photon Energy (MeV)	α Detectable w/ Gas Proportional	β Detectable w/ Gas Proportional	γ Detectable w/ NaI 2x2"
H-3		0.018	0.005				
C-14		0.158	0.049				
Fe-55				0.23 (0.004%) bremsstrahlung			
Co-60		0.314	0.094	1.173 (100%), 1.332 (100%)		√	√
Ni-63		0.066	0.017				
Sr-90		0.544 2.245 (Y-90)	0.200 0.931			√	
Nb-94		0.50	0.156	0.702 (100%), 0.871 (100%)		√	√
Tc-99		0.295	0.085			√	
Ag-108m		1.65 (Ag-108)	0.624 (Ag-108)	0.434 (0.45%), 0.511 (0.56%) 0.615 (0.18%), 0.632 (1.7%)			√
Sb-125		0.612	0.084	0.6, 0.25, 0.41, 0.46, 0.68, 0.77, 0.92, 1.10, 1.34		√	√
Cs-134		1.453	0.152	0.57 (23%), 0.605 (98%) 0.796 (99%), 1.038 (1.0%) 1.168 (1.9%), 1.365 (3.4%)		√	√
Cs-137		1.167	0.195	0.662 (85%) Ba-137m X-rays		√	√
Eu-152		1.840	0.288	0.122 (37%), 0.245 (8%) 0.344 (27%), 0.779 (14%) 0.965 (15%), 1.087 (12%) 1.113 (14%), 1.408 (22%)		√	√
Eu-154		1.850 (10%)	0.228				
Eu-155		0.247	0.044	0.087 (32%), 0.105 (20%)		√	
Pu-238	5.50 (72%) 5.46 (28%)			0.099 (8E-3%) 0.150 (1E-3%) 0.77 (5E-5%)	√		
Pu-239	5.16 (88%) 5.11 (11%)			0.039 (0.007%), 0.052 (0.20%), 0.129 (0.005%)...	√		
Pu-241	4.90 (0.0019%) 4.85 (0.0003%)	0.021	0.005	0.145 (1.6E-4%)			
Am-241	5.49 (85%) 5.44 (13%)			0.060 (36%), 0.101 (0.04%)...	√		
Cm-243	6.06 (6%) 5.99 (6%) 5.79 (73%) 5.74 (11.5%)			0.209 (4%), 0.228 (12%), 0.278 (14%)	√		

NUREG-1507 and ISO 7503-1 provide guidance for selecting calibration sources and their use in determining total efficiency. It is common practice to calibrate instrument efficiency for a single beta energy; however the energy of this reference source should not be significantly greater than the beta energy of the lowest energy to be measured.

Tc-99 (0.295 MeV max) and Th-230 (4.68 MeV at 76% and 4.62 MeV at 24%) have been selected as the beta and alpha calibration standards respectively, because their energies conservatively approximate the beta and alpha energies of the plant specific radionuclides.

4.0 Efficiency Determination:

Typically, using the instrument 4π efficiency exclusively provides a good approximation of surface activity. Using these means for calculating the efficiency often results in an under estimate of activity levels in the field. Applying both the instrument 2π efficiency and the surface efficiency components to determine the total efficiency allows for a more accurate measurement due to consideration of the actual characteristics of the source surfaces. ISO 7503-1 [8.2] recommends that the total surface activity be calculated using:

$$A_s = \frac{R_{S+B} - R_B}{(\varepsilon_i)(W)(\varepsilon_s)},$$

where:
A_s is the total surface activity in dpm/cm^2,
R_{S+B} is the gross count rate of the measurement in cpm,
R_B is the background count rate in cpm,
ε_i is the instrument or detector 2π efficiency
ε_s is the efficiency of the source
W is the area of the detector window (cm^2)

4.1 Alpha and Beta Instrument Efficiency (ε_i):

Instrument efficiency (ε_i) reflects instrument characteristics and counting geometry, such as source construction, activity distribution, source area, particles incident on the detector per unit time and therefore source to detector geometry. Theoretically the maximum value of ε_i is 1.0, assuming all the emissions from the source are 2π and that all emissions from the source are detected. The ISO 7503-1 methodology for determining the instrument efficiency is similar to the historical 4π approach; however the detector response, in cpm, is divided by the 2π surface emission rate of the calibration source. The instrument efficiency is calculated by dividing the net count rate by the 2π surface emission rate ($q_{2\pi}$) (includes absorption in detector window, source detector geometry). The instrument efficiency is expressed in ISO 7503-1 by:

$$\varepsilon_i = \frac{R_{S+B} - R_B}{q_{2\pi}}$$

where:
R_{S+B} is the gross count rate of the measurement in cpm,
R_B is the background count rate in cpm,
$q_{2\pi}$ is the 2π surface emission rate in reciprocal seconds

Note that both the 2π surface emission rate and the source activity are usually stated on the certification sheet provided by the calibration source manufacturer and certified as National Institute of Standards and Technology (NIST) traceable. Table 4.1 depicts instrument efficiencies that have been determined during calibration using the 2π surface emission rate of the source.

Table 4.1
Instrument Efficiencies (ε_i)

Source	Emission	Active Area of Source (cm^2)	Effective Area of Detector	100 cm^2 Gas Proportional HP-100 Instrument Efficiency (ε_i) (Contact)
Tc-99	β	*15.2*	100 cm^2	0.4148
Th-230	α	*15.2*	100 cm^2	0.5545

4.2 Source to Detector Distance Considerations:
A major factor affecting instrument efficiency is source to detector distance. Consideration must be given to this distance when selecting accurate instrument efficiency. The distance from the source to the detector shall to be as close as practicable to geometric conditions that exist in the field. A range of source to detector distances has been chosen, taking into account site specific survey conditions. In an effort to minimize the error associated with geometry, instrument efficiencies have been determined for source to detector distances representative of those survey distances expected in the field. The results shown in Table 4.2 illustrate the imposing reduction in detector response with increased distance from the source. Typically this source to detector distance will be 0.5 inches for fixed point measurements and 0.5 inches for scan surveys on flat surfaces, however they may differ for other surfaces. Table 4.2 makes provisions for the selection of source to detector distances for field survey conditions of up to 2 inches. If surface conditions dictate the placement of the detector at distances greater than 2 inches instrument efficiencies will be determined on an as needed basis.

4.2.1 Methodology:
The practical application of choosing the proper instrument efficiency may be determined by averaging the surface variation (peaks and valleys narrower than the length of the detector) and adding 0.5 inches, the spacing that should be maintained between the detector and the highest peaks of the surface. Select the source to detector distance from Table 4.2 that best reflects this pre-determined geometry.

Table 4.2
Source to Detector Distance Effects on Instrument Efficiencies for α- β Emitters

Source to Detector Distance (cm)	Instrument Efficiency (ε_i)	
	Tc-99 Distributed	Th-230 Distributed
Contact	0.4148	0.5545
1.27 (0.5 in)	0.2413	0.1764
2.54 (1 in)	0.1490	0.0265
5.08 (2 in)	0.0784	0.0002

4.3 Source (or Surface) Efficiency (ε_s) Determination:

Source efficiency (ε_s), reflects the physical characteristics of the surface and any surface coatings. The source efficiency is the ratio between the number of particles emerging from surface and the total number of particles released within the source. The source efficiency accounts for attenuation and backscatter. ε_s is nominally 0.5 (no self-absorption/attenuation, no backscatter)–backscatter increases the value, self-absorption decreases the value. Source efficiencies may either be derived experimentally or simply selected from the guidance contained in ISO 7503-1. ISO 7503-1 takes a conservative approach by recommending the use of factors to correct for alpha and beta self-absorption/attenuation when determining surface activity. However, this approach may prove to be too conservative for radionuclides with max beta energies that are marginally lower than 0.400 MeV, such as Co-60 with a βmax of 0.314 MeV. In this situation, it may be more appropriate to determine the source efficiency by considering the energies of other beta emitting radionuclides. Using this approach it is possible to determine weighted average source efficiency. For example, a source efficiency of 0.375 may be calculated based on a 50/50 mix of Co-60 and Cs-137. The source efficiencies for Co-60 and Cs-137 are 0.25 and 0.5 respectively, since the radionuclide fraction for Co-60 and Cs-137 is 50% for each, the weighted average source efficiency for the mix may be calculated in the following manner:

$$(0.25)(0.5)+(0.5)(0.5)=0.375$$

Table 4.3 lists guidance on source efficiencies from ISO 7503-1.

Table 4.3
Source Efficiencies as listed in ISO 7503-1

	> 0.400 MeV_{max}	≤ 0.400 MeV_{max}
Beta emitters	$\varepsilon_s = 0.5$	$\varepsilon_s = 0.25$
Alpha emitters	$\varepsilon_s = 0.25$	$\varepsilon_s = 0.25$

It should be noted that source efficiency is not typically addressed for gamma detectors as the value is effectively unity.

5.0 Instrument Conversion Factor (E) (Instrument Efficiency for Scanning):

Separate modeling analysis (Microshield™) was conducted using the common gamma emitters with a concentration of 1 pCi/g of uniformly distributed contamination throughout the volume. MicroShield is a comprehensive photon/gamma ray shielding and dose assessment program, which is widely used throughout the radiological safety community. An activity concentration of 1 pCi/g for the nuclides was entered as the source term. The radial dimension of the cylindrical source was 28 cm, the depth was 15 cm, and the dose point above the surface was 10 cm with a soil density of 1.6 g/cm^3. The instrument efficiency when scanning, E_i, is the product of the modeled exposure rate (MicroShield™) in mRhr^{-1}/pCi/g for and the energy response factor in cpm/mR/hr as derived from the energy response curve provided by Eberline Instruments (Appendix O). Table 5.1 demonstrates the derived efficiencies for the major gamma emitting isotopes listed in Table 3.1.

