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September 7, 2006
BYR 2006-079

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-AUX02-00, the Final Status Survey Report for Survey Areas AUX-02

Dear Madam/Sir:

This letter submits YNPS-FSS-AUX02-00, Final Status Survey Report for AUX-02. This report 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.

Sincerely,

YANKEE ATOMIC ELECTRIC COMPANY

Joseph R. Lynch
Joseph R. Lynch
Regulatory Affairs Manager

Enclosure: YNPS-FSS-AUX02-00 (2 hard copies plus CDs)

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Yankee Nuclear Plant Station Final Status Survey Report For AUX-02

Yankee Atomic Electric Company

YANKEE NUCLEAR POWER STATION
FINAL STATUS SURVEY REPORT

REPORT NO.: YNPS-FSS-AUX-02-00

Prepared by: ______________________ Date: 9-6-06
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Reviewed by: ______________________ Date: 9-6-06
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Approved by: ______________________ Date: 9/6/06
Martin Erickson, FSS Manager

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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

A Final Status Survey (FSS) was performed of Survey Area AUX-02 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 AUX-02 structure will be subsurface at license termination. This practice conservatively implements LTP criteria that subsurface structure surfaces be evaluated for the presence of contamination.

1.1 Identification of Survey Area and Units

AUX-02 consists of that portion of the Primary Auxiliary Building (PAB) that was not designed to contain portions of the primary (radioactive) operating systems of the plant. The design of the AUX-02 portion of the PAB did not provide for collection and control of radioactive liquid and gaseous spills or releases, if they occurred within this portion of the PAB. All areas within AUX-02 had floor drains that channeled liquids to the storm drain system. These spaces were not ventilated through the Primary Ventilation System. AUX-02 is bounded by NOL-01 and NOL-06 on the north, AUX-01 on the east, NOL-05 on the south and NOL-06 on the west.

1.2 Dates(s) of Survey

Table 1 Date of Surveys

Survey Unit	Survey Start Date	Survey End Date	DQA Date
AUX-02-01	6/16/2006	6/22/2006	7/24/2006
AUX-02-02	6/16/2006	6/22/2006	7/24/2006

1.3 Number and Types of Measurements Collected

Final Status Survey Plan (FSSP) was developed for these Survey Units 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 40 systematic fixed-point measurements were taken in the 2 Survey Units, providing data for the non-parametric testing of the Survey Area. In addition to the fixed-point samples, ISOCS and 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. Fixed point surveys indicated that none of the systematic measurements exceeded the $DCGL_W$, depicted in Attachment B. Retrospective power curves were generated and demonstrated that an adequate number of samples were collected to support the Data Quality Objectives. 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, AUX-02 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. 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 Description

AUX-02 consists of that portion of the PAB that was not designed to contain portions of the primary (radioactive) operating systems of the plant. The design of the AUX-02 portion of the PAB did not provide for collection and control of radioactive liquid and gaseous spills or releases, if they occurred within this portion of the PAB. All areas within AUX-02 had floor drains that channeled liquids to the storm drain system. These spaces are not ventilated through the Primary Ventilation System. AUX-02 is bounded by NOL-01 and NOL-06 on the north, AUX-01 on the east, NOL-05 on the south and NOL-06 on the west. Survey Unit AUX-02-02 consists of the north face of the south PAB wall in the west end section of the former structure and contains a total surface area of 58 m2. Survey Unit AUX-02-01 consists of the west face of the east PAB wall in the west end section of the former structure and contains a total surface area of 16 m2.

3.2 History of Survey Area

The AUX-02 area of the PAB was identified as a contaminated area as a result of a cross-contaminating event where water spilled from the seal water system vent. Contamination of AUX-02 also occurred when the Safety Injection Tank heating system pump leaked resulting in contamination of the floor and floor drains in the lower level of the PAB. Over the operating history of the YNPS, this portion of the plant has been decontaminated, in order to maintain it as a non-contaminated area. The majority of the PAB was demolished to ~3ft above ground level.

3.3 Division of Survey Area into Survey Units

AUX-02 consists of two Survey Units, AUX-02-01, and AUX-02-02.

4.0 SURVEY UNIT INFORMATION

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

4.1.1 Chronology and Description of Surveys Since HSA

Isolation and control measures were implemented for the FSS. The condition of AUX-02 Survey Units 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 the AUX-02 Survey Units.

4.1.3 Scoping & Characterization

The identities of the radionuclides-of-concern for this survey effort, as well as the statistical data, are based on results acquired from the FSS of survey units AUX-01-01 and AUX-01-02 as well as information provided in the free release effort. Pre-remediation and investigation data indicates a 70/30 to 80/20 Cs-137 to Co-60 ratio. In addition to the pre-remediation data, ISOCS assays of AUX-01-02 indicate the major isotopic contributor to be Cs-137. If a weighted DCGLw were to be calculated utilizing this data the resultant values would be considerably higher than using the DCGL value for Co-60 alone. In keeping with the previous conservative approach to the PAB concrete surfaces (i.e. protocols used for AUX-01-01 and AUX-01-02), the survey plan used the DCGL values for the most limiting isotope Co-60 for AUX-02 FSSP calculations.

4.2 Basis for Classification

Based upon the radiological condition of this survey area identified in the operating history and as a result of the decommissioning activities performed to date, survey area AUX-02 is identified as a Class 1 Area.

4.3 Remedial Actions and Further Investigations

No investigations were performed in AUX-02.

4.4 Unique Features of Survey Area

Survey Area AUX-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 (Appendix 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 4.2 of the YA-REPT-00-

015-04 (Appendix 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 each Survey Unit in the AUX-02 Survey Area which concluded that additional remediation was not warranted. These evaluations are found in Appendix C.

5.0 SURVEY UNIT FINAL STATUS SURVEY

5.1 Survey Planning

5.1.1 Final Status Survey Plan and Associated DQOs

The FSS for AUX-02 Survey Units 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 Plans 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 below.

Table 2 Survey Area AUX-02 Design Parameters

Survey Unit	Design Parameter	Value	Basis
AUX-02-01	Survey Unit Area	16 m2	Class 1, Concrete, ≤ 100 m2
	Number of Direct Measurements	15 (calculated) + 5 (added) Total: 20	α (Type I) = 0.05 β (Type II) = 0.05 σ: 636 Relative Shift: 2 DCGLw: 7200 LBGR: 5928
	Critical Value	14 for Sign test.	(20/2)+(1.645/2)*Square Root (20)
	Gridded Sample Area Size Factor	0.8m2	Area / Number of Samples (16 m2/20)
	Sample Grid Spacing:	Triangular: 1m	Square Root (16 m2/(0.866*20))

Survey Unit	Design Parameter	Value	Basis
	Direct Measurement Investigation Level	> DCGLemc or > DCGLw + 3 Sigma	Class 1 Area: > DCGLemc or > DCGLw + 3 Sigma
	Scanning Coverage Requirements	16 m2	Class 1 Concrete Area: 100%
	Scan Investigation Level	Co-60: 2.9E3 dpm/100cm2 Cs-137 : 1.1E4 dpm/100cm2	Class 1 Area: > DCGLemc
AUX-02-02	Survey Unit Area	58 m2	Class 1, Concrete, ≤ 100 m2
	Number of Direct Measurements	15 (calculated) + 5 (added) Total: 20	α (Type I) = 0.05 β (Type II) = 0.05 σ: 636 Relative Shift: 2 DCGLw: 7200 LBGR: 5928
	Critical Value	14 for Sign test.	(20/2)+(1.645/2)*Square Root (20)
	Gridded Sample Area Size Factor	2.9m2	Area / Number of Samples (58 m2/20)
	Sample Grid Spacing:	Triangular: 1.8m	Square Root (58 m2/(0.866*20))
	Direct Measurement Investigation Level	> DCGLemc or > DCGLw + 3 Sigma	Class 1 Area: > DCGLemc or > DCGLw + 3 Sigma
	Scanning Coverage Requirements	58 m2	Class 1 Concrete Area: 100%
	Scan Investigation Level	Co-60: 2.9E3 dpm/100cm2 Cs-137 : 1.1E4 dpm/100cm2	Class 1 Area: > DCGLemc

5.1.2 Deviations from the FSS Plan as Written in the LTP

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 AUX-02 were met in accordance with YNPS LTP. DCGL values and the associated MDC values can be found in Table 3.

Table 3 $DCGL_W$, $DCGL_{EMC}$ 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	7.2E+03	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 Area need to be evaluated.

5.1.3 DCGL Selection and Use

It must be noted that for the final evaluation of the AUX-02 Survey Units 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 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.

5.1.4 Measurements

Error tolerances and characterization sample population statistics drove the selection of the number of fixed point measurements.

The fixed-point sampling grid was developed as a systematic grid with spacing consisting of a triangular pitch pattern with a random starting point. Sample measurement locations are provided in Attachment A.

A total of 17 ISOCS scans were performed in the Survey Units 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 D).

5.2 Survey Implementation Activities

Table 3 provides a summary of daily activities performed during the Final Status Survey of Survey Units in AUX-02.

Table 4 FSS Activity Summary for AUX-02 Survey Units

Survey Unit	Date	Activity
AUX-02-01	6/13/2006	Performed Job Hazard Analysis
	6/13/2006	Performed Unit Classification
	6/16/2006	Performed Sample Quantity Calculations, established DQOs
	6/20/2006	Performed walk-down of Survey Unit
	6/20/2006	Established Isolation and Controls
	6/20/2006	Generated FFS Sample Plans
	6/21/2006	Initiated Scans, and Direct measurements.
	7/24/2006	Performed DQA, FSS Complete
AUX-02-02	6/13/2006	Performed Job Hazard Analysis
	6/13/2006	Performed Unit Classification
	6/16/2006	Performed Sample Quantity Calculations, established DQOs
	6/20/2006	Performed walk-down of Survey Unit
	6/20/2006	Established Isolation and Controls
	6/20/2006	Generated FFS Sample Plans
	6/21/2006	Initiated Scans, and Direct measurements.
	7/24/2006	Performed DQA, FSS Complete

5.3 Surveillance Surveys

5.3.1 Periodic Surveillance Surveys

There is no footprint to base a periodic surveillance survey upon, so Survey Area AUX-02 was not placed into the program for periodic surveillance surveys in accordance with YNPS procedure DP-8860, "*Area Surveillance Following Final Status Survey.*"

5.3.2 Resurveys

No resurveys were performed.

5.3.3 Investigations

No additional investigations were required for this Survey Unit due to surveillance surveys.

5.4 Survey Results

Direct measurement surveys indicated that no Survey Units had systematic measurements that exceeded the $DCGL_W$, depicted in Attachment B. Retrospective power curves were generated and demonstrated that an adequate number of samples were collected to support the Data Quality Objectives. Therefore, the null hypothesis (H_o) (that the Survey Units exceeds the release criteria) is rejected.

Table 5 Direct Measurement Summary (DPM/100cm2)

Survey Unit	Systematic Samples	Average	Standard Deviation	Maximum	Samples Above DCGLw	Samples Above DCGLemc
AUX-02-01	20	620	420	1372	0	0
AUX-02-02	20	574	277	974	0	0

Table 6 Direct Measurements (DPM/100cm2)

Sample Description	Activity	Sample Description	Activity
AUX-02-01-001-F-FM	1,372	AUX-02-02-001-F-FM	625
AUX-02-01-002-F-FM	1,239	AUX-02-02-002-F-FM	377
AUX-02-01-003-F-FM	642	AUX-02-02-003-F-FM	526
AUX-02-01-004-F-FM	261	AUX-02-02-004-F-FM	824
AUX-02-01-005-F-FM	1,140	AUX-02-02-005-F-FM	974
AUX-02-01-006-F-FM	891	AUX-02-02-006-F-FM	509
AUX-02-01-007-F-FM	1,040	AUX-02-02-007-F-FM	808
AUX-02-01-008-F-FM	625	AUX-02-02-008-F-FM	62
AUX-02-01-009-F-FM	824	AUX-02-02-009-F-FM	659
AUX-02-01-010-F-FM	858	AUX-02-02-010-F-FM	742
AUX-02-01-011-F-FM	791	AUX-02-02-011-F-FM	78
AUX-02-01-012-F-FM	(21)	AUX-02-02-012-F-FM	841
AUX-02-01-013-F-FM	443	AUX-02-02-013-F-FM	344
AUX-02-01-014-F-FM	426	AUX-02-02-014-F-FM	625
AUX-02-01-015-F-FM	95	AUX-02-02-015-F-FM	194
AUX-02-01-016-F-FM	543	AUX-02-02-016-F-FM	824
AUX-02-01-017-F-FM	775	AUX-02-02-017-F-FM	692
AUX-02-01-018-F-FM	493	AUX-02-02-018-F-FM	592
AUX-02-01-019-F-FM	95	AUX-02-02-019-F-FM	941
AUX-02-01-020-F-FM	(121)	AUX-02-02-020-F-FM	244

Table 7 Replicate Surveys Direct Measurements (DPM/100cm2)

Sample Description	Activity	Sample Description	Activity
AUX-02-01-001-Q-FM	961	AUX-02-02-001-Q-FM	528
AUX-02-01-002-Q-FM	943	AUX-02-02-002-Q-FM	1,308
AUX-02-01-003-Q-FM	1,009	AUX-02-02-003-Q-FM	1,407
AUX-02-01-004-Q-FM	578	AUX-02-02-004-Q-FM	213

Sample Description	Activity	Sample Description	Activity
AUX-02-01-005-Q-FM	760	AUX-02-02-005-Q-FM	313
AUX-02-01-006-Q-FM	727	AUX-02-02-006-Q-FM	1,225
AUX-02-01-007-Q-FM	1,175	AUX-02-02-007-Q-FM	1,109
AUX-02-01-008-Q-FM	843	AUX-02-02-008-Q-FM	1,125
AUX-02-01-009-Q-FM	1,739	AUX-02-02-009-Q-FM	1,175
AUX-02-01-010-Q-FM	1,092	AUX-02-02-010-Q-FM	429
AUX-02-01-011-Q-FM	1,606	AUX-02-02-011-Q-FM	479
AUX-02-01-012-Q-FM	893	AUX-02-02-012-Q-FM	180
AUX-02-01-013-Q-FM	1,474	AUX-02-02-013-Q-FM	993
AUX-02-01-014-Q-FM	246	AUX-02-02-014-Q-FM	711
AUX-02-01-015-Q-FM	462	AUX-02-02-015-Q-FM	1,524
AUX-02-01-016-Q-FM	1,258	AUX-02-02-016-Q-FM	1,125
AUX-02-01-017-Q-FM	1,457	AUX-02-02-017-Q-FM	877
AUX-02-01-018-Q-FM	1,076	AUX-02-02-018-Q-FM	528
AUX-02-01-019-Q-FM	993	AUX-02-02-019-Q-FM	-268
AUX-02-01-020-Q-FM	1,192	AUX-02-02-020-Q-FM	-69

Table 8 Original and Replicate ISOCS Scan Data

Sample Title	Unity	Sample Title	Unity	Sample Title	Unity
AUX-02-01-101-F-G	0.00	AUX-02-02-104-F-G	0.00	AUX-02-02-109-Q-G	0.00
AUX-02-01-101-Q-G	0.00	AUX-02-02-104-Q-G	0.00	AUX-02-02-110-F-G	0.00
AUX-02-01-102-F-G	0.00	AUX-02-02-105-F-G	0.00	AUX-02-02-110-Q-G	0.00
AUX-02-01-102-Q-G	0.00	AUX-02-02-105-Q-G	0.00	AUX-02-02-111-F-G	0.06
AUX-02-01-103-F-G	0.00	AUX-02-02-106-F-G	0.00	AUX-02-02-111-Q-G	0.00
AUX-02-01-103-Q-G	0.00	AUX-02-02-106-Q-G	0.00	AUX-02-02-112-F-G	0.00
AUX-02-02-101-F-G	0.00	AUX-02-02-107-F-G	0.00	AUX-02-02-112-Q-G	0.00
AUX-02-02-101-Q-G	0.00	AUX-02-02-107-Q-G	0.00	AUX-02-02-113-F-G	0.00
AUX-02-02-102-F-G	0.00	AUX-02-02-108-F-G	0.00	AUX-02-02-113-Q-G	0.00
AUX-02-02-102-Q-G	0.00	AUX-02-02-108-Q-G	0.00	AUX-02-02-114-F-G	0.00
AUX-02-02-103-F-G	0.00	AUX-02-02-109-F-G	0.00	AUX-02-02-114-Q-G	0.00
AUX-02-02-103-Q-G	0.00				

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.

A data review was performed and statistical quantities were calculated. The final standard deviations for both units were less than the estimated standard deviations used for the DQOs. The data were within three standard deviations of their respective mean. The frequency and scatter plots for AUX-02-01 exhibit a normal Poisson distribution with the data distributed about the mean. The frequency and scatter plots for AUX-02-02 indicate a slight skew to the right accounting for some asymmetry in the upper quartile; however neither posting plot clearly reveal any systematic spatial trends. The data for both units verifies the assumptions for the statistical test.

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*".

The Data Quality Assessment power curves, scatter, quantile and frequency plots are found in Attachment B. Posting Plots are found in Attachment A.

6.0 QUALITY ASSURANCE AND QUALITY CONTROL

6.1 Instrument QC Checks

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. All instrumentation involved with the FSS of AUX-02 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 soil samples and provides no criteria for fixed-point measurements therefore no measurement comparison were made.

6.3 Self-Assessments

Replicate surveys were performed on AUX-02-01 and AUX-02-02 to satisfy the quality control requirements of the QAPP, APF-8852. A replication of five percent of the direct measurements are suggested in APF-8852, however the decision was made to replicate all 40 measurements in this Survey Area to add additional quality to the evaluation. The true variance of the replicate survey sample results were evaluated against the estimated variance of the original FSS sample data. Two statistical differences were found out of 40 samples. However the two differences were due to an extremely low variance in the source data, and did not adversely affect the radiological status of the survey unit. No Type I errors occurred and no data were greater than 1/3 of the DCGLw. A copy of the replicate survey evaluations is found in Attachment B.

7.0 CONCLUSION

The FSS of AUX-02 has been performed in accordance with YNPS LTP and applicable FSS procedures. Evaluation of the fixed-point data has shown none of the systematic fixed-point measurements exceeded the $DCGL_W$, depicted in Attachment B. Retrospective power curves were generated and demonstrated that an adequate number of samples were collected to support the Data Quality Objectives. Therefore, the null hypothesis (H_0) is rejected.

AUX-02 meets the objectives of the Final Status Survey.

Based upon the evaluation of the data acquired for the FSS, AUX-02 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

List of Attachments

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

Final Status Survey Planning Worksheet

GENERAL SECTION	
Survey Area #: AUX-02	Survey Unit #: 01
Survey Unit Name: PAB West End	
FSSP Number: YNPS-FSSP-AUX02-01-00	

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 State the problem:

Survey Unit AUX-02-01 has been selected to have a replicate survey. This is the FSS survey. The replicate survey is a subset of this plan.

Survey Unit AUX-02-01 consists of the west face of the east PAB wall in the west end section of the former structure and contains a total surface area of 16 m^2.

This wall, in conjunction with the remaining PAB walls, was originally part of a "free release" effort prior to demolition of the PAB structure.

The identities of the radionuclides-of-concern for this survey effort, as well as the statistical data, are based on results acquired from the FSS of survey units AUX-01-01 and AUX-01-02 as well as information provided in the "free release" effort. Pre-remediation and investigation data indicates a 70/30 to 80/20 Cs^{137} \ Co^{60} ratio. In addition to the pre-remediation data, ISOCS assays of AUX-01-02 indicate the major isotopic contributor to be Cs^{137}. If a weighted $DCGL_W$ were to be calculated utilizing this data the resultant values would be considerably higher than using the DCGL value for Co^{60} alone. In keeping with the previous conservative approach to the PAB concrete surfaces (i.e. protocols used for AUX-01-01 and AUX-01-02), this survey plan will use the DCGL values for the most limiting isotope Co^{60} for AUX-02-01 FSSP calculations.

Data used to determine the number of samples are derived from the FSS of survey unit AUX-01-02.

Initial HSA and surveys prompted a LTP MARSSIM Classification of 1 for AUX-02, and due to remedial activities performed in adjacent areas, AUX-02-01 will remain a Class 1 area.

The problem, therefore, is to determine and demonstrate that residual licensed radioactive materials, if present in AUX-02-01, meets the LTP release criterion

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:

The decision to be made can be stated "Does residual plant-related radioactivity, if present in the survey unit, exceed the release criteria?"

Alternative actions that may be employed are investigation, re-survey and remediation or disposal.

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}.

DCGLs:

Applicable DCGL$_w$: 7200 dpm/100cm^2 (Co^{60} assumed as a conservative measure)

__Note__: The DCGL$_W$ value corresponds to ~~8.73~~ 10 mrem/y. MR 8-31-06

Some surfaces 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 as much as 1 inch. 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 on irregular surfaces. The ε_i value for a distance of ½ inch will be applied to HP-100 data collected from smooth concrete surfaces. 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

Gross measurement $DCGL_W$ (for HP-100): 7200 dpm/100cm^2

- for smooth concrete surface: 7200 dpm/100cm^2 * 0.0603 c/d = 434 cpm/100cm^2
- for pitted/irregular surface: 7200 dpm/100cm2 * 0.0373 c/d = 269 cpm/100cm^2

Applicable $DCGL_{EMC}$ for fixed-point measurements*:* $DCGL_w$ * AF = 7200 dpm/100cm^2 *7.3 = 52,600 dpm/100cm^2

- for smooth concrete surface: 52,600 dpm/100cm^2 * 0.0603 c/d = 3170 cpm/100cm^2
- for pitted/irregular surface: 52,600 dpm/100cm2 * 0.0373 c/d = 1960 cpm/100cm^2.

<u>Note</u>: The $DCGL_W$ and $DCGL_{EMC}$ values refer to above-background radioactivity.

Investigation Level for fixed-point measurement:

- for smooth concrete surface: >3170 cpm/100cm^2 above background
- for pitted/irregular concrete surface: >1960 cpm/100cm^2 above background

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

Investigation Level for ISOCS scans: 1m90d scan height: 1.7^{E+04} dpm/100cm^2 (Co^{60}).
2m90d scan height: 2.91^{E+03} dpm/100cm^2 (Co^{60}).

<u>Note</u>: The investigation levels for the ISOCS scans 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 2m scan height and 3.14m^2 for 1m scan height) 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 (52,600 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} and in turn the f($DCGL_{EMC}$) will be compared to Unity (i.e. SOF<1).

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}	5200	Sb^{125}	29,000	Eu^{152}	11,000
Nb^{94}	7600	Cs^{134}	8600	Eu^{154}	10,000
Ag^{108m}	7300	Cs^{137}	19,000	Eu^{155}	190,000

<u>Note:</u> The MDCs listed in the above table are 10% of the $DCGL_{EMC}$ values (based on concrete surface DCGLs & nuclide-specific AF value for 6m^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.

MDC_{fixed}: Refer to Attachments 1 and 1A.

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

QC checks and measurements: QC checks for the survey instruments will be performed in accordance with DP-8534 and DP-8540. 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.

Investigation level for SPA-3 scans: 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).

4.0 Define the boundaries of the survey:

AUX-02-01 is comprised of the west face of the south PAB wall in the west end section of the former structure and contains a total surface area of 16 m^2. **Note:** A random-start systematic grid has been developed to identify the fixed-point measurement locations.

Surveying of AUX-02-01 will be performed when weather conditions will not adversely affect the data acquisition.

5.0 Develop a decision rule:

(a) If all of the data show that the concentrations of all plant-related nuclides are below the $DCGL_W$ and the sum of their DCGL fractions are less than unity then reject the null hypothesis (i.e. the Survey Unit meets the release criteria).

(b) If the action levels are exceeded, then perform an investigation survey.

(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 concentration exceeds the $DCGL_W$ then accept the null hypothesis (i.e. the Survey Area does not 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 AUX-02-01 exceeds the release criterion".

Probability of type I (α) error: 0.05
Probability of type II (β) error: 0.05

LBGR: $DCGL_w/2$ = 3600 dpm/100cm^2 (systematic measurements)

7.0 Optimize Design:

Type of statistical test: **Sign Test**

Number of measurements: 20 (Systematic grid from a random start point.)

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. If any surface areas are not accessible with the ISOCS, scan with the E600/HP-100 in accordance with DP-8534.
4. The job hazards associated with the FSS in Survey Unit 01 are addressed in the accompanying JHA.
5. All personnel participating in this survey shall be trained in accordance with DP-8868.

SPECIFIC INSTRUCTIONS

1. Grid AUX-02-01 for 100% scan coverage 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 (AUX-02-01-xxx-F-G [xxx is the 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 $\geq$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 AUX-02-01-021-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: 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 shown on the Direct Measurement maps 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 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).

(c) Designation for fixed-point measurements: AUX-02-01-001-F-FM through AUX-02-01-020-F-FM corresponding to FSS measurement locations 001 through 020.