TABLE 5.1
Energy Response and Efficiency for Photon Emitting Isotopes

Isotope	Calculations for E_i See appendix A through L	E_i (cpm/pCi/g)
Co-60	See Appendix Aand B	379
Nb-94	See Appendix C and D	416
Ag-108m	See Appendix E and F	637
Sb-125	See Appendix G and H	210
Cs-134	See Appendix I and J	506
Cs-137	See Appendix K and L	188
Eu-152	See Appendix M and N	344

When performing gamma scan measurements on soil surfaces the effective source to detector geometry is as close as is reasonably possible (less than 3 inches).

6.0 Applying Efficiency Corrections Based on the Effects of Field Conditions for Total Efficiency:

The total efficiency for any given condition can now be calculated from the product of the instrument efficiency ε_i and the source efficiency ε_s.

$$\varepsilon_{tot} = \varepsilon_i \times \varepsilon_s$$

The following example illustrates the process of determining total efficiency. For this example we will assume the following:

- Surface activity readings need to be made in the Primary Auxiliary Building (PAB) on the concrete wall surfaces using the E-600 and C-100 gas proportional detector.
- Data obtained from characterization results from the PAB indicate the presence of beta emitters with energies greater than 0.400 Mev.
- The source (activity on wall) to detector distance is 1.27 cm (0.5 in detector stand off). To calculate the total efficiency, ε_{tot}, refer to Table 4.2 "Source to Detector Distance Effects on Instrument Efficiencies for α- β Emitters" to obtain the appropriate ε_i value.
- Contamination on all surfaces is distributed relative to the effective detector area.

- When performing fixed point measurements with gas proportional instrumentation the effective source to detector geometry is representative of the calibrated geometries listed in Table 4.2 "Source to Detector Distance Effects on Instrument Efficiencies for α- β Emitters".
- Corrections for temperature and pressure are not substantial.

In this example, the value for ε_i is 0.2413 as depicted in Table 4.2 "Source to Detector Distance Effects on Instrument Efficiencies for α- β Emitters". The ε_s value of 0.5 is chosen refer to Table 4.3 "Source Efficiencies as listed in ISO 7503-1". Therefore the total efficiency for this condition becomes $\varepsilon_{tot} = \varepsilon_i \times \varepsilon_s = 0.2413 \times 0.5 = 0.121$ or 12.1%.

7.0 Conclusion:

Field conditions may significantly influence the usefulness of a survey instrument. When applying the instrument and source efficiencies in MDC calculations, field conditions must be considered. Tables have been constructed to assist in the selection of appropriate instrument and source efficiencies. Table 4.2 "Source to Detector Distance Effects on Instrument Efficiencies for α-β Emitters" lists instrument efficiencies (ε_i) at various source to detector distances for alpha and beta emitters. The appropriate ε_i value should be applied, accounting for the field condition, i.e. the relation between the detector and the surface to be measured.

Source efficiencies shall be selected from Table 4.3 "Source Efficiencies as listed in ISO 7503-1". This table lists conservative ε_s values that correct for self-absorption and attenuation of surface activity. Table 5.1 "Energy Response and Efficiency for Photon Emitting Isotopes" lists E_i values that apply to scanning MDC calculations. The Microshield™ model code was used to determine instrument efficiency assuming contamination conditions and detector geometry cited in section 5.6.2.4.4 "MDCs for Gamma Scans of Land Areas" of the License Termination Plan [8.6].

Detector and source conditions equivalent to those modeled herein may directly apply to the results of this report.

8.0 References

8.1 NUREG-1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions," 1998

8.2 ISO 7503-1, "Evaluation of Surface Contamination – Part I: Beta Emitters and Alpha Emitters," 1988-08-01.

8.3 ISO 8769, "Reference Sources for the Calibration of Surface Contamination Monitors-Beta-emitters (maximum beta energy greater 0.15MeV) and Alpha-emitters," 1988-06-15.

8.4 "Radiological Health Handbook," Revised Edition 1970.

8.5 DP-8534, "Operation and source Checks of Portable Friskers".

8.6 Yankee Nuclear Plant Site License Termination Plan, Rev.0, November 2003.

APPENDIX A

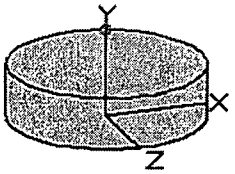
MicroShield v6.02 (6.02-00253)

Page	:1		
DOS File	:SPA3-EFF-Co-60.ms6	File Ref	:
Run Date	: September 10, 2004	Date	:
Run Time	: 8:56:50 AM	By	:
Duration	: 00:00:00	Checked	:

Case Title: SPA3-EFF-Co-60
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Co-60
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)



Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Co-60	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.6938	2.230e-01	9.055e-06	1.590e-05	1.748e-08	3.070e-08
1.1732	1.367e+03	1.098e-01	1.669e-01	1.962e-04	2.982e-04
1.3325	1.367e+03	1.293e-01	1.904e-01	2.244e-04	3.303e-04
Totals	**2.734e+03**	**2.391e-01**	**3.573e-01**	**4.205e-04**	**6.286e-04**

APPENDIX B

Co-60
Microsoft Excel E_i Calculation Sheet

	Energy MeV	Energy keV	Exposure Rate (mR/hr-1/pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
694	0.6938	694	3.07E-08	1,112,630	0
1173	1.1732	1,173	2.98E-04	660,557	197
1333	1.3325	1,333	3.30E-04	552,233	182
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E_i) Total:	**379**

APPENDIX C

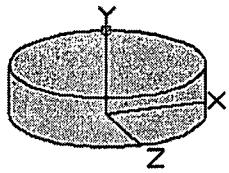
MicroShield v6.02 (6.02-00253)

Page	:1	File Ref	:
DOS File	:SPA3-EFF-Nb-94.ms6	Date	:
Run Date	: September 16, 2004	By	:
Run Time	: 3:22:38 PM	Checked	:
Duration	: 00:00:00		

Case Title: SPA3-EFF-Nb-94
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Nb-94
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)



Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Nb-94	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0023	9.067e-02	1.391e-10	1.430e-10	1.851e-10	1.913e-10
0.0174	4.834e-01	8.762e-09	9.129e-09	4.729e-10	4.927e-10
0.0175	9.260e-01	1.719e-08	1.792e-08	9.104e-10	9.491e-10
0.0196	2.720e-01	7.924e-09	8.356e-09	2.925e-10	3.085e-10
0.7026	1.367e+03	5.643e-02	9.872e-02	1.088e-04	1.904e-04
0.8711	1.367e+03	7.464e-02	1.228e-01	1.405e-04	2.312e-04
Totals	**2.736e+03**	**1.311e-01**	**2.216e-01**	**2.493e-04**	**4.216e-04**

APPENDIX D

Nb-94

	Energy MeV	Energy keV	Exposure Rate (mR/hr-1/pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
2	0.0023	2	1.91E-10		0
17	0.0174	17	4.93E-10		0
18	0.0175	18	9.49E-10		0
20	0.0196	20	3.09E-10		0
703	0.7026	703	1.90E-04	1,110,370	211
871	0.8711	871	2.31E-04	884,689	205
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E_i) Total:	**416**

APPENDIX E

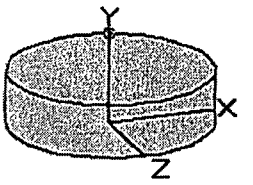
MicroShield v6.02 (6.02-00253)

Page	:1	File Ref	:
DOS File	:SPA3-EFF-Ag-108m.ms6	Date	:
Run Date	: September 16, 2004	By	:
Run Time	: 3:30:40 PM	Checked	:
Duration	: 00:00:00		

Case Title: SPA3-EFF-Ag-108m
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Ag-108m
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)



Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ag-108m	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0028	6.580e+01	1.252e-07	1.287e-07	1.351e-07	1.388e-07
0.003	7.853e+00	1.568e-08	1.612e-08	1.612e-08	1.657e-08
0.021	2.491e+02	9.534e-06	1.015e-05	2.824e-07	3.007e-07
0.0212	4.727e+02	1.862e-05	1.985e-05	5.389e-07	5.744e-07
0.022	7.024e+00	3.202e-07	3.434e-07	8.233e-09	8.831e-09
0.0222	1.330e+01	6.251e-07	6.714e-07	1.568e-08	1.685e-08
0.0238	1.501e+02	9.273e-06	1.010e-05	1.863e-07	2.029e-07
0.0249	4.289e+00	3.145e-07	3.464e-07	5.492e-09	6.050e-09
0.0304	2.902e-04	4.431e-11	5.248e-11	4.230e-13	5.010e-13
0.0792	9.687e+01	2.008e-04	4.802e-04	3.190e-07	7.629e-07
0.4339	1.229e+03	2.705e-02	5.514e-02	5.294e-05	1.079e-04
0.6144	1.236e+03	4.282e-02	7.808e-02	8.347e-05	1.522e-04
0.7229	1.237e+03	5.300e-02	9.194e-02	1.019e-04	1.768e-04
Totals	**4.768e+03**	**1.231e-01**	**2.257e-01**	**2.398e-04**	**4.389e-04**