6. If necessary, perform a background survey as follows:

(a) Cover the detector with 1/8-inch Lucite shield, or equivalent, and collect a series of 21, one-minute background readings according to the following plan:

(1) Find three locations, as widely separated as possible, that are at least one meter from any edge of the concrete. At each of these locations position the detector one meter from the wall, facing the wall and take a set of seven, one-minute scaler counts.

(2) Mark the approximate location on a blank map

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

Prepared by J. Hummer Date 6-20-06
FSS Radiological Engineer

Reviewed by Tozzie Date 6/20/06
FSS Radiological Engineer

Approved by Martin C Erickson Date 6/20/06
FSS Manager

Final Status Survey Planning Worksheet

GENERAL SECTION	
Survey Area #: AUX-02	Survey Unit #: 02
Survey Unit Name: PAB West End	
FSSP Number: YNPS-FSSP-AUX02-02-00	

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 State the problem:

Survey Unit AUX-02-02 has been selected to have a replicate survey. This is the FSS survey. The replicate survey is a subset of this plan.

Survey Unit AUX-02-02 consists of the north face of the south PAB wall in the west end section of the former structure and contains a total surface area of 58 m^2.

This wall, in conjunction with the remaining PAB walls, was originally part of a "free release" effort prior to demolition of the PAB structure.

The identities of the radionuclides-of-concern for this survey effort, as well as the statistical data, are based on results acquired from the FSS of survey units AUX-01-01 and AUX-01-02 as well as information provided in the "free release" effort. Pre-remediation and investigation data indicates a 70/30 to 80/20 Cs^{137} \ Co^{60} ratio. In addition to the pre-remediation data, ISOCS assays of AUX-01-02 indicate the major isotopic contributor to be Cs^{137}. If a weighted $DCGL_W$ were to be calculated utilizing this data the resultant values would be considerably higher than using the DCGL value for Co^{60} alone. In keeping with the previous conservative approach to the PAB concrete surfaces (i.e. protocols used for AUX-01-01 and AUX-01-02), this survey plan will use the DCGL values for the most limiting isotope Co^{60} for AUX-02-02 FSSP calculations.

Data used to determine the number of samples are derived from the FSS of survey unit AUX-01-02.

Initial HSA and surveys prompted a LTP MARSSIM Classification of 1 for AUX-02, and due to remedial activities performed in adjacent areas, AUX-02-02 will remain a Class 1 area.

The problem, therefore, is to determine and demonstrate that residual licensed radioactive materials, if present in AUX-02-02, meets the LTP release criterion

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:

The decision to be made can be stated "Does residual plant-related radioactivity, if present in the survey unit, exceed the release criteria?"

Alternative actions that may be employed are investigation, re-survey and remediation or disposal.

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}.

DCGLs:

Applicable $DCGL_w$: 7200 dpm/100cm^2 (Co^{60} assumed as a conservative measure)

Note: The $DCGL_w$ value corresponds to 10 mrem/y.

Some surfaces 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 as much as 1 inch. 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 on irregular surfaces. The ε_i value for a distance of ½ inch will be applied to HP-100 data collected from smooth concrete surfaces. 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

Gross measurement $DCGL_W$ (for HP-100): 7200 dpm/100cm^2

- for smooth concrete surface: 7200 dpm/100cm^2 * 0.0603 c/d = 430 cpm/100cm^2
- for pitted/irregular surface: 7200dpm/100cm2 * 0.0373 c/d = 270 cpm/100cm^2

Applicable $DCGL_{EMC}$ for fixed-point measurements*:* $DCGL_w$ * AF = 7200 dpm/100cm^2 *2.4 = 17300 dpm/100cm^2

- for smooth concrete surface: 17300 dpm/100cm^2 * 0.0603 c/d = 1040 cpm/100cm^2
- for pitted/irregular surface: 17300 dpm/100cm2 * 0.0373 c/d = 640 cpm/100cm^2.

Note: The $DCGL_W$ and $DCGL_{EMC}$ values refer to above-background radioactivity.

Investigation Level for fixed-point measurement:

- for smooth concrete surface: >1040 cpm/100cm^2 above background
- for pitted/irregular concrete surface: >640 cpm/100cm^2 above background

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

Investigation Level for ISOCS scans: 1m90d scan height: 17,280 dpm/100cm^2 (Co^{60}).
2m90d scan height: 2910 dpm/100cm^2 (Co^{60}).

Note: The investigation levels for the ISOCS scans 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 2m scan height and 3.14m^2 for 1m scan height) 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 (52,600 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} and in turn the $f(DCGL_{EMC})$ will be compared to Unity (i.e. SOF<1).

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}	1700	Sb^{125}	9700	Eu^{152}	3600
Nb^{94}	2500	Cs^{134}	2900	Eu^{154}	3300
Ag^{108m}	2400	Cs^{137}	6300	Eu^{155}	2400

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 4m^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.

MDC_{fixed}: Refer to Attachments 1 and 1A.

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

QC checks and measurements: QC checks for the survey instruments will be performed in accordance with DP-8534 and DP-8540. 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.

Investigation level for SPA-3 scans: 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).

4.0 Define the boundaries of the survey:

AUX-02-02 is comprised of the north face of the south PAB wall in the west end section of the former structure and contains a total surface area of 58 m^2. **Note:** A random-start systematic grid has been developed to identify the fixed-point measurement locations.

Surveying of AUX-02-02 will be performed when weather conditions will not adversely affect the data acquisition.

5.0 Develop a decision rule:

(a) If all of the data show that the concentrations of all plant-related nuclides are below the $DCGL_W$ and the sum of their DCGL fractions are less than unity then reject the null hypothesis (i.e. the Survey Unit meets the release criteria).

(b) If the action levels are exceeded, then perform an investigation survey.

(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 concentration exceeds the $DCGL_W$ then accept the null hypothesis (i.e. the Survey Area does not 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 AUX-02-02 exceeds the release criterion".

Probability of type I (α) error: 0.05
Probability of type II (β) error: 0.05

LBGR: $DCGL_w/2 = 3600$ dpm/100cm^2 (systematic measurements)

7.0 Optimize Design:

Type of statistical test: **Sign Test**

Number of measurements: 20 (Systematic grid from a random start point.)

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. If any surface areas are not accessible with the ISOCS, scan with the E600/HP-100 in accordance with DP-8534.
4. The job hazards associated with the FSS in Survey Unit 02 are addressed in the accompanying JHA.
5. All personnel participating in this survey shall be trained in accordance with DP-8868.

SPECIFIC INSTRUCTIONS

1. Grid AUX-02-02 for 100% scan coverage 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 (AUX-02-02-xxx-F-G) (xxx is the sequential number starting at 101) 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 $\geq$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 19,000 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 AUX-02-02-021-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: 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 shown on the Direct Measurement maps 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 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).

(c) Designation for fixed-point measurements: AUX-02-02-001-F-FM through AUX-02-02-020-F-FM corresponding to FSS measurement locations 001 through 020.

6. If necessary, perform a background survey as follows:

(a) Cover the detector with 1/8-inch Lucite shield, or equivalent, and collect a series of 21, one-minute background readings according to the following plan:

(1) Find three locations, as widely separated as possible, that are at least one meter from any edge of the concrete. At each of these locations position the detector one meter from the wall, facing the wall and take a set of seven, one-minute scaler counts.

(2) Mark the approximate location on a blank map

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

Prepared by ______________ Date 6/20/06
FSS Radiological Engineer

Reviewed by J. Hummer Date 6-20-06
FSS Radiological Engineer

Approved by ______________ Date 6/20/06
FSS MANAGER

Attachment 1

SPA-3 Scan

Inputs:

Scan speed: 0.13 m/s MDCR = 1.38*sqrt(b)/sqrt(p)*t

Where:

b = background counts in time t

p = surveyor efficiency = 0.5

t = time the detector is above localized activity = 4.31 s = 0.0718 min

Assume:

Localized contam diam = 56 cm

$$MDC(fDCGL_{EMC}) = MDCR\sum(f^i / E_i AF^i DCGL^i) \quad \text{(DP-8853)}$$

AF= Area Factor

E_i = Scanning instrument efficiency (YA-REPT-00-015-04)

f = radionuclide fraction

	Cs-137	Co-60	
E_i =	188	379	cpm/pCi/g*
DCGL	3	1.4	
f =	0	1	
AF =	3.1	2.4	

BKG(cpm)	BKG/t	MDCR	MDC(fDCGL$_{emc}$(8.73))
7000	502.6	609	4.79E-01
8000	574.4	651	5.12E-01
9000	646.2	691	5.43E-01
10000	717.9	728	5.72E-01
11000	789.7	764	6.00E-01
12000	861.5	798	6.27E-01
13000	933.3	830	6.52E-01
14000	1005.1	862	6.77E-01
15000	1076.9	892	7.01E-01
16000	1148.7	921	7.23E-01
17000	1220.5	950	7.46E-01
18000	1292.3	977	7.67E-01
19000	1364.1	1004	7.88E-01
20000	1435.9	1030	8.09E-01
21000	1507.7	1055	8.29E-01
22000	1579.5	1080	8.48E-01
23000	1651.3	1105	8.67E-01
24000	1723.1	1128	8.86E-01

*E_i values from YA-REPT-00=015-04, "Instrument Efficiency Determination for Use in Minimum Detectable Concentration Calculations in Support of Final Status Survey at Yankee Rowe"

YNPS-FSSP-AUX-02-02-00
Attachment 2

DCGL MDC Table

Nuclide	Building Surfac 10 mr/yr (dpm/100cm2)	10% MDC DCGL	50% MDC DCGL	Easy to Detect?	Area Factor	DCGLemc
Co-60	7.2E+03	1.4E-01	7.0E-01	ETD	2.4E+00	1.7E+04
Nb-94	1.0E+04	2.5E-01	1.3E+00	ETD	2.4E+00	2.4E+04
Ag-108m	1.0E+04	2.5E-01	1.3E+00	ETD	2.4E+00	2.4E+04
Sb-125	4.0E+04	1.1E+00	5.6E+00	ETD	2.4E+00	9.6E+04
Cs-134	1.2E+04	1.7E-01	8.7E-01	ETD	2.5E+00	3.0E+04
Cs-137	2.5E+04	3.0E-01	1.5E+00	ETD	2.5E+00	6.3E+04
Eu-152	1.5E+04	3.6E-01	1.8E+00	ETD	2.4E+00	3.6E+04
Eu-154	1.4E+04	3.3E-01	1.7E+00	ETD	2.4E+00	3.4E+04
Eu-155	2.6E+05	1.4E+01	6.9E+01	ETD	2.5E+00	6.5E+05
Am-241	2.0E+03	1.0E+00	5.1E+00	ETD	4.9E+00	9.8E+03
H-3	1.4E+08	1.3E+01	6.4E+01	HTD	4.9E+00	6.9E+08
C-14	4.0E+06	1.9E-01	9.7E-01	HTD	4.9E+00	2.0E+07
Fe-55	1.6E+07	1.0E+03	5.1E+03	HTD	4.9E+00	7.8E+07
Ni-63	1.5E+07	2.8E+01	1.4E+02	HTD	4.9E+00	7.4E+07
Sr-90	5.6E+04	6.0E-02	3.0E-01	HTD	4.8E+00	2.7E+05
Tc-99	5.6E+06	5.0E-01	2.5E+00	HTD	4.7E+00	2.6E+07
Pu-238	2.3E+03	1.2E+00	5.8E+00	HTD	4.9E+00	1.1E+04
Pu-239	2.0E+03	1.1E+00	5.3E+00	HTD	4.9E+00	9.8E+03
Pu-241	1.0E+05	3.4E+01	1.7E+02	HTD	4.9E+00	4.9E+05
Cm-243	2.9E+03	1.1E+00	5.6E+00	HTD	4.7E+00	1.4E+04

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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:	Christopher Alvarez	Date:	10-7-04
Reviewer:	James R. Hummer	Date:	10/7/04
Approver (Cognizant Manager):	R C Smith	Date:	10/7/04

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Appendix

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_i), 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

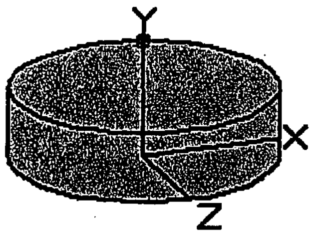
MicroShield v6.02 (6.02-00253)

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

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
				(E) Total:	**379**

APPENDIX C

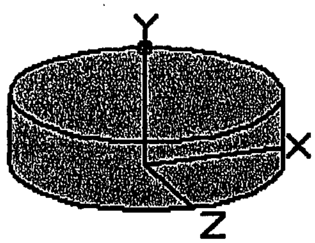
MicroShield v6.02 (6.02-00253)