APPENDIX F

Ag-108m
Microsoft Excel E_i Calculation Sheet

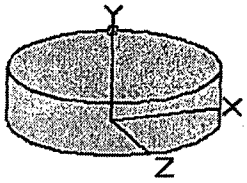
	Energy, MeV	Energy, keV	Exposure Rate (mR/hr-1/pCi/g)	Energy Response (cpm/mR/h)	E_i (cpm/pCi/g)
3	0.0028	3	1.39E-07		0
3	0.003	3	1.66E-08		0
21	0.021	21	3.01E-07		0
21	0.0212	21	5.74E-07		0
22	0.022	22	8.83E-09		0
22	0.0222	22	1.69E-08		0
24	0.0238	24	2.03E-07		0
25	0.0249	25	6.05E-09		0
30	0.0304	30	5.01E-13	1086720	0
79	0.0792	79	7.63E-07	11696000	9
434	0.4339	434	1.08E-04	2061265	222
614	0.6144	614	1.52E-04	1402440	213
723	0.7229	723	1.77E-04	1086291	192
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E_i) Total:	**637**

APPENDIX G

MicroShield v6.02 (6.02-00253)

Page	:1		
DOS File	:SPA3-EFF-Sb-125.ms6	File Ref	:
Run Date	: September 16, 2004	Date	:
Run Time	: 3:34:07 PM	By	:
Duration	: 00:00:00	Checked	:

Case Title: SPA3-EFF-Sb-125
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Sb-125
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)

Dose Points

A	X	Y	Z
4.1	0 cm	21 cm	0 cm
	0.0 in	0.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	Becquerels	uCi/cm³	Bq/cm³
Sb-125	3.6945e-008	1.367e+03	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0038	6.762e+01	1.708e-07	1.756e-07	1.388e-07	1.427e-07
0.0272	1.748e+02	1.785e-05	2.020e-05	2.376e-07	2.689e-07
0.0275	3.262e+02	3.453e-05	3.922e-05	4.461e-07	5.067e-07
0.031	1.132e+02	1.857e-05	2.221e-05	1.670e-07	1.997e-07
0.0355	5.693e+01	1.492e-05	1.918e-05	9.090e-08	1.169e-07
0.117	3.568e+00	1.380e-05	3.715e-05	2.346e-08	5.778e-08
0.159	9.531e-01	5.634e-06	1.499e-05	9.416e-09	2.505e-08
0.1726	2.478e+00	1.634e-05	4.395e-05	2.787e-08	7.326e-08
0.1763	9.422e+01	6.392e-04	1.674e-03	1.096e-06	2.870e-06
0.2041	4.410e+00	3.830e-05	9.230e-05	6.435e-08	1.636e-07
0.2081	3.324e+00	2.805e-05	7.103e-05	4.994e-08	1.264e-07
0.2279	1.796e+00	1.708e-05	4.229e-05	3.098e-08	7.670e-08
0.321	5.701e+00	8.474e-05	1.899e-04	1.620e-07	3.632e-07
0.3804	2.045e+01	3.792e-04	8.052e-04	7.364e-07	1.564e-06
0.408	2.486e+00	5.051e-05	1.049e-04	9.853e-08	2.047e-07
0.4279	4.009e+03	8.068e-03	1.774e-02	1.695e-05	3.470e-05
0.4435	4.130e+00	9.356e-05	1.894e-04	1.832e-07	3.709e-07
0.4634	1.415e+02	3.395e-03	6.781e-03	6.658e-06	1.330e-05
0.6006	2.430e+02	8.174e-03	1.501e-02	1.595e-05	2.930e-05
0.6066	6.864e+01	2.340e-03	4.283e-03	4.564e-06	8.355e-06
0.6359	1.548e+02	5.609e-03	1.012e-02	1.091e-05	1.967e-05
0.6714	2.478e+01	9.640e-04	1.710e-03	1.867e-06	3.311e-06
Totals	**1.916e+03**	**3.060e-02**	**5.901e-02**	**6.046e-05**	**1.158e-04**

APPENDIX H

Sb-125

	Energy MeV	Energy keV	Exposure Rate (mR/hr-1/pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
4	0.0038	4	1.43E-07	6,618,312	0
27	0.0272	27	2.69E-07	510,290	0
28	0.0275	28	5.07E-07	554,334	0
31	0.031	31	2.00E-07	1,219,281	0
36	0.0355	36	1.17E-07	2,418,948	0
117	0.117	117	5.78E-08	9,167,000	1
159	0.159	159	2.51E-08	8917000	0
173	0.1726	173	7.33E-08	6859000	1
176	0.1763	176	2.87E-06	6192600	18
204	0.2041	204	1.64E-07	6011300	1
208	0.2081	208	1.26E-07	4073050	1
228	0.2279	228	7.67E-08	3110500	0
321	0.321	321	3.63E-07	3000500	1
380	0.3804	380	0.000001564	2348000	4
408	0.408	408	2.047E-07	2155800	0
428	0.4279	428	0.0000347	2083165	72
444	0.4435	444	3.709E-07	2026225	1
463	0.4634	463	0.0000133	1953590	26
601	0.6006	601	0.0000293	1452810	43
607	0.6066	607	0.000008355	1430910	12
636	0.6359	636	0.00001957	1323965	26
671	0.6714	671	0.000003311	1194390	4
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E_i) Total:	**210**

APPENDIX I

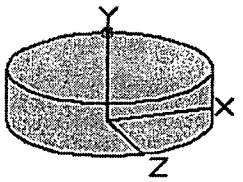
MicroShield v6.02 (6.02-00253)

Page	:1	File Ref	:
DOS File	:SPA3-EFF-Cs-134.ms6	Date	:
Run Date	: September 16, 2004	By	:
Run Time	: 3:39:09 PM	Checked	:
Duration	: 00:00:00		

Case Title: SPA3-EFF-Cs-134
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Cs-134
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)



Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Cs-134	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.222e+00	3.658e-09	3.760e-09	2.507e-09	2.577e-09
0.0318	2.931e+00	5.271e-07	6.386e-07	4.391e-09	5.320e-09
0.0322	5.407e+00	1.014e-06	1.236e-06	8.157e-09	9.943e-09
0.0364	1.968e+00	5.611e-07	7.321e-07	3.188e-09	4.160e-09
0.2769	4.839e-01	5.931e-06	1.391e-05	1.113e-08	2.610e-08
0.4753	1.996e+01	4.950e-04	9.808e-04	9.712e-07	1.924e-06
0.5632	1.146e+02	3.545e-03	6.648e-03	6.940e-06	1.302e-05
0.5693	2.109e+02	6.619e-03	1.237e-02	1.295e-05	2.421e-05
0.6047	1.334e+03	4.529e-02	8.300e-02	8.836e-05	1.619e-04
0.7958	1.167e+03	5.668e-02	9.564e-02	1.079e-04	1.820e-04
0.8019	1.193e+02	5.852e-03	9.853e-03	1.113e-05	1.874e-05
1.0386	1.367e+01	9.377e-04	1.472e-03	1.717e-06	2.696e-06
1.1679	2.461e+01	1.964e-03	2.990e-03	3.514e-06	5.349e-06
1.3652	4.156e+01	4.055e-03	5.936e-03	6.993e-06	1.024e-05
Totals	**3.058e+03**	**1.254e-01**	**2.189e-01**	**2.405e-04**	**4.202e-04**

APPENDIX J

Cs-134

Microsoft Excel E_i Calculation Sheet

	Energy MeV	Energy keV	Exposure Rate (mR/hr-1/pCi/g)	Energy Response (cpm/mR/h)	E_i (cpm/pCi/g)
5	0.0045	5	2.58E-09		0
32	0.0318	32	5.32E-09	1,406,947	0
32	0.0322	32	9.94E-09	1,505,273	0
36	0.0364	36	4.16E-09	2,696,122	0
277	0.2769	277	2.61E-08	3,637,000	0
475	0.4753	475	1.92E-06	1,910,155	4
563	0.5632	563	1.30E-05	1,589,320	21
569	0.5693	569	2.42E-05	1,567,055	38
605	0.6047	605	1.62E-04	1,437,845	233
796	0.7958	796	1.82E-04	998,082	182
802	0.8019	802	1.87E-05	939,149	18
1039	1.0386	1,039	2.70E-06	752,085	2
1168	1.1679	1,168	5.35E-06	664,161	4
1365	1.3652	1,365	1.02E-05	573,136	6
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E_i) Total:	**506**

APPENDIX K

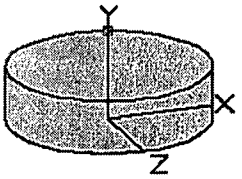
MicroShield v6.02 (6.02-00253)

Page	:1	File Ref	:
DOS File	:SPA3-EFF-Cs-137.ms6	Date	:
Run Date	: September 10, 2004	By	:
Run Time	: 8:52:18 AM	Checked	:
Duration	: 00:00:00		

Case Title: SPA3-EFF-Cs-137
Description: SPA-3 Soil scen - 28 cm radius 1pCi/cm3 Cs-137 and Daughters
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)



Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	3.4950e-008	1.2932e+003	9.4600e-007	3.5002e-002
Cs-137	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.342e+01	4.020e-08	4.133e-08	2.755e-08	2.833e-08
0.0318	2.677e+01	4.815e-06	5.834e-06	4.011e-08	4.850e-08
0.0322	4.939e+01	9.260e-06	1.129e-05	7.452e-08	9.084e-08
0.0364	1.797e+01	5.126e-06	6.688e-06	2.912e-08	3.800e-08
0.6616	1.164e+03	4.442e-02	7.913e-02	8.611e-05	1.534e-04
Totals	**1.271e+03**	**4.444e-02**	**7.915e-02**	**8.628e-05**	**1.536e-04**

APPENDIX L

Cs-137
Microsoft Excel E_i Calculation Sheet

	Energy MeV	Energy keV	Exposure Rate (mR/hr-1/pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
5	0.0045	5	2.83E-08		0
32	0.0318	32	4.86E-08	1,406,947	0
32	0.0322	32	9.08E-08	1,505,273	0
36	0.0364	36	3.80E-08	2,696,122	0
662	0.6616	662	1.53E-04	1,228,700	188
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
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0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E_i) Total:	**188**

APPENDIX M

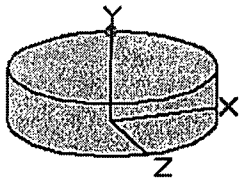
MicroShield v6.02 (6.02-00253)

Page	:1	File Ref	:
DOS File	:SPA3-EFF-Eu-152.ms6	Date	:
Run Date	: October 7, 2004	By	:
Run Time	: 11:25:11 AM	Checked	:
Duration	: 00:00:00		

Case Title: SPA-3-EFF-Eu-152
Description: SPA-3 Soil scan - 28cm radius 1 pCi/cm3 Eu-152
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)



Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Eu-152	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.077e+02	2.087e-06	2.146e-06	1.790e-07	1.841e-07
0.04	8.088e+02	3.131e-04	4.331e-04	1.385e-06	1.916e-06
0.05	2.022e+02	1.507e-04	2.467e-04	4.014e-07	6.572e-07
0.1	3.887e+02	1.189e-03	3.118e-03	1.819e-06	4.770e-06
0.2	1.024e+02	8.207e-04	2.097e-03	1.448e-06	3.700e-06
0.3	3.696e+02	5.029e-03	1.151e-02	9.540e-06	2.184e-05
0.4	8.590e+01	1.701e-03	3.555e-03	3.314e-06	6.926e-06
0.5	7.711e+00	2.043e-04	3.984e-04	4.010e-07	7.819e-07
0.6	5.797e+01	1.948e-03	3.579e-03	3.802e-06	6.985e-06
0.8	2.434e+02	1.190e-02	2.005e-02	2.263e-05	3.813e-05
1.0	5.849e+02	3.820e-02	6.058e-02	7.042e-05	1.117e-04
1.5	3.171e+02	3.490e-02	4.999e-02	5.871e-05	8.411e-05
Totals	**3.376e+03**	**9.635e-02**	**1.556e-01**	**1.740e-04**	**2.817e-04**

APPENDIX N

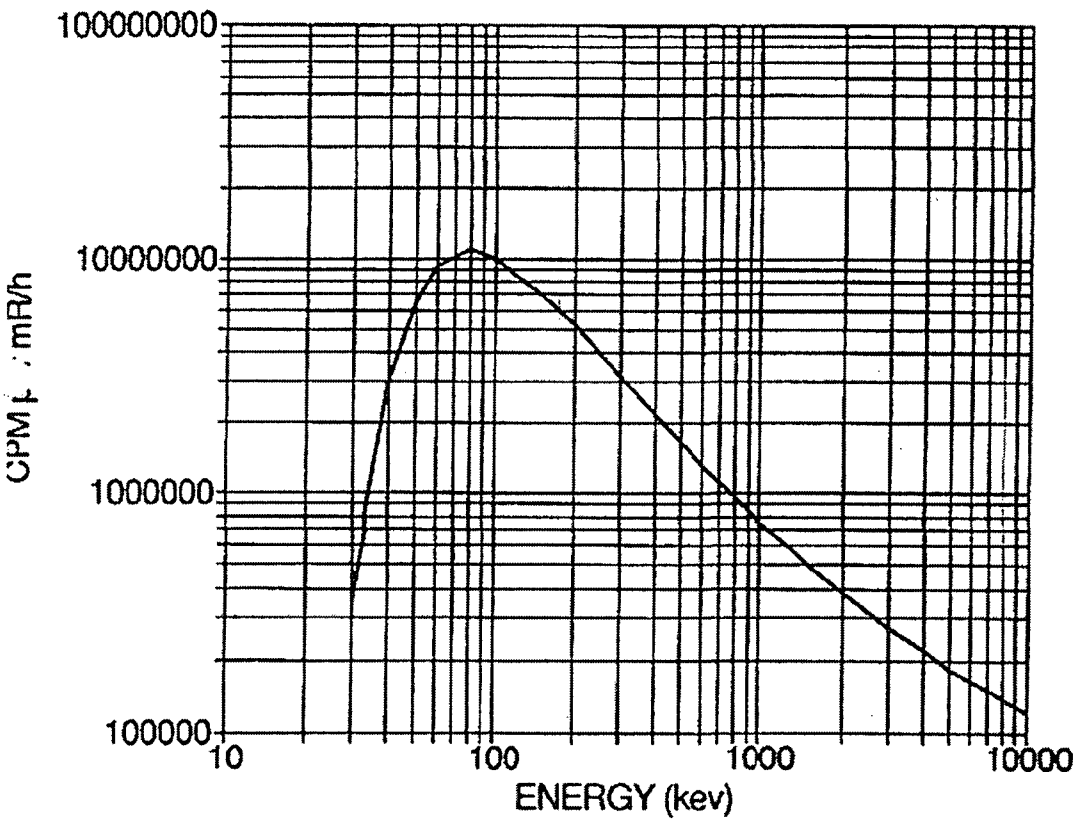
Eu-152

Energy MeV	Energy keV	Exposure Rate (mR/hr 1/pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
15	0.015	15	1.84E-07	0
40	0.04	40	1.92E-06	3,897,600	7
50	0.05	50	6.57E-07	6,500,000	4
100	0.1	100	4.77E-06	9,958,333	48
200	0.2	200	3.70E-06	4,850,000	18
300	0.3	300	2.18E-05	3,200,000	70
400	0.4	400	6.93E-06	2,185,000	15
500	0.5	500	7.82E-07	1,820,000	1
600	0.6	600	6.99E-06	1,455,000	10
800	0.8	800	3.81E-05	993,000	38
1000	1	1,000	1.12E-04	783,019	87
1500	1.5	1,500	8.41E-05	530,000	45
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
			(E_i) Total:	**344**

APPENDIX O

Calculated Energy Response (Eberline Instruments)

CPM/mR/h



Appendix C

YA-REPT-00-018-05

Use of *In-Situ* Gamma Spectrum Analysis To Perform Elevated Measurement Comparisons In Support of Final Status Surveys

Use Of In-Situ Gamma Spectrum Analysis To Perform
Elevated Measurement Comparisons In Support Of Final Status Surveys

YA-REPT-00-018-05

Approvals	**(Print & Sign Name)**		
Preparer:	Greg Astrauckas/Signature on file	Date:	10/10/05
Preparer:	Gordon Madison, CHP/Signature on file	Date:	10/11/05
Reviewer:	Jim Hummer, CHP/Signature on file	Date:	10/18/05
Approver (FSS Manager):	Dann Smith, CHP/Signature on file	Date:	11/4/05

Rev. 0

YA-REPT-00-018-05
Rev. 0

Technical Report YA-REPT-00-018-05, Rev. 0

Use Of In-Situ Gamma Spectrum Analysis To Perform
Elevated Measurement Comparisons In Support Of Final Status Surveys

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1.0 REPORT

1.1 Introduction

The ISOCS In-Situ Gamma Spectrum detector system manufactured by Canberra Industries is being employed to perform elevated measurement comparison (EMC) surveys in support of the Final Status Surveys at Yankee Atomic's Yankee Rowe facility. This system uses an HPGe detector and specialized efficiency calibration software designed to perform in-situ gamma-spectroscopy assays. The ISOCS system will primarily be employed to evaluate survey units for elevated measurement comparisons. The ISOCS system can obtain a static measurement at a fixed distance from a pre-determined location. Count times can be tailored to achieve required detection sensitivities. Gamma spectroscopy readily distinguishes background activity from plant-related licensed radioactivity. This attribute is particularly beneficial where natural radioactivity introduces significant investigation survey efforts. Additionally, background subtraction or collimation can be employed where background influences are problematic due to the presence of stored spent fuel (ISFSI).

This technical report is intended to outline the technical approach associated with the use of ISOCS for implementing a MARSSIM-based Final Status Survey with respect to scanning surveys for elevated measurement comparisons for both open land areas and building surfaces. While the examples and discussions in this report primarily address open land areas, the same approach and methodology will be applied when deriving investigation levels, grid spacing and measurement spacing for evaluating building surfaces.

Validation of the ISOCS software is beyond the scope of this technical report. Canberra Industries has performed extensive testing and validation on both the MCNP-based detector characterization process and the ISOCS calibration algorithms associated with the calibration software. The full MCNP method has been shown to be accurate to within 5% typically. ISOCS results have been compared to both full MCNP and to 119 different radioactive calibration sources. In general, ISOCS is accurate to within 4-5% at high energies and 7-11% at 1 standard deviation for low energies. Additionally, the ISOCS technology has been previously qualified in Yankee Atomic Technical Report YA-REPT-00-022-04, "Use Of Gamma Spectrum Analysis To Evaluate Bulk Materials For Compliance With License Termination Criteria."