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	1.861e-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)	E, (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
				(E) Total	416

APPENDIX E

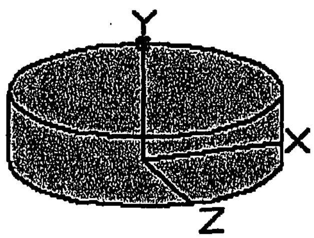
MicroShield v6.02 (6.02-00253)

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

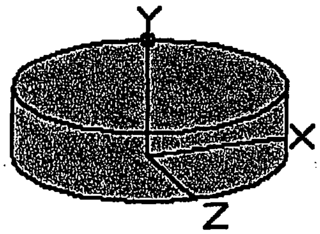
Ag-108m Microsoft Excel E_i Calculation Sheet					
	Energy MeV	Energy kev	Exposure Rate (mR/hr /pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
3	0.0028	3	1.39E-07		0
3	0.003	3	1.66E-08		0
21	0.021	21	3.01E-07		0
21	0.0212	21	5.74E-07		0
22	0.022	22	8.83E-09		0
22	0.0222	22	1.69E-08		0
24	0.0238	24	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
				(E_i) Total:	637

APPENDIX G

MicroShield v6.02 (6.02-00253)

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

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
# 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
Sb-125	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
0.0038	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	2.146e-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	4.295e-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	3.630e-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+02	8.668e-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

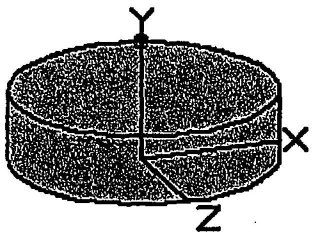
Sb-125					
	Energy MeV	Energy keV	Exposure Rate (mR/hr / 1pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
4	0.0038	4	1.43E-07	6,618,312	0
27	0.0272	27	2.69E-07	510,290	0
28	0.0275	28	5.07E-07	554,334	0
31	0.031	31	2.00E-07	1,219,281	0
36	0.0355	36	1.17E-07	2,418,948	0
117	0.117	117	5.78E-08	9,167,000	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	5011300	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	0.00001967	1323965	26
671	0.6714	671	0.00003311	1194390	4
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(Ei) 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

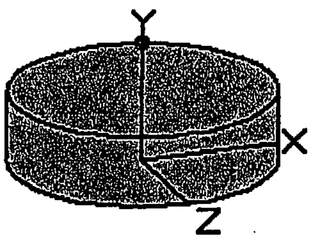
	Energy MeV	Energy keV	Exposure Rate (mR/hr-1/pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
5	0.0045	5	2.58E-09		0
32	0.0318	32	5.32E-09	1,406.947	0
32	0.0322	32	9.94E-09	1,505.273	0
36	0.0364	36	4.16E-09	2,696.122	0
277	0.2769	277	2.61E-08	3,637.000	0
475	0.4753	475	1.92E-06	1,910.155	4
563	0.5632	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
				(Ei) 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 scan - 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	4.860e-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)	E_i (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
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:	188

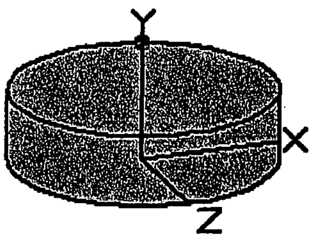
APPENDIX M

MicroShield v6.02 (6.02-00253)

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

File Ref	:
Date	:
By	:
Checked	:

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**

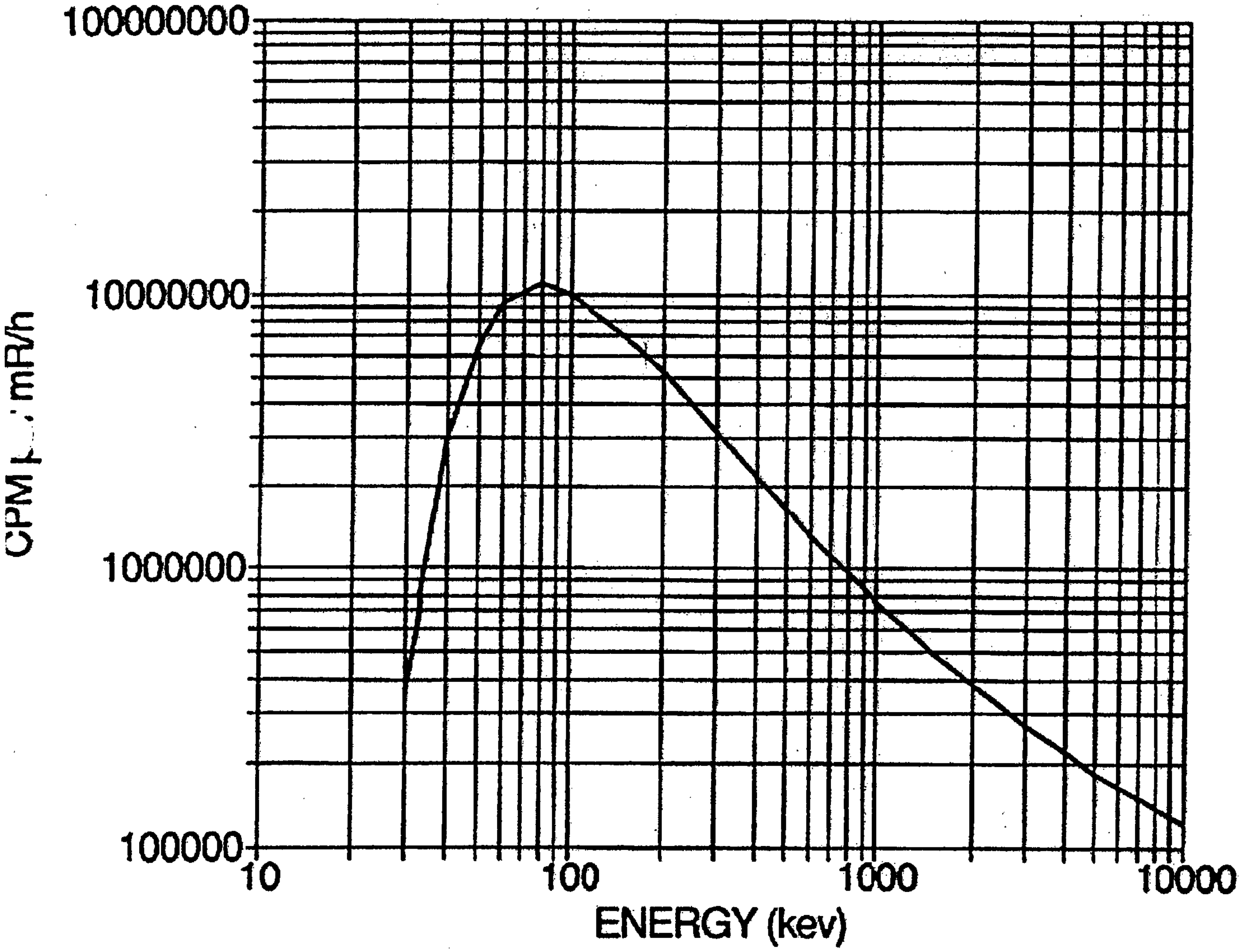
APPENDIX N

	Energy MeV	Energy keV	Exposure Rate (mR/hr / pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
Eu-152					
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
				(E) Total:	344

APPENDIX O

Calculated Energy Response
(Eberline Instruments)

CPM/mR/h



Generic ALARA Evaluation Comparison Worksheet

Survey Area: AUX-02 Survey Unit: 01 & 02 LD 6/16/06

Reference Generic ALARA Evaluation No.: ________

Applicable Generic ALARA AL: ________

	Radionuclide	Average Concentration	DCGL	fraction DCGL
1	Co-60	0.0335	7200	4.65E-06
2				
3				
4				
			Σ(fraction DCGL):	4.65E-06

If the Σ(fraction DCGL) < the generic ALARA AL, then the generic ALARA evaluation is applicable to the survey unit.

Check one:

✓ X Generic ALARA AL **IS** satisfied.

~~X Generic ALARA AL **IS NOT** satisfied.~~ LD 6/16/06

Prepared by: L. Dockins [signature] Date: 6/16/2006
FSS Radiological Engineer

Reviewed by: Martin Erickson [signature] Date: 6/16/2006
FSS Project Manager/Radiation Protection Manager

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 Als	1.45E+02

DCGL Fraction < ALARA AL?	**YES**

Survey Area: AUX02	Survey Unit: 01 & 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^{-8} 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^{-8} 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

JD 6/16/06

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

DCGL Fractions

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

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). Concentrations at or above these levels automatically warrant remediation.

Generic ALARA Evaluation Comparison Worksheet

Survey Area: AUX-02 Survey Unit: 01 & 02 LD 6/16/06

Reference Generic ALARA Evaluation No.: ______

Applicable Generic ALARA AL: ______

	Radionuclide	Average Concentration	DCGL	fraction DCGL
1	Co-60	0.0335	7200	4.65E-06
2				
3				
4				
			Σ(fraction DCGL):	4.65E-06

If the Σ(fraction DCGL) < the generic ALARA AL, then the generic ALARA evaluation is applicable to the survey unit.

Check one:

✓ x Generic ALARA AL **IS** satisfied.

~~x Generic ALARA AL **IS NOT** satisfied.~~ LD 6/16/06

Prepared by: L. Dockins [signature] Date: 6/16/2006
FSS Radiological Engineer

Reviewed by: Martin Erickson [signature] Date: 6/16/2006
FSS Project Manager/Radiation Protection Manager

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 Als	1.45E+02

DCGL Fraction < ALARA AL?	**YES**

Survey Area: AUX02 **Survey Unit:** 01 & 02	JD 6/16/06
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^{-8} 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^{-8} 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

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

DCGL Fractions

Radionuclide	Ave. Conc *pci*/gm	DCGL *pci*/gm	Relative Fraction	DCGL Fraction
H-3	0.00E+00		0	#DIV/0!
C-14	0.00E+00		0.00E+00	#DIV/0!
Fe-55	0.00E+00		0.00E+00	#DIV/0!
Co-60*	3.45E+03	3450	7.04E-01	1.0000
Ni-63	0.00E+00		0.00E+00	#DIV/0!
Sr-90	0.00E+00		0.00E+00	#DIV/0!
Nb-94	0.00E+00		0.00E+00	#DIV/0!
Tc-99	0.00E+00		0.00E+00	#DIV/0!
Ag-108m	0.00E+00		0.00E+00	#DIV/0!
Sb-125	0.00E+00		0.00E+00	#DIV/0!
Cs-134	0.00E+00		0.00E+00	#DIV/0!
Cs-137*	1.45E+03	1450	2.96E-01	1.0000
Eu-152	0.00E+00		0.00E+00	#DIV/0!
Eu-154	0.00E+00		0.00E+00	#DIV/0!
Eu-155	0.00E+00		0.00E+00	#DIV/0!
Pu-238	0.00E+00		0.00E+00	#DIV/0!
Pu-239	0.00E+00		0.00E+00	#DIV/0!
Pu-241	0.00E+00		0.00E+00	#DIV/0!
Am-241	0.00E+00		0.00E+00	#DIV/0!
Cm-243	0.00E+00		0.00E+00	#DIV/0!
	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). Concentrations at or above these levels automatically warrant remediation.

1 of 19

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/		Date: 10/10/05
Preparer: Gordon Madison, CHP/		Date: 10/11/05
Reviewer: Jim Hummer, CHP/	J. Hummer	Date: 10/18/05
Approver (FSS Manager): Dann Smith, CHP/		Date: 11/4/05

Rev. 0

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

γ

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

TABLE OF CONTENTS

3

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

	Efficiencies		Deviation due to density
keV	1.7 g/cc	2.08 g/cc	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:

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- 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.