1.2 Discussion

1.2.1 Detector Description

Two ISOCS-characterized HPGe detectors manufactured by Canberra Industries have been procured. Each detector is a reverse-electrode HPGe

detector rated at 50% efficiency (relative to a NaI detector). Resolution for these detectors is 2.2 keV @ 1332 keV. As the project progresses, other ISOCS detectors (e.g. standard electrode coaxial), if available, may be used to increase productivity. The key element regarding the use of other types of ISOCS® detectors is that specific efficiency calibrations will be developed to account for each detector's unique characteristics.

The HPGe detector is mounted on a bracket designed to hold the detector / cryostat assembly and associated collimators. This bracket may be mounted in a wheeled cart or in a cage-like frame. Both the wheeled cart and frame permit the detector to be oriented (pointed) over a full range from a horizontal to vertical position. The frame's design allows the detector to be suspended above the ground. Photographs of the frame-mounted system are presented in Attachment 1. During evaluations of Class1 areas for elevated radioactivity, the detector will generally be outfitted with the 90-degree collimator. Suspending the detector at 2 meters above the target surface yields a nominal field-of-view of 12.6 m^2.

The InSpector (MCA) unit that drives the signal chain and the laptop computer that runs the acquisition software (Genie-2000) are mounted either in the frame or on the wheeled cart. These components are battery powered. Back-up power supplies (inverter or UPS) are available to support the duty cycle. A wireless network has been installed at the site so that the laptop computers used to run the systems can be completely controlled from any workstation at the facility. This configuration also enables the saving of data files directly to a centralized file server. Radio communication will be used to coordinate system operation.

1.2.2 Traditional Approach

With respect to Class 1 Survey Units, small areas of elevated activity are evaluated via the performance of scan surveys. The size of the potential area of elevated activity affects the $DCGL_{EMC}$ and is typically determined by that area bounded by the grid points used for fixed measurements. This area in turn dictates the area factor(s) used for deriving the associated $DCGL_{EMC}$.

These scan surveys are traditionally conducted with hand-held field instruments that have a detection sensitivity sufficiently low to identify areas of localized activity above the $DCGL_{EMC}$. Occasionally, the detection sensitivity of these instruments is greater than the $DCGL_{EMC}$. In order to increase the $DCGL_{EMC}$ to the point where hand-held instrumentation can be reasonably employed, the survey design is augmented to require additional fixed-point measurements. The effect of these additional measurement points is to tighten the fixed measurement grid spacing, thus reducing the area applied to deriving the $DCGL_{EMC}$ and increasing the detection sensitivity criteria.

Background influences (from the ISFSI) and natural terrestrial sources further impact the sensitivity of these instruments. To address these impacts, the fixed-point grid spacing would again need to be reduced (requiring even more samples) in order to increase the $DCGL_{EMC}$ to the point where hand-held instrumentation can be used. Generally, the collection of additional fixed measurements (i.e. samples) increases project costs.

Survey designs for Class 2 and Class 3 survey units are not driven by the elevated measurement comparison because areas of elevated activity are not expected. In Class 2 areas, any indication of activity above the $DCGL_W$ requires further investigation. Similarly, in Class 3 areas, any positive indication of licensed radioactivity also requires further investigation. Because the $DCGL_{EMC}$ is not applicable to Class 2 or Class 3 areas, adjustments to grid spacing do not occur. However, the increased field-of-view associated with the in-situ gamma spectroscopy system improves the efficiency of the survey's implementation.

1.2.3 Innovative Approach

In-situ assays allow fixed-point grid spacing to be uncoupled from the derivation of applicable investigation levels. In contrast to the traditional approach where the $DCGL_{EMC}$ (based on grid size) determines both investigation levels and detection sensitivities, the use of this technology provides two independent dynamics as follows:

- Detection sensitivity is determined by the $DCGL_{EMC}$ associated with the (optimal) fixed-point grid spacing.
- Investigation levels are based on the detector's field-of-view and adjusted for the smallest area of concern (i.e. 1 m^2).

1.2.4 Investigation Level

Development of the investigation (action) levels applied to in-situ assay results is a departure from the traditional approach for implementing a MARSSIM survey. Examples are provided for both open land areas (i.e. soil) and for building surfaces, however the approach for both is identical.

To support the use of in-situ spectroscopy to evaluate areas of elevated activity the HPGe detector's field-of-view was characterized. Attachment 2 presents data from the field-of-view characterization for a detector configured with a 90-degree collimator positioned 2 meters from the target surface. Alternate configurations will be evaluated in a similar manner before being employed. As exhibited in Attachment 2, when the detector is positioned at 2 meters above the target surface the field-of-view has a radius of at least 2.3

meters. This value was rounded down to 2.0 meters for implementation purposes, introducing a conservative bias (approximately 9%) in reported results. The example provided in this technical report assumes a 2-meter source-to-detector distance, yielding a nominal field-of-view surface area of 12.6 m^2.

Occasionally, alternate source-to-detector distances (using the 90-degree collimator) may be employed, particularly in a characterization or investigation capacity. In such cases, the detector's field-of-view will be calculated by setting the radius equal to the source-to-detector distance, thereby maintaining the conservative attribute previously described. If alternative collimator configurations are used to perform elevated measurement comparisons, then specific evaluations will be documented in the form of a technical evaluation or similar. Associated investigation levels will be derived using the same approach and methodology outlined below in this section.

After the detector's field-of-view is determined, an appropriate investigation level is developed to account for a potential one-meter square area of elevated activity. $DCGL_{EMC}$ values for a one-square meter area are presented in Table 1.

TABLE 1, SOIL $DCGL_{EMC}$ FOR 1 m^2

	Soil $DCGL_W$ (pCi/g) (NOTE 1)	Soil $DCGL_W$ (pCi/g) (NOTE 2)	Area Factor for 1 m^2 (NOTE 3)	$DCGL_{EMC}$ for 1 m^2 (pCi/g) (NOTE 4)
Co-60	3.8	1.4	11	15
Ag-108m	6.9	2.5	9.2	23
Cs-134	4.7	1.7	16	28
Cs-137	8.2	3.0	22	66

NOTE 1 – LTP Table 6-1
NOTE 2 – Adjusted to 8.73 mRem/yr
NOTE 3 – LTP Appendix 6Q
NOTE 4 – Soil $DCGL_W$ (adjusted to 8.73 mRem/yr) for a 1 m^2 area

The $^{1m2}DCGL_{EMC}$ values listed in Table 1 do not account for a source positioned at the edge of the field-of-view. Therefore, the $^{1m2}DCGL_{EMC}$ values are adjusted via a correction factor. To develop this correction factor, a spectrum free of plant-related radioactivity was analyzed using two different efficiency calibrations (i.e. geometries). The first scenario assumes radioactivity uniformly distributed over the detector's 12.6 m^2 field-of-view. The second scenario assumes radioactivity localized over a 1 m^2 situated at the edge of the detector's field-of-view. The resultant MDC values were compared to characterize the difference in detection efficiencies between the two scenarios. As expected, the condition with localized (1 m^2) radioactivity at the edge of the detector's field-of-view yielded higher MDC values. The ratio between the reported MDC values for the two scenarios is used as a correction factor. This correction factor is referred to as the offset geometry

adjustment factor. The investigation levels for soils presented in Table 2 were calculated as follows:

Nuclide Investigation Level (pCi/g) = ($DCGL_{EMC}$) * CF

Where: $DCGL_{EMC}$ = ($DCGL_W$ or $DCGL_{SURR}$) * $AF_{(1\ m^2)}$, and
CF = Mean offset geometry adjustment factor

TABLE 2, SOIL INVESTIGATION LEVEL DERIVATION

	MDC pCi/g (NOTE 1)	MDC pCi/g (NOTE 2)	RATIO (NOTE 3)	$DCGL_{EMC}$ for 1 m² (NOTE 5)	INVESTIGATION LEVEL pCi/g (NOTE 6)
Co-60	0.121	1.86	0.0651	15	1.0
Ag-108m	0.184	2.82	0.0652	23	1.5
Cs-134	0.189	2.90	0.0652	28	1.8
Cs-137	0.182	2.78	0.0655	66	4.3
Offset Geometry Adjustment Factor (NOTE 4)			**0.0653**		

NOTE 1 – Assumed activity distributed over the 12.6 m² field-of-view.
NOTE 2 – Efficiency calibration modeled for a 1 m² area situated (off-set) at the edge of the detector's field-of-view. The model assumes that all activity is distributed within the 1 m².
NOTE 3 – Ratio = (12.6 m² MDC ÷ 1 m² MDC).
NOTE 4 – The mean value of the ratios is applied as the off-set geometry adjustment factor.
NOTE 5 – $DCGL_{EMC}$ values for 1 m² (from Table 1)
NOTE 6 – Investigation levels derived by applying of the off-set geometry adjustment factor (e.g. 0.0653) to the $DCGL_{EMC}$ for a 1 m² area for each radionuclide.

With respect to building surfaces, the development of the investigation level is identical to that for soil surfaces. The one-meter square $DCGL_{EMC}$ for building surfaces are presented in Table 3.