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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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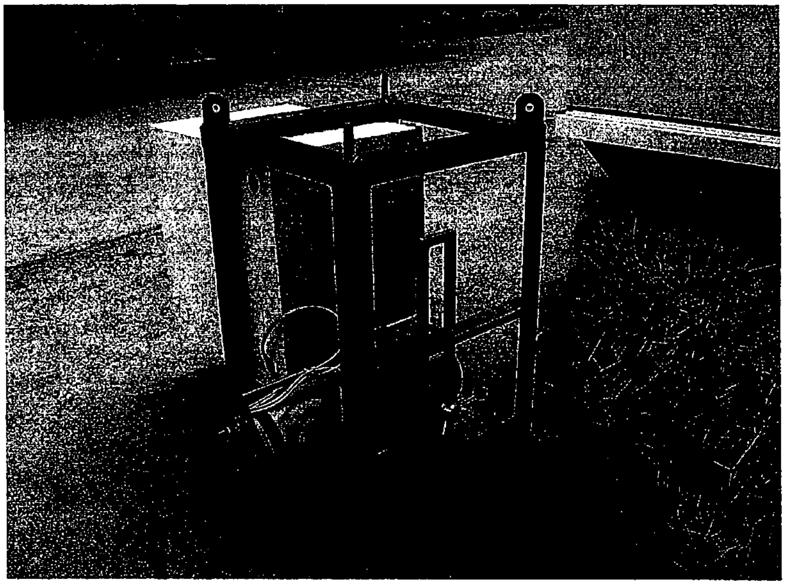
Attachment 1
Portable ISOCS® Detector System Photos



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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

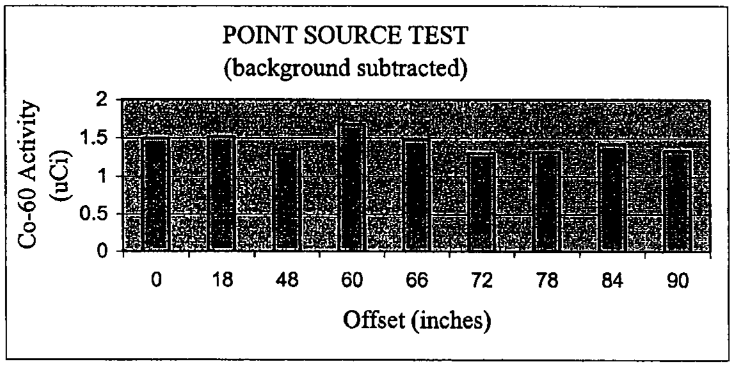
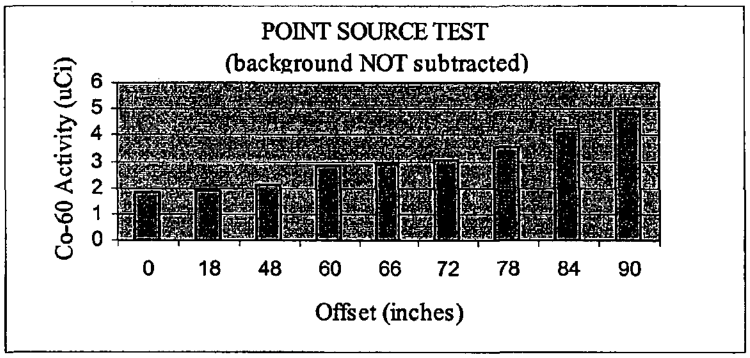


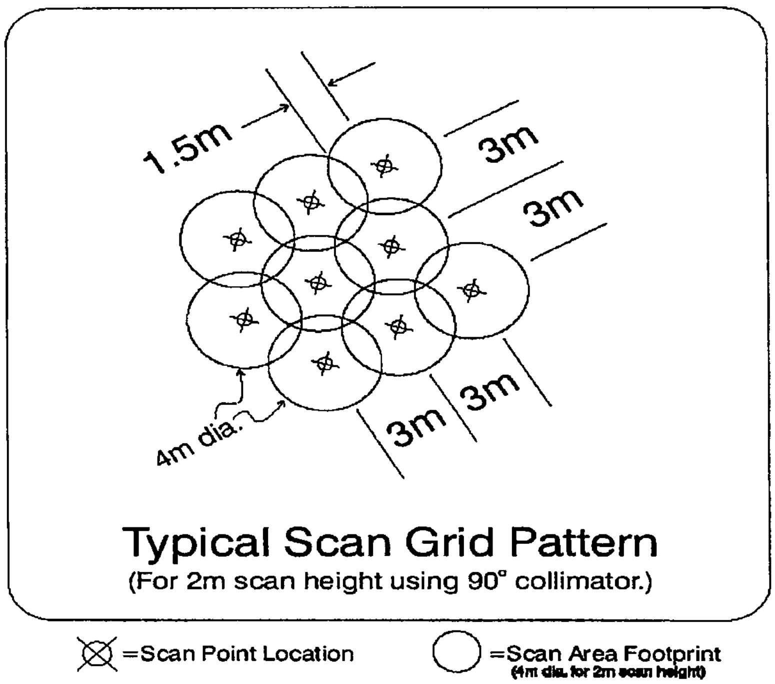
Figure 2 shows the effect of plant-derived materials present in the reference background, which indicates an increasing over-response the further the point source is moved off center. Detector response outside the assumed (i.e. 2-meter) field-of-view would yield conservative results. Normally, source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

19

Attachment 3
Typical Grid Pattern For In-Situ Gamma Spectroscopy



Attachment A – Maps and Posting Plots

List of Figures

Figure 1 AUX-02 Relative to Structures

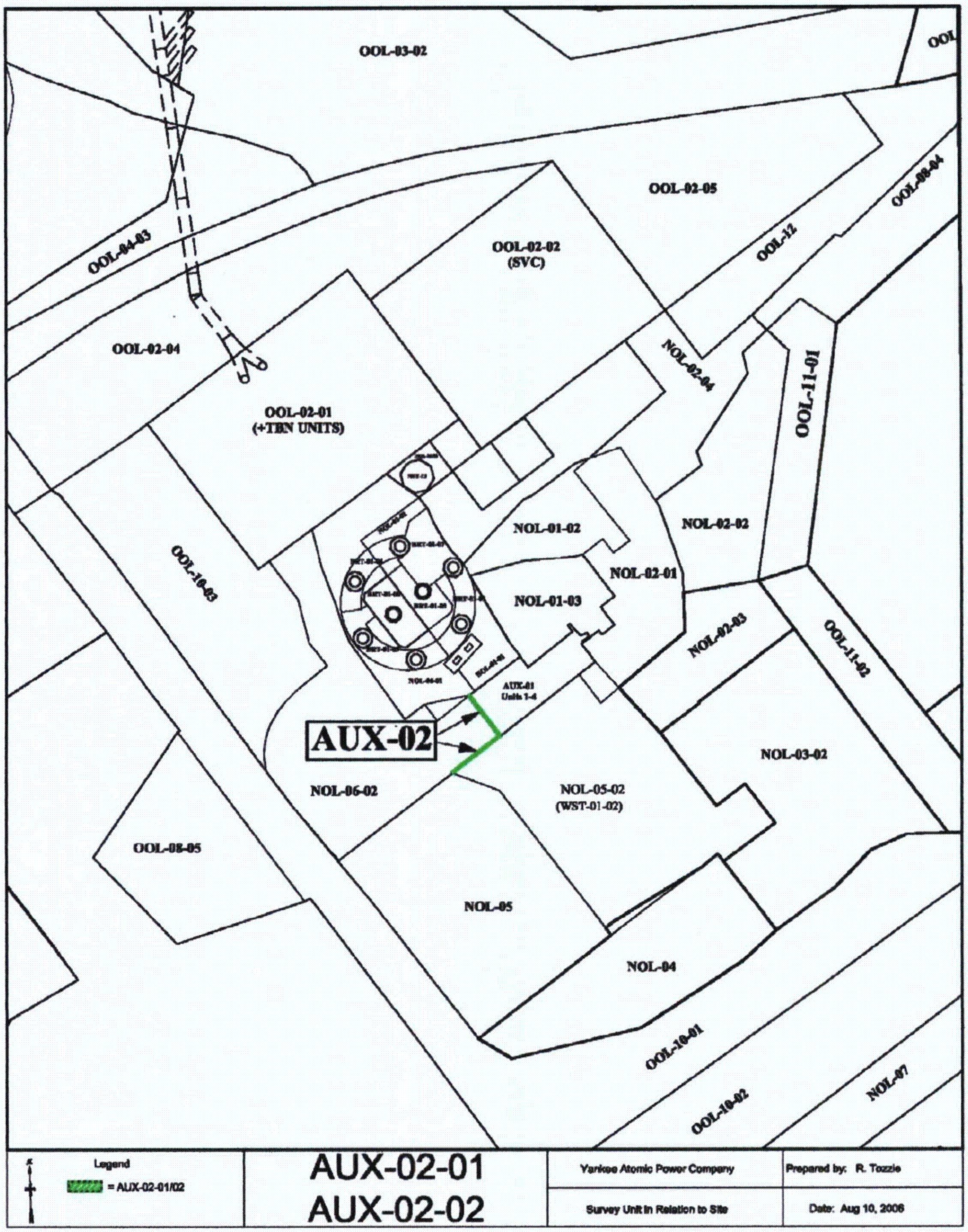


Figure 2 AUX-02-01 Posting Plot

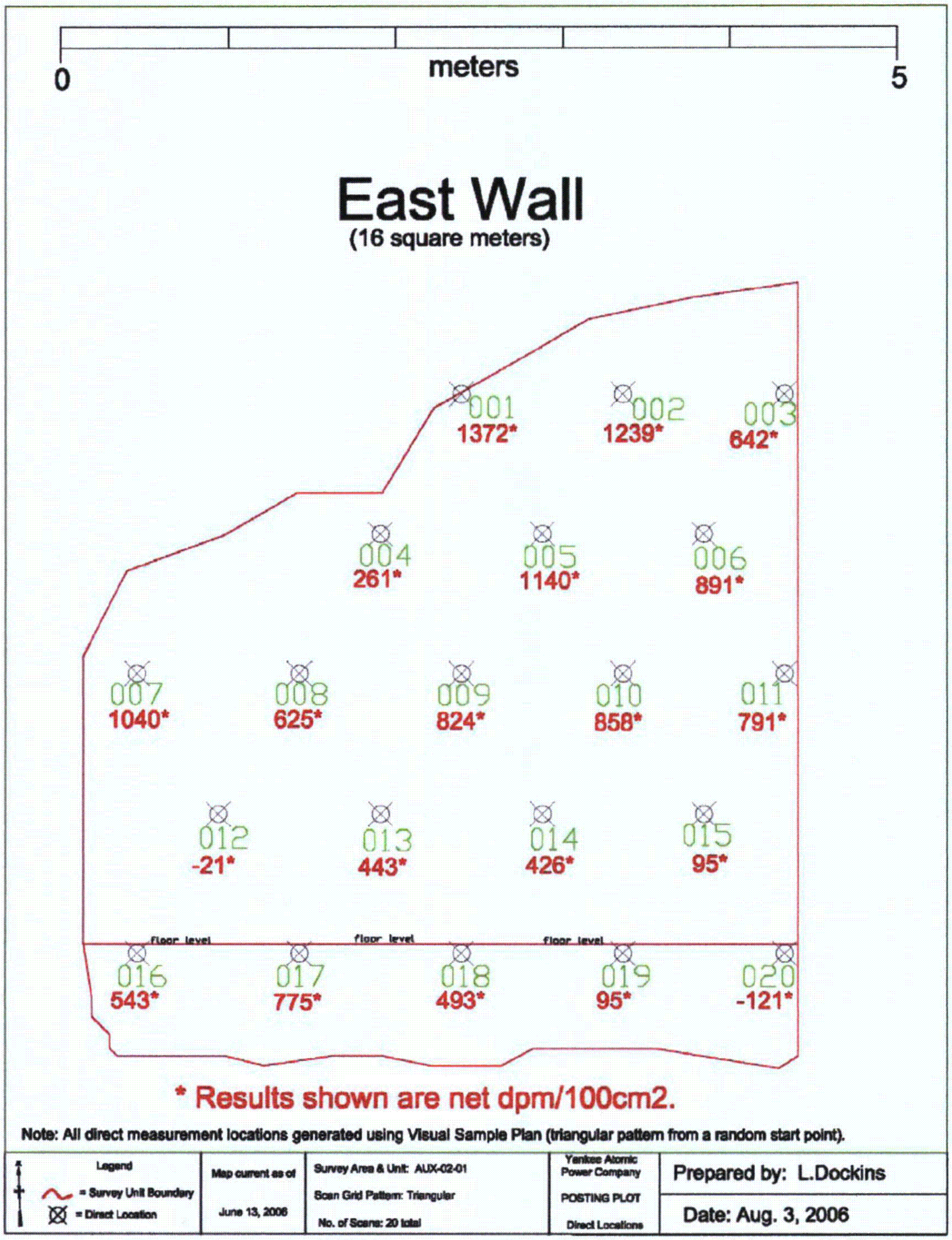
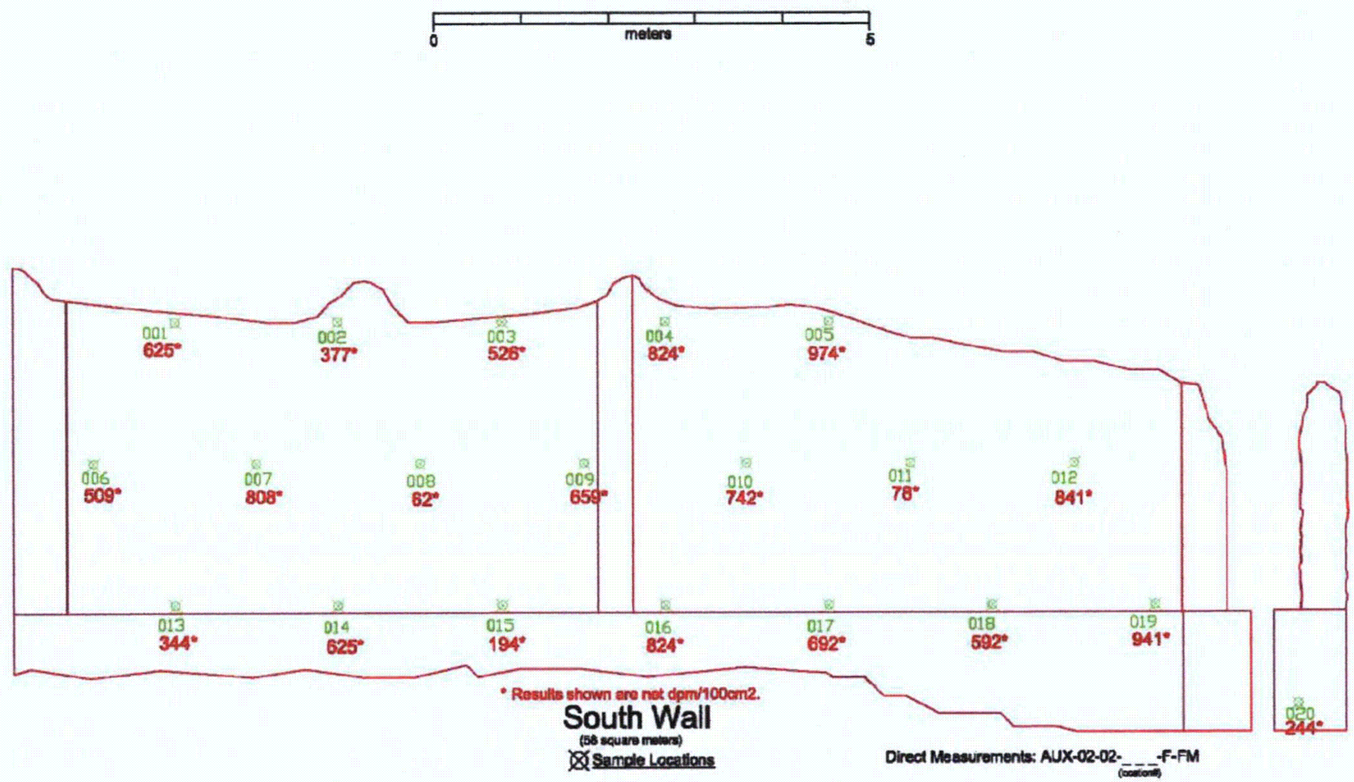