TABLE 3, BUILDING SURFACE $DCGL_{EMC}$ FOR 1 m²

	Bldg $DCGL_W$ (dpm/100m²) (NOTE 1)	Bldg $DCGL_W$ (dpm/100cm²) (NOTE 2)	Area Factor For 1 m² (NOTE 3)	$DCGL_{EMC}$ For 1 m² (dpm/100cm²) (NOTE 4)
Co-60	18,000	6,300	7.3	46,000
Ag-108m	25,000	8,700	7.2	62,600
Cs-134	29,000	10,000	7.4	74,000
Cs-137	63,000	22,000	7.6	167,000

NOTE 1 – LTP Table 6-1
NOTE 2 – Adjusted to 8.73 mRem/yr
NOTE 3 – LTP Appendix 6S
NOTE 4 – Building $DCGL_W$ (adjusted to 8.73 mRem/yr) for a 1 m² area

Using the same approach described for soils, a correction factor to account for efficiency differences due to geometry considerations is developed the one-meter square $DCGL_{EMC}$. ISOCS efficiency calibrations for activity distributed over the detector's field-of-view and for activity within one-square meter located at the edge of the detector's field-of-view were developed. The MDC values for these two geometries were compared to characterize the difference in detection efficiencies. As expected, the condition with localized (1 m²)

radioactivity at the edge of the detector's field-of-view yielded higher MDC values. The ratio between the reported MDC values for the two scenarios is used as the offset geometry adjustment factor. The MDC values, the associated ratios, and the derived investigation level for building surfaces are presented in Table 4.

TABLE 4, BUILDING SURFACE INVESTIGATION LEVEL DERIVATION

	12.6 m² MDC (dpm/100cm²) (NOTE 1)	1 m² MDC (dpm/100cm²) (NOTE 2)	RATIO (NOTE 3)	$DCGL_{EMC}$ For 1 m² (dpm/100cm²) (NOTE 5)	BUILDING SURFACE INVESTIGATION LEVEL (dpm/100cm²) (NOTE 6)
Co-60	785	12,400	0.0633	46,000	2,900
Ag-108m	839	13,000	0.0645	62,600	3,900
Cs-134	900	14,200	0.0634	74,000	4,700
Cs-137	922	14,600	0.0632	167,000	10,600
Offset Geometry Adjustment Factor (NOTE 4)			**0.0636**		

NOTE 1 – Assumed activity distributed over the 12.6 m² field-of-view.
NOTE 2 – Efficiency calibration modeled for a 1 m² area situated (off-set) at the edge of the detector's field-of-view. The model assumes that all activity is distributed within the 1 m².
NOTE 3 – Ratio = (12.6 m² MDC ÷ 1 m² MDC).
NOTE 4 – The mean value of the ratios is applied as the off-set geometry adjustment factor.
NOTE 5 – $DCGL_{EMC}$ values for 1 m² (from Table 3)
NOTE 6 – Investigation levels derived by applying of the off-set geometry adjustment factor (e.g. 0.0636) to the one-square meter $DCGL_{EMC}$

In summary, effective investigation levels for both open land areas (i.e. soils) and for building surfaces can be derived and applied to in-situ gamma spectroscopy results. Note the MDC values associated with the detector's field-of-view were well below the derived investigation levels.

The investigation levels presented in Table 2 and Table 4 do not address the use of surrogate DCGLs. Use of surrogate DCGLs will be addressed in Final Status Survey Plans, particularly where it is necessary to evaluate non-gamma emitting radionuclides on building surfaces. When surrogate DCGLs are employed, investigation levels will be developed on a case-by-case basis using the approach outlined in this document. Similarly, the offset geometry adjustment factor presented in Table 2 and Table 4 will vary for different geometries. Although unlikely, if different geometries are employed, this value will be determined on a case-by-case basis using the methodology reflected in Table 2 and will be documented in the applicable Final Status Survey Plan.

For both open land areas and for building surfaces, when an investigation level is encountered, investigatory protocols will be initiated to evaluate the presence of elevated activity and bound the region as necessary. Such evaluations may include both hand-held field instrumentation as well as the in-situ HPGe detector system. After investigation activities are completed,

subsequent (follow-up) scanning evaluations will most likely be conducted using the in-situ gamma spectroscopy system.

1.2.5 Detector Sensitivity

For Class 1 scan surveys, the minimum detectable concentration is governed by the $DCGL_{EMC}$ associated with the grid area used to locate fixed-point measurements. The system's count time can be controlled to achieve the required detection sensitivity. Therefore, the grid spacing for the fixed-point measurements can be optimized thus eliminating unnecessary increases to the number of fixed-point measurements while ensuring that elevated areas between fixed measurement locations can be identified and evaluated.

Based on preliminary work, it has been determined that a count time of 900 seconds will yield an acceptable sensitivity for many areas on the site. This count time provides MDC values well below the investigation levels presented in Table 2 and Table 4. Count times will be adjusted as necessary as survey unit-specific investigation levels are derived or where background conditions warrant to ensure that detection sensitivities are below the applicable investigation level. Since each assay report includes a report of the MDC values achieved during the assay, this information is considered technical support that required MDC values were met.

1.2.6 Area Coverage

Based on the nominal 12.6 m^2 field-of-view, a 3-meter spacing between each survey point will result in well over 100% of the survey unit to be evaluated for elevated activity. This spacing convention typically employs a grid pattern that is completely independent from the grid used to locate fixed-point measurements. An example of the grid pattern and spacing is presented in Attachment 3.

Alternate spacing conventions may be applied on a case-by-case basis. For instance, spacing may be decreased when problematic topographies are encountered. Note that decreased grid spacing in this context is not associated to the fixed-point measurements. Occasionally it may be necessary to position the detector at one meter or less from the target surface to evaluate unusual (e.g. curved) surfaces or to assist in bounding areas of elevated activity. In cases where it may be desirable to increase the field-of-view via collimator or source-to-detector distances, grid-spacing conventions (and applicable investigation levels) will be determined using the approach described in this document.

1.2.7 Moisture Content in the Soil Matrix

In-situ gamma spectroscopy of open land areas is inherently subject to various environmental variables not present in laboratory analyses. Most notably is the impact that water saturation has on assay results. This impact has two components. First, the total activity result for the assay is assigned over a larger, possibly non-radioactive mass introduced by the presence of water. Secondly, water introduces a self-absorption factor.

The increase in sample mass due to the presence of water is addressed by the application of a massimetric efficiency developed by Canberra Industries. Massimetric efficiency units are defined as [counts per second]/[gammas per second per gram of sample]. Mathematically, this is the product of traditional efficiency and the mass of the sample. When the efficiency is expressed this way, the efficiency asymptotically approaches a constant value as the sample becomes very large (e.g. infinite). Under these conditions changes in sample size, including mass variations from excess moisture, have little impact on the counting efficiency. However, the massimetric efficiency does not completely address attenuation characteristics associated with water in the soil matrix.

To evaluate the extent of self-absorption, (traditional) counting efficiencies were compared for two densities. Based on empirical data associated with the monitoring wells, typical nominally dry in-situ soil is assigned a density of 1.7 g/cc. A density of 2.08 g/cc, obtained from a technical reference publication by Thomas J. Glover, represents saturated soil. A density of 2.08 g/cc accounts for a possible water content of 20%. A summary of this comparison is presented in Table 5.

TABLE 5, COUNTING EFFICIENCY COMPARISONS

keV	Efficiencies 1.7 g/cc	Efficiencies 2.08 g/cc	Deviation due to density increase (excess moisture)
434	3.3 E-6	2.7 E-6	-18.7%
661.65	2.9 E-6	2.4 E-6	-17.5%
1173.22	2.5 E-6	2.1 E-6	-15.4%
1332.49	2.4 E-6	2.1 E-6	-14.8%

In cases when the soil is observed to contain more than "typical" amounts of water, potential under-reporting can be addressed in one of two manners. One way is to adjust the investigation level down by 20%. The second way is to reduce the sample mass by 20%. Either approach achieves the same objective: to introduce a conservative mechanism for triggering the investigation level where the presence of water may inhibit counting efficiency. The specific mechanism to be applied will be prescribed in implementing procedures.

The presence of standing water (or ice or snow) on the surface of the soil being assayed will be accounted for in customized efficiency calibrations applied during data analysis activities.

1.2.8 Discrete Particles in the Soil Matrix

Discrete particles are not specifically addressed in the License Termination Plan. However, an evaluation was performed assuming all the activity in the detector's field-of-view, to a depth of 15 cm, was situated in a discrete point-source configuration. A concentration of 1.0 pCi/g (Co-60), corresponding to the investigation level presented in Table 2, correlates to a discrete point-source of approximately 3.2 μCi. This activity value is considered as the discrete particle of concern. Since the presence of any discrete particles will most likely be accompanied by distributed activity, the investigation level may provide an opportunity to detect discrete particles below 3.2 μCi.

Discrete particles exceeding this magnitude would readily be detected during characterization or investigation surveys. The MDCs associated with hand-held field instruments used for scan surveys are capable of detecting very small areas of elevated radioactivity that could be present in the form of discrete point sources. The minimum detectable particle activity for these scanning instruments and methods correspond to a small fraction of the TEDE limit provided in 10CFR20 subpart E. Note that the MDC values presented in Table 2 are significantly lower than those published in Table 5-4 of the License Termination Plan.

When the investigation level in a Class 1 area is observed, subsequent investigation surveys will be performed to include the use of hand-held detectors. The detection sensitivities of instruments used for these surveys have been previously addressed in the LTP. Furthermore, discrete point sources do not contribute to the uniformly distributed activity of the survey unit. It is not expected that such sources at this magnitude would impact a survey unit's ability to satisfy the applicable acceptance criteria.