Figure 3 AUX-02-02 Posting Plot



Note: All direct measurement locations generated using Visual Sample Plan (triangular pattern from a random start point).

Legend = Survey Unit Boundary =Direct Locations	Map current as of June 13, 2006	Survey Area & Unit: AUX-02-02 Grid Pattern: Triangular (Direct) No. of Samples: 20 Directs Total Area Size: 58 m2	Yankee Atomic Power Company POSTING PLOT Direct Measurement Locations	Prepared by: L.Dockins Date: Aug. 3, 2006

Attachment B

Data Quality Assessment Plots and Curves

List of Figures

The LBGR on the Power Curves have been adjusted to demonstrate the actual power of the survey.

Figure 1 AUX-02-01 Prospective Power Curve

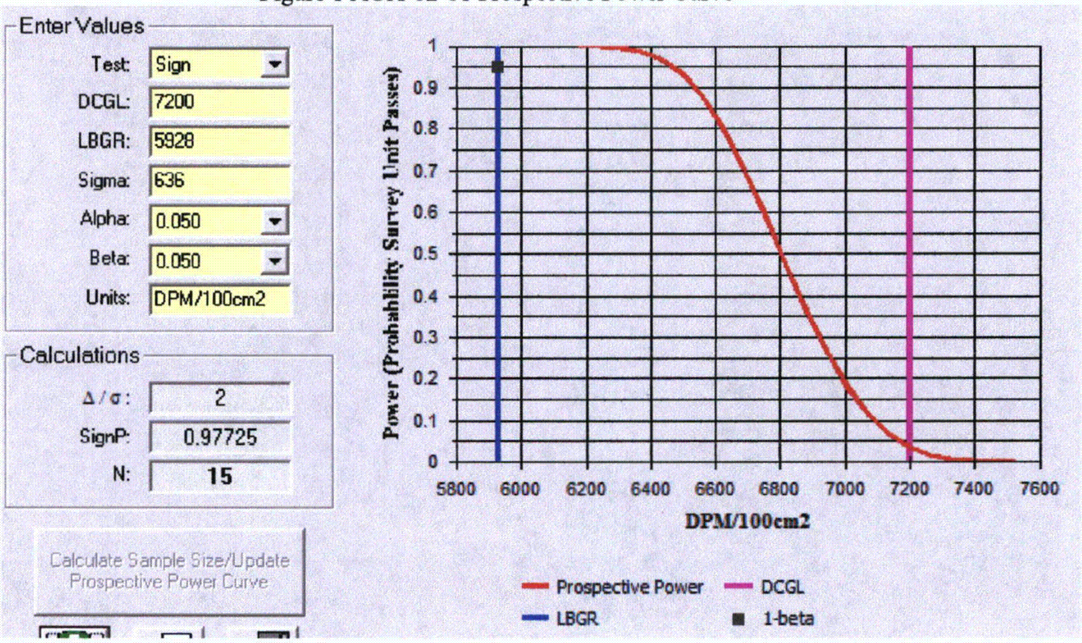


Figure 2 AUX-02-01 Retrospective Power Curve

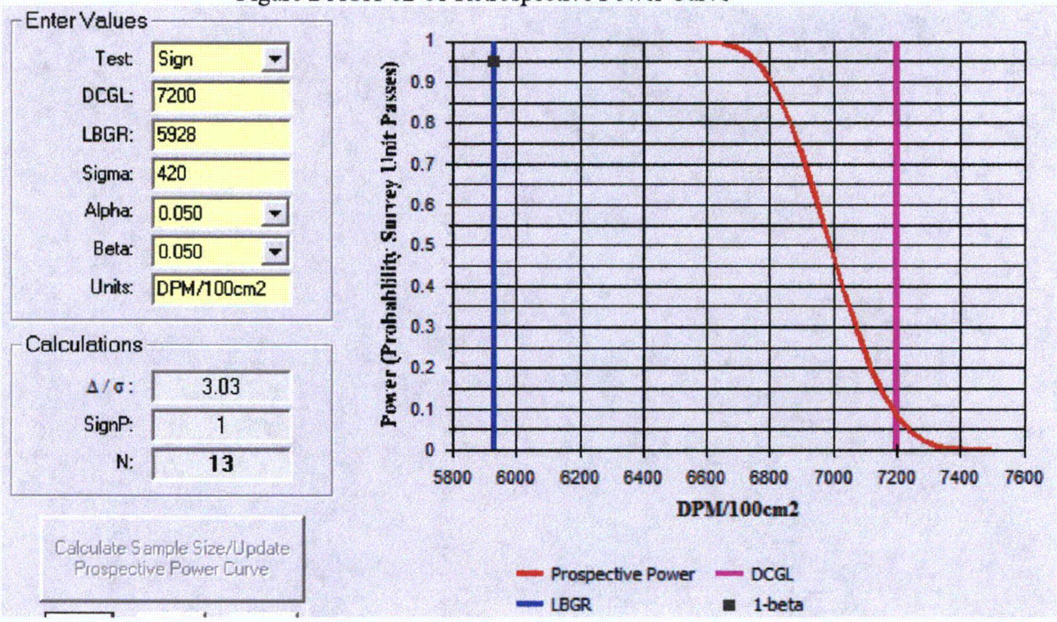


Figure 3 AUX-02-01 Scatter Plot

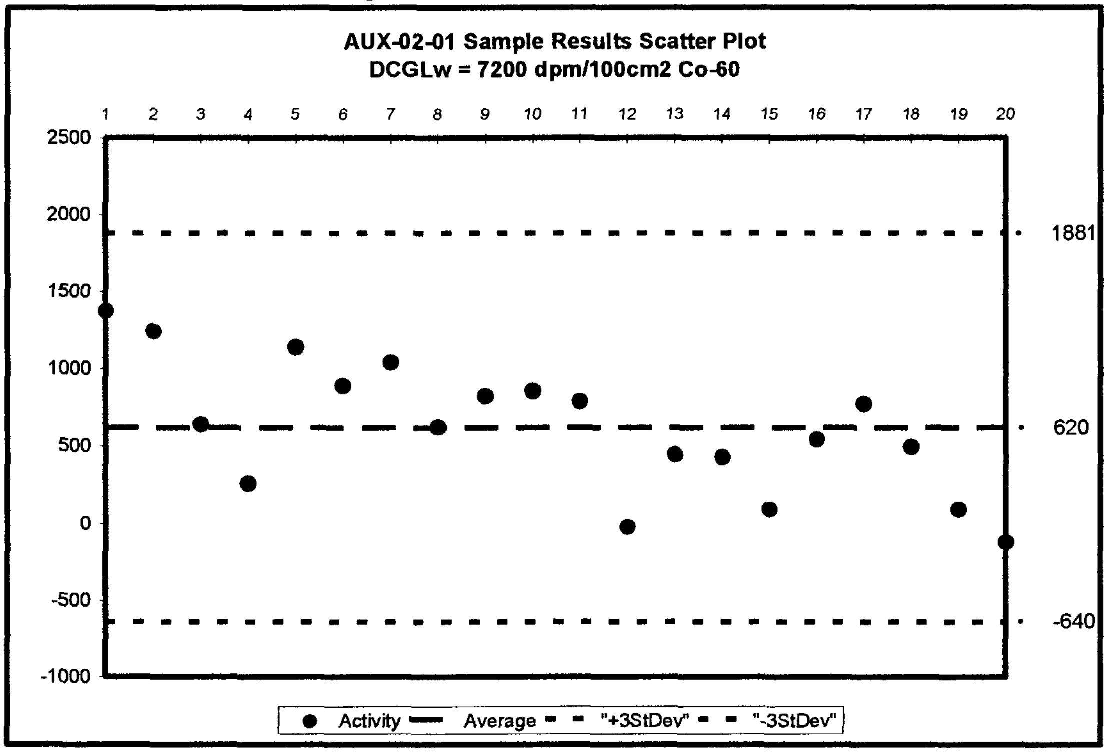


Figure 4 AUX-02-01 Quantile Plot

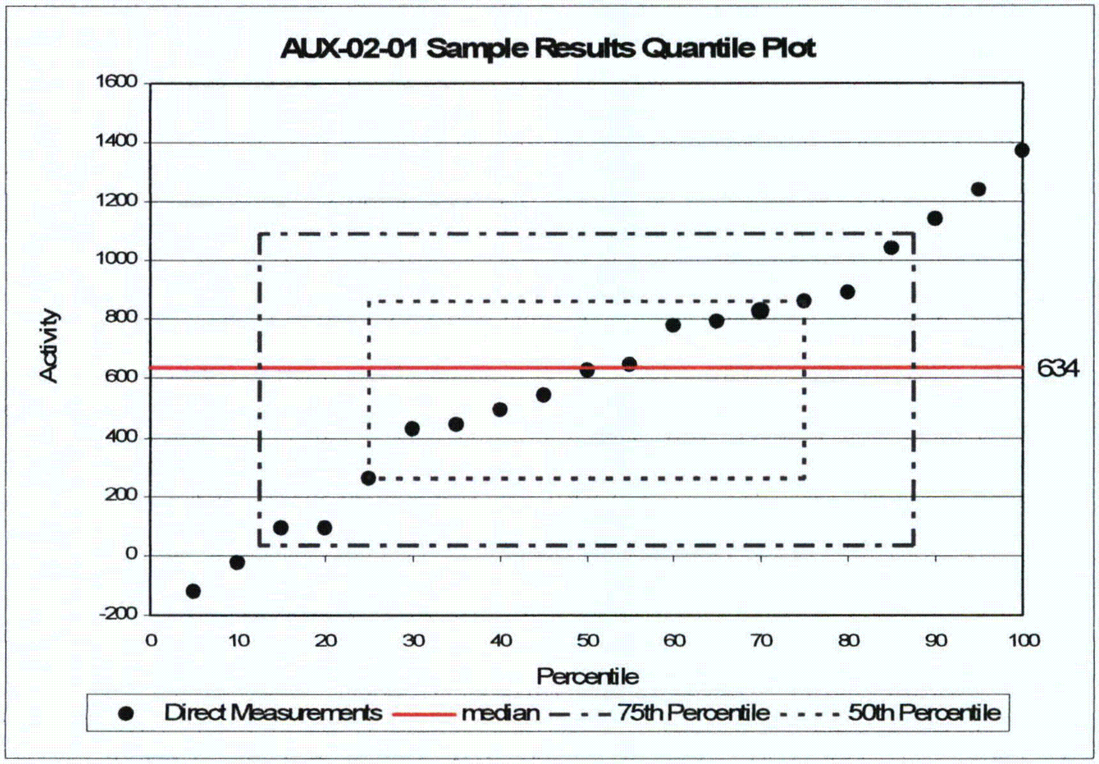


Figure 5 AUX-02-01 Frequency Plot

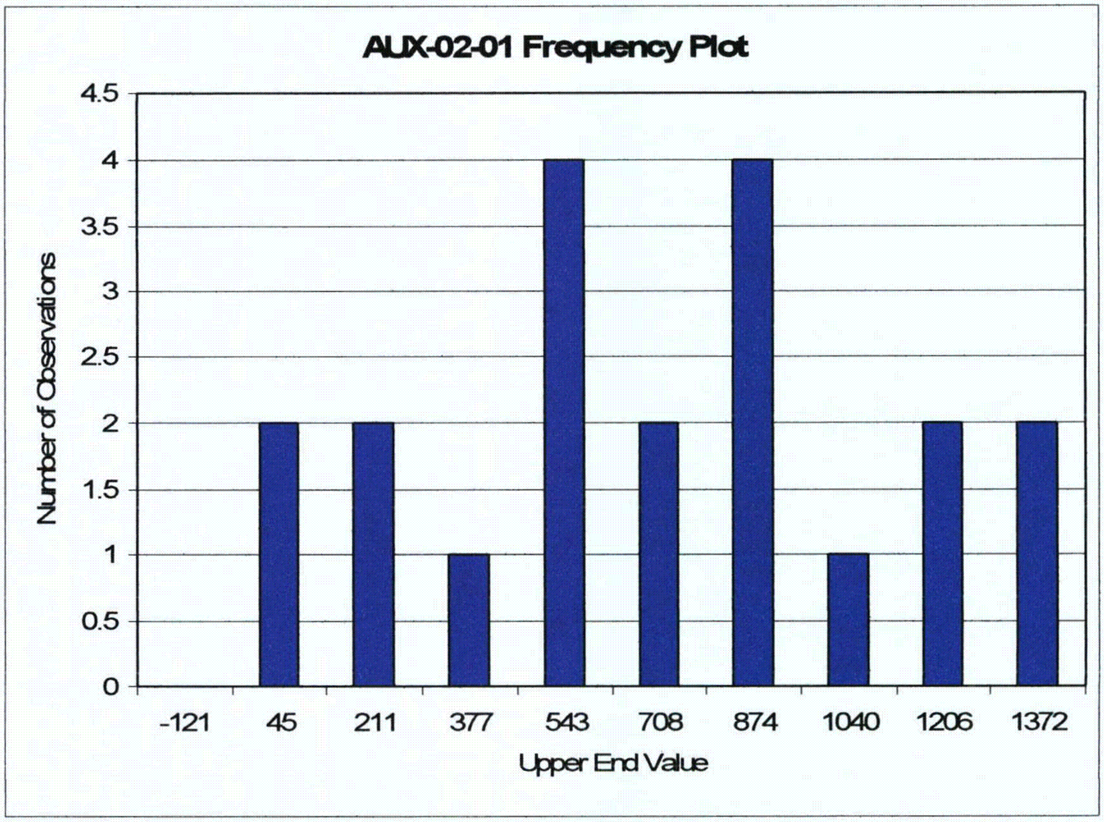


Figure 6 AUX-02-01 Replicate DQA

	Sample Description	Original	Replicate	True Variance	2 X 95% Conf Estimated Variance	Diff	Worst Case
1	AUX-02-01-001-Q-FM	1,372	961	411	1,646	No Diff	1,792
2	AUX-02-01-002-Q-FM	1,239	943	296	1,646	No Diff	1,659
3	AUX-02-01-003-Q-FM	642	1,009	367	1,646	No Diff	1,429
4	AUX-02-01-004-Q-FM	261	578	317	1,646	No Diff	998
5	AUX-02-01-005-Q-FM	1,140	760	380	1,646	No Diff	1,560
6	AUX-02-01-006-Q-FM	891	727	164	1,646	No Diff	1,311
7	AUX-02-01-007-Q-FM	1,040	1,175	135	1,646	No Diff	1,595
8	AUX-02-01-008-Q-FM	625	843	218	1,646	No Diff	1,263
9	AUX-02-01-009-Q-FM	824	1,739	915	1,646	No Diff	2,159
10	AUX-02-01-010-Q-FM	858	1,092	234	1,646	No Diff	1,512
11	AUX-02-01-011-Q-FM	791	1,606	815	1,646	No Diff	2,026
12	AUX-02-01-012-Q-FM	-21	893	914	1,646	No Diff	1,313
13	AUX-02-01-013-Q-FM	443	1,474	1,031	1,646	No Diff	1,894
14	AUX-02-01-014-Q-FM	426	246	180	1,646	No Diff	846
15	AUX-02-01-015-Q-FM	95	462	367	1,646	No Diff	882
16	AUX-02-01-016-Q-FM	543	1,258	715	1,646	No Diff	1,678
17	AUX-02-01-017-Q-FM	775	1,457	682	1,646	No Diff	1,877
18	AUX-02-01-018-Q-FM	493	1,076	583	1,646	No Diff	1,496
19	AUX-02-01-019-Q-FM	95	993	898	1,646	No Diff	1,413
20	AUX-02-01-020-Q-FM	-121	1,192	1,313	1,646	No Diff	1,612
21							
22							
23							
24							
25							
26							

DCGLw:	7200	dpm/100cm2
		Co-60

Maximum Value	1739
Minimum Value	-121
Mean	822
Median	851
Estimated Stdev	420
Number of Samples	20