Noting that Class 2 or Class 3 area survey designs do not employ elevated measurement comparisons, associated investigation levels are based on positive indications of licensed radioactivity above the $DCGL_W$ or above background. Because such areas are minimally impacted or disturbed, potential discrete particles would most likely be situated near the soil surface where detection efficiencies are highest.

1.2.9 Procedures And Guidance Documents

General use of the portable ISOCS system is administrated by departmental implementing procedures that address the calibration and operation activities as well as analysis of the data. These procedures are listed as follows:

- DP-8869, "In-Situ (ISOCS) Gamma Spectrum Assay System Calibration Procedure."
- DP-8871, "Operation Of The Canberra Portable ISOCS Assay System."
- DP-8872, "ISOCS Post Acquisition Processing And Data Review."

Where the portable ISOCS® system is used for Final Status Surveys, the applicable FSS Plan will address detector and collimator configurations, applicable (surrogated) investigation levels, MDC requirements, and appropriate Data Quality Objectives, as applicable.

A secondary application of the portable ISOCS® system is to assay surfaces or bulk materials for characterization or unconditional release evaluations. Use of the portable ISOCS® system for miscellaneous evaluations will be administrated under a specific guidance document (e.g. Sample Plan, etc.). Operating parameters such as physical configuration, efficiency calibrations, count times, and MDCs will be applied so as to meet the criteria in the associated controlling documents. Such documents will also address any unique technical issues associated with the application and may provide guidance beyond that of procedure AP-0052, "Radiation Protection Release of Materials, Equipment and Vehicles."

1.2.10 Environmental Backgrounds

If background subtraction is used, an appropriate background spectrum will be collected and saved. Count times for environmental backgrounds should exceed the count time associated with the assay. In areas where the background radioactivity is particularly problematic (e.g. ISFSI), the background will be characterized to the point of identifying gradient(s) such that background subtractions are either appropriate or conservative. Documentation regarding the collection and application of environmental backgrounds will be provided as a component of the final survey plan.

1.2.11 Quality Control

Quality Control (QC) activities for the ISOCS system ensure that the energy calibration is valid and detector resolution is within specifications. A QC file will be set up for each detector system to track centroid position, FWHM, and activity. Quality Control counts will be performed on a shiftly basis prior to the system's use to verify that the system's energy calibration is valid. The Na-22 has a 1274.5 keV photon which will be the primary mechanism used for performance monitoring. If the energy calibration is found to be out of an acceptable tolerance (e.g. greater than ±4 channels), then the amplifier gain may be adjusted and a follow-up QC count performed. If the detector's resolution is found to be above the factory specification, then an evaluation

will be performed to determine if the detector should be removed from service and/or if the data is impacted. Evaluations associated with QC counts shall be documented. Such documentation may be limited to a remark directly on the applicable QC report or in a logbook if the resolution does not render the system out of service. Otherwise the evaluation should be separately documented (e.g. Condition Report, etc.) so as to address the impact of any assay results obtained since the last acceptable QC surveillance.

Where it is determined that background subtraction is necessary, a baseline QC background will be determined specific to that area or region. When background subtraction is required, a QC background surveillance will be performed before a set of measurements are made to verify the applicability of the background to be subtracted. Due to the prevailing variability of the background levels across the site, the nature and extent of such surveillances will be on a case-by-case basis and should be addressed in the documentation associated with the applicable survey plan(s).

In addition to the routine QC counts, each assay report is routinely reviewed with respect to K-40 to provide indications where amplifier drift impacts nuclide identification routines. This review precludes the necessity for specific (i.e. required) after-shift QC surveillances. It also minimizes investigations of previously collected data should the system fail a before-use QC surveillance on the next day of use.

1.2.12 Data Collection

Data collection to support FSS activities will be administered by a specific Survey Plan. Survey Plans may include an index of measurement locations with associated spectrum filenames to ensure that all the required measurements are made and results appropriately managed. Personnel specifically trained to operate the system will perform data collection activities.

Data collection activities will address environmental conditions that may impact soil moisture content. Logs shall be maintained so as to provide a mechanism to annotate such conditions to ensure that efficiency calibration files address the in-situ condition(s). In extreme cases (e.g. standing water, etc.) specific conditions will be addressed to ensure that analysis results reflect the conditions. As previously discussed with respect to water, when unique environmental conditions exist that may impact analysis results, conservative compensatory factors will be applied to the analysis of the data.

1.2.13 Efficiency Calibration

The central feature of the portable ISOCS technology is to support in-situ gamma spectroscopy via the application of mathematically derived efficiency calibrations. Due to the nature of the environment and surfaces being evaluated (assayed), input parameters for the ISOCS efficiency calibrations will be reviewed on a case-by-case basis to ensure the applicability of the resultant efficiency. Material densities applied to efficiency calibrations will be documented. In practice, a single efficiency calibration file may be applied to the majority of the measurements.

The geometry most generally employed will be a circular plane assuming uniformly distributed activity. Efficiency calibrations will address a depth of 15 cm for soil and a depth up to 5 cm for concrete surfaces to account for activity embedded in cracks, etc. Other geometries (e.g. exponential circular plane, rectangular plane, etc.) will be applied if warranted by the physical attributes of the area or surface being evaluated. Efficiency calibrations are developed by radiological engineers who have received training with respect to the ISOCS® software. Efficiency calibrations will be documented in accordance with procedure DP-8869, "In-Situ (ISOCS) Gamma Spectrum Assay System Calibration Procedure."

1.2.14 Data Management

Data management will be implemented in various stages as follows:

- An index or log will be maintained to account for each location where evaluations for elevated activity are performed. Raw spectrum files will be written directly or copied to a central file server.

- Data Analysis – After the spectrum is collected and analyzed, a qualified Radiological Engineer will review the results. The data review process includes application of appropriate background, nuclide libraries, and efficiency calibrations. Data reviews also verify assay results with respect to the applicable investigation levels and the MDCs achieved. Data reviews may include monitoring system performance utilizing K-40. When the data analysis is completed, the analyzed data file will be archived to a unique directory located on a central file server.

- Data Reporting – The results of data files whose reviews have been completed and are deemed to be acceptable may be uploaded to a central database for subsequent reporting and statistical analysis.

- Data Archiving – Routinely (daily) the centralized file server(s) where the raw and analyzed data files are maintained will be backed up to tape.

1.3 Conclusions/Recommendations

The in-situ gamma spectroscopy system is a cost-effective technology well-suited to replace traditional scanning survey techniques to evaluate areas for elevated radioactivity. The static manner in which this system is operated eliminates many variables and limitations inherent to hand-held detectors moving over a surface. This system provides a demonstrably lower detection sensitivity than those offered by hand-held field instruments. This attribute qualifies this system as an alternative technology in lieu of hand-held NaI field instruments in areas where background radiation levels would prohibit the use of such detectors to evaluate for elevated gross activity. The MDC to which this system will be operated satisfies (or exceeds) criteria applied to traditional scan surveys using hand-held field instruments.

Effective investigation levels for both open land areas (i.e. soils) and for building surfaces can be derived and applied to in-situ gamma spectroscopy results. Where surrogate DCGLs are employed, investigation levels will developed on a case-by-case basis using the approach outlined in this document.

The manner in which investigation levels are derived employs several conservative decisions and assumptions. Additionally, adequate spacing applied to scanning survey locations yields an overlap in surface coverage providing 100-percent coverage of Class 1 areas and redundant opportunities in a significant portion of the survey area to detect localized elevated activity.

1.4 References

1. YNPS License Termination Plan, Revision 1
2. Multi-Agency Radiation Survey And Site Investigation Manual (MARSSIM) Revision 1, 2000
3. Canberra User's Manual Model S573 ISOCS Calibration Software, 2002
4. Decommissioning Health Physics - A Handbook for MARSSIM Users, E.W. Abelquist, 2001
5. Canberra's Genie 2000 V3.0 Operations Manual, 2004
6. In-Situ (ISOCS) Gamma Spectrum Assay System Calibration Procedure DP-8869, Revision 0
7. Operation of the Canberra Portable ISOCS Assay System DP-8871 Revision 0
8. Technical Ref., by Thomas J. Glover.

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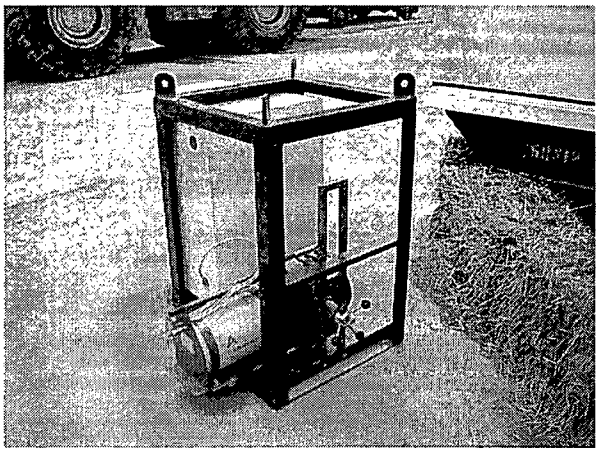
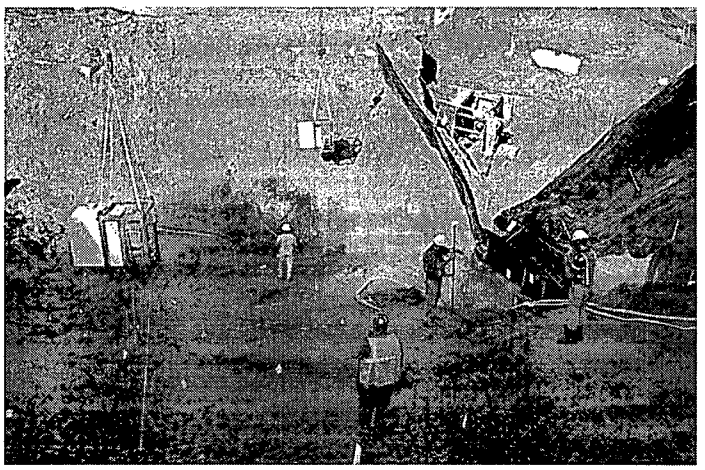
Attachment 1
Portable ISOCS® Detector System Photos





Attachment 2
Field-Of-View Characterization

Generally, the HPGe detector will be outfitted with a 90-degree collimator situated at 2 meters perpendicular to the surface being evaluated. Note that characterizing the detector's field-of-view could be performed without a source by comparing ISOCS-generated efficiencies for various geometries. If a different collimator configuration is to be employed, a similar field-of-view characterization will be performed.

To qualify the field-of-view for this configuration, a series of measurements were made at various off-sets relative to the center of the reference plane. The source used for these measurements was a 1.2 µCi Co-60 point-source with a physical size of approximately 1 cm^3. Each spectrum was analyzed as a point source both with and without background subtract. It was observed that the detector responded quite well to the point source.

Figure 1 presents the results with background subtraction applied. Note that there is a good correlation with the expected nominal activity and that outside the 2-meter radius of the "working" field-of-view (i.e. at 90 inches) some detector response occurs. This validates that the correct attenuation factors are applied to the algorithms used to compute the efficiency calibration.

FIGURE 1

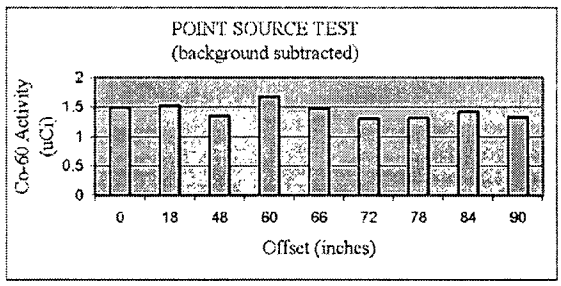
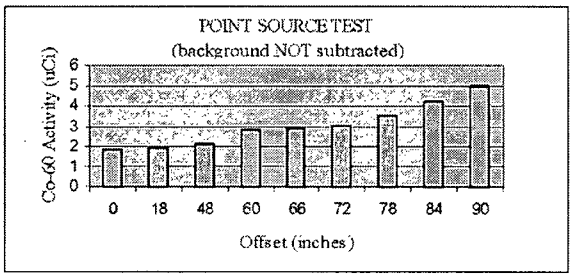


Figure 2 shows the effect of plant-derived materials present in the reference background, which indicates an increasing over-response the further the point source is moved off center. Detector response outside the assumed (i.e. 2-meter) field-of-view would yield conservative results. Normally, source term adjacent to the survey units should be reduced to eliminate background interference.

FIGURE 2


POINT SOURCE TEST
(background NOT subtracted)
Co-60 Activity (uCi)
6
5
4
3
2
1
0
0
18
48
60
66
72
78
84
90
Offset (inches)

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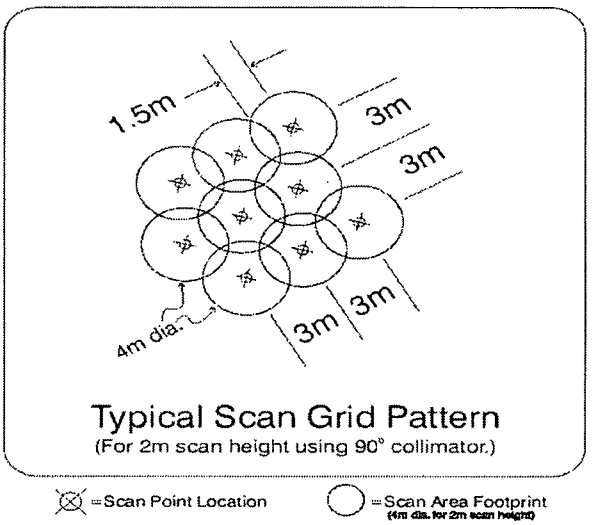
Attachment 3
Typical Grid Pattern For In-Situ Gamma Spectroscopy



Appendix D - ALARA Evaluation WST-01-02

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Figure 1 ALARA Analysis Worksheet

ALARA Analysis Worksheet

11. Decision Criteria: If the sum of the DCGL fractions < AL, then additional remediation is not cost beneficial. If the sum of the fractions > AL, then additional remediation is cost beneficial.

Check one: Additional remediation **IS NOT** cost beneficial ✔
Additional remediation **IS** cost beneficial _____

Prepared by: _____ Date: 12/22/05
FSS Radiological Engineer

Independent Review by: _____ Date: 12-22-05
FSS Project Manager/Radiation Protection Manager

Figure 2 ALARA Worksheet

Survey Area: WST01 Survey Unit: 02	
1. Cost of performing remediation work ($Cost_R$)	$3,840
2. Cost of waste disposal ($Cost_{WD}$) = (2.a) * (2.b) a. estimated waste volume 1 m^3 b. cost of waste disposal 810 $/$m^3$	$810
3. Cost of workplace accident ($Cost_{ACC}$) = $3,000,000 $person^{-1}$ * 4.2 x 10^{-6} h^{-1} * (3.a) a. time to perform remediation action 32 person-hours	$4
4. Cost of traffic fatality ($Cost_{TF}$) = {$3,000,000 * 3.8 x 10^{-6} km^{-1} * (2.a) * (4.a)}/(4.b) a. total distance traveled per shipment 1481 km b. waste volume per shipment 13.6 m^3, if unknown, use 13.6m^3 as a default value	$12
5. Cost of worker dose ($Cost_{WDose}$) = $2,000 per person-rem * (5.a) * (5.b) a. worker TEDE 0.00001 rem/h b. remediation exposure time 32 person-hour	$0
$Cost_T$	$4,666

Figure 3 DCGL Fractions

DCGL Fractions

Radionuclide	Ave. Conc *pci*/gm	DCGL *pci*/gm	Relative Fractio	DCGL Fraction
H-3	0.00E+00		0	
C-14	0.00E+00		0.00E+00	
Fe-55	0.00E+00		0.00E+00	
Co-60*	3.45E+03	3450	7.04E-01	1.0000
Ni-63	0.00E+00		0.00E+00	
Sr-90	0.00E+00		0.00E+00	
Nb-94	0.00E+00		0.00E+00	
Tc-99	0.00E+00		0.00E+00	
Ag-108m	0.00E+00		0.00E+00	
Sb-125	0.00E+00		0.00E+00	
Cs-134	0.00E+00		0.00E+00	
Cs-137*	1.45E+03	1450	2.96E-01	1.0000
Eu-152	0.00E+00		0.00E+00	
Eu-154	0.00E+00		0.00E+00	
Eu-155	0.00E+00		0.00E+00	
Pu-238	0.00E+00		0.00E+00	
Pu-239	0.00E+00		0.00E+00	
Pu-241	0.00E+00		0.00E+00	
Am-241	0.00E+00		0.00E+00	
Cm-243	0.00E+00		0.00E+00	
	Total Concentration	4.90E+03		

Total DCGL Fraction	2.00

* Co-60 and Cs-137 concentrations assumed to be at the worst case (i.e. at their DCGL values). Concentratio at or above these levels automatically warrant remediation.

Figure 4 ALARA Action Levels
ALARA Action Levels

Calculation of ALARA Action Level (AL)

1. Removable fraction for remediation action being evaluated 1
2. Monetary discount rate 0.07 y^{-1}
3. Number of years over which the collective dose is calculated 70 y
4. Population density for the critical group 0.09 people/m^2
5. Survey unit area 1 m^2

Radionuclide	AL
H-3	<MDA
C-14	<MDA
Fe-55	<MDA
Co-60	1.21E+02
Ni-63	<MDA
Sr-90	<MDA
Nb-94	<MDA
Tc-99	<MDA
Ag-108m	<MDA
Sb-125	<MDA
Cs-134	<MDA
Cs-137	2.35E+01
Eu-152	<MDA
Eu-154	<MDA
Eu-155	<MDA
Pu-238	<MDA
Pu-239/240	<MDA
Pu-241	<MDA
Am-241	<MDA
Cm-243/244	<MDA

Sum of AIs	1.45E+02

DCGL Fraction < ALARA AL?	YES

Figure 5 ALARA Cost Worksheet

ATTACHMENT A

$Cost_R$

Equipment rental[1]	$1,920	2 jackhammers for a day $200 air compressor for a day $60
2 construction specialists[2]	$1,120	2X8hrsX$70/hr
1 RP Support [3]	$400	1X8hrsX$50/hr
1 Rad Waste Shipper[4]	$400	1X8hrsX$50
Total	$3,840	

[1] Based on interview of Al Stevens of Cianbro
[2] Based on interview of Al Stevens of Cianbro
[3] Based on Duratek supplying RP Personnel
[4] Based on Duratek supplying Rad Waste Shipper