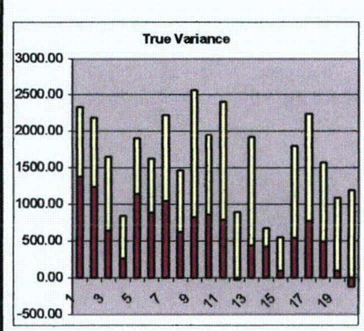


Figure 7 AUX-02-02 Prospective Power Curve

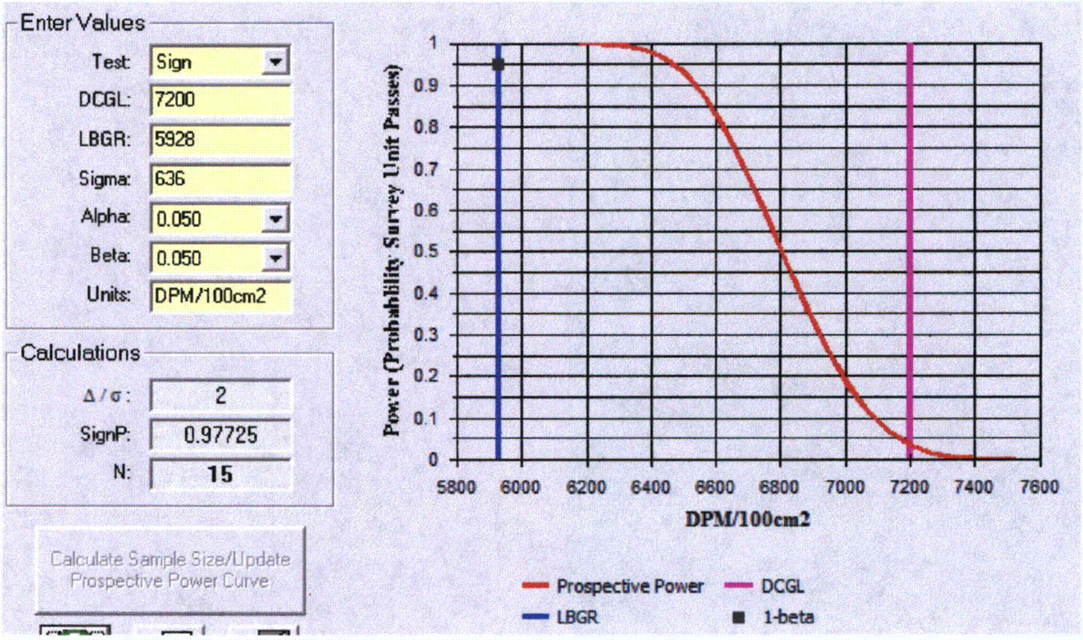


Figure 8 AUX-02-02 Retrospective Power Curve

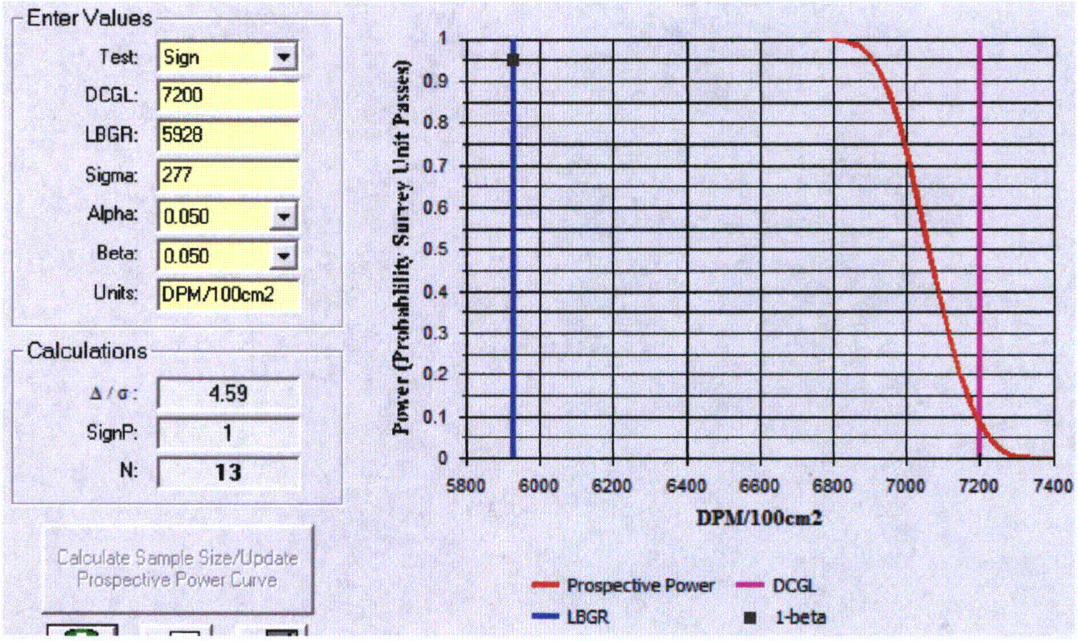


Figure 9 AUX-02-02 Scatter Plot

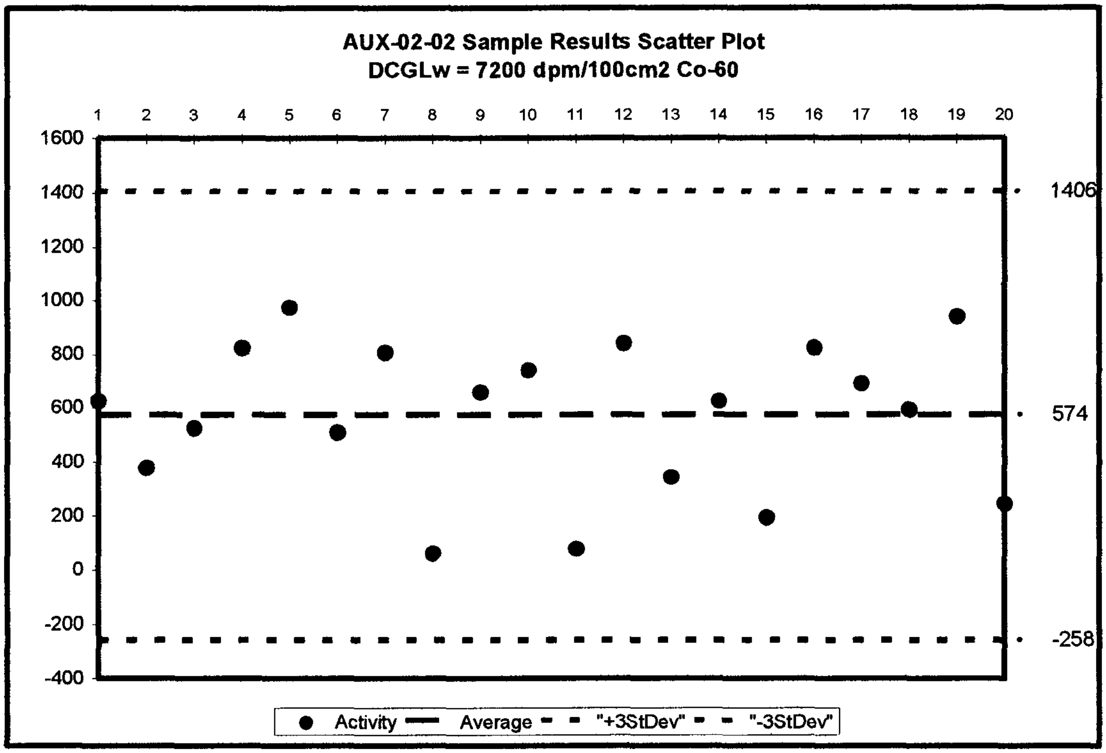


Figure 10 AUX-02-02 Quantile Plot

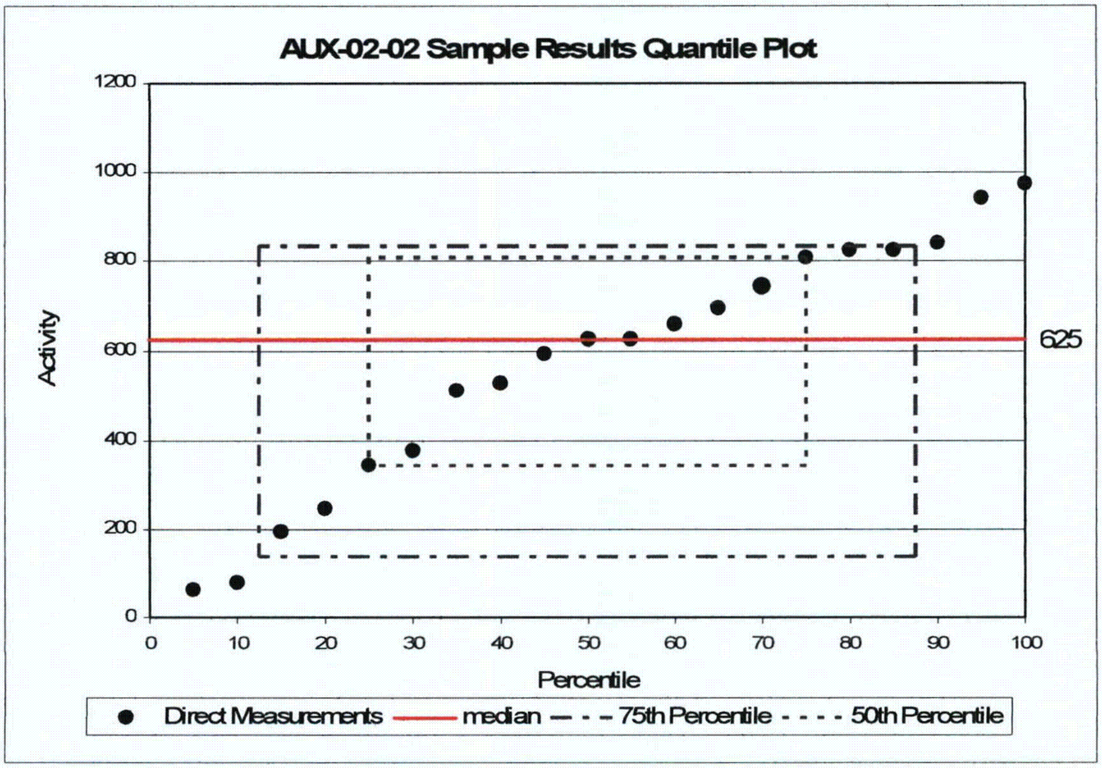


Figure 11 AUX-02-02 Frequency Plot

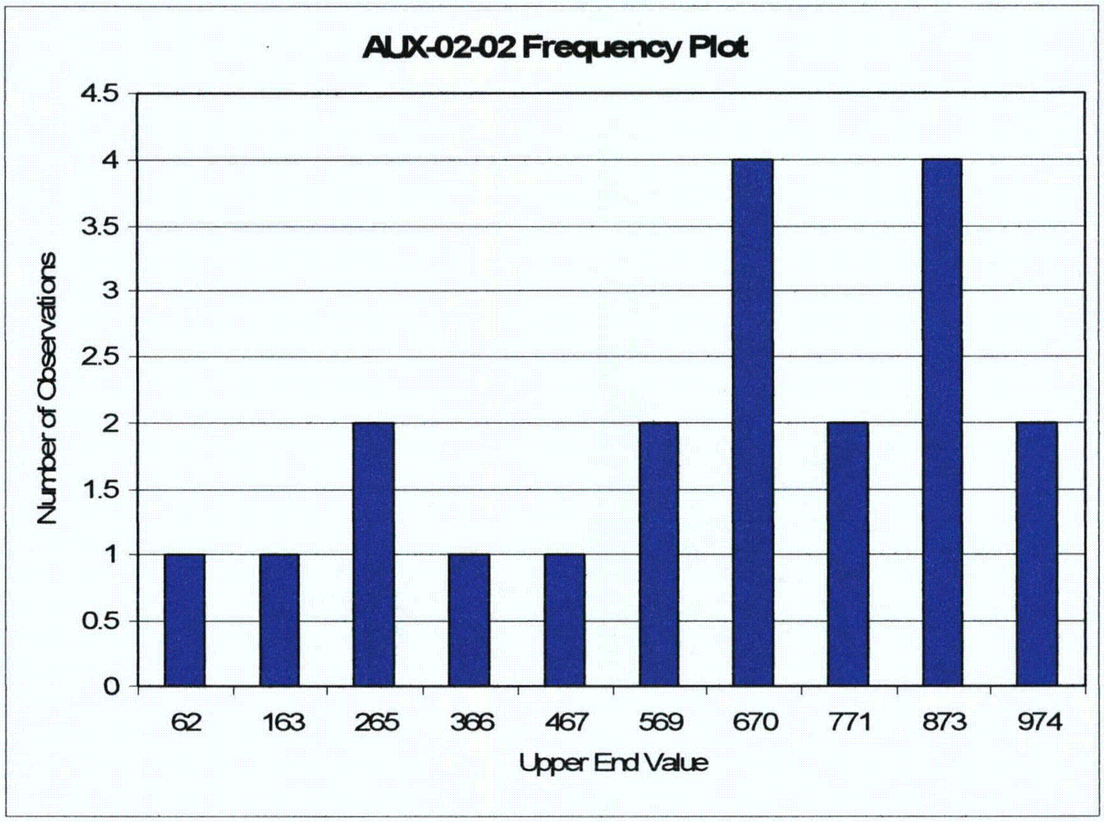
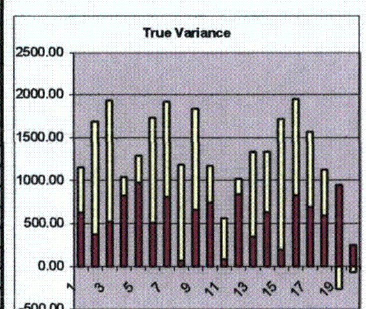


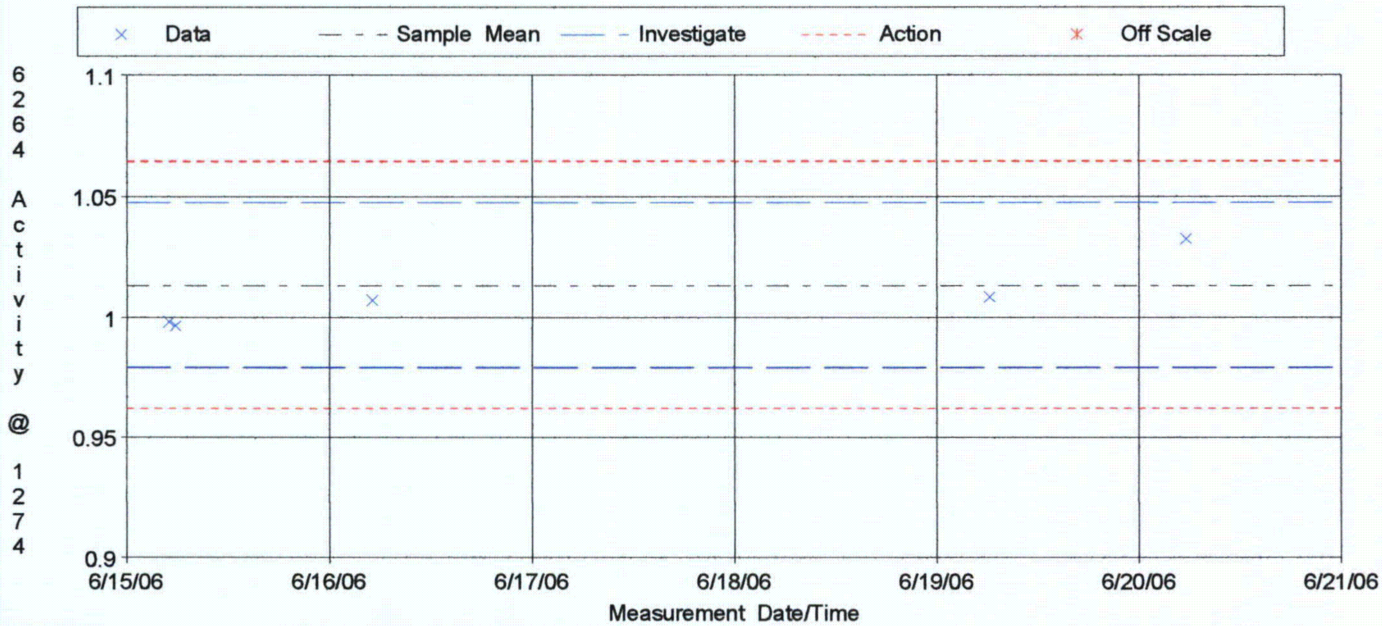
Figure 12 AUX-02-02 Replicate DQA

	Sample Description	Original	Replicate	True Variance	2 X 95% Conf Estimated Variance	Diff	Worst Case
1	AUX-02-02-001-Q-FM	625	528	97	1,086	No Diff	1,139
2	AUX-02-02-002-Q-FM	377	1,308	931	1,086	No Diff	1,822
3	AUX-02-02-003-Q-FM	526	1,407	881	1,086	No Diff	1,921
4	AUX-02-02-004-Q-FM	824	213	611	1,086	No Diff	1,338
5	AUX-02-02-005-Q-FM	974	313	661	1,086	No Diff	1,488
6	AUX-02-02-006-Q-FM	509	1,225	715	1,086	No Diff	1,739
7	AUX-02-02-007-Q-FM	808	1,109	301	1,086	No Diff	1,623
8	AUX-02-02-008-Q-FM	62	1,125	1,064	1,086	No Diff	1,639
9	AUX-02-02-009-Q-FM	659	1,175	516	1,086	No Diff	1,689
10	AUX-02-02-010-Q-FM	742	429	313	1,086	No Diff	1,256
11	AUX-02-02-011-Q-FM	78	479	400	1,086	No Diff	993
12	AUX-02-02-012-Q-FM	841	180	661	1,086	No Diff	1,355
13	AUX-02-02-013-Q-FM	344	993	649	1,086	No Diff	1,507
14	AUX-02-02-014-Q-FM	625	711	85	1,086	No Diff	1,225
15	AUX-02-02-015-Q-FM	194	1,524	1,330	1,086	Diff	2,038
16	AUX-02-02-016-Q-FM	824	1,125	301	1,086	No Diff	1,639
17	AUX-02-02-017-Q-FM	692	877	185	1,086	No Diff	1,391
18	AUX-02-02-018-Q-FM	592	528	64	1,086	No Diff	1,106
19	AUX-02-02-019-Q-FM	941	-268	1,208	1,086	Diff	1,455
20	AUX-02-02-020-Q-FM	244	-69	313	1,086	No Diff	758
21							
22							
23							
24							
25							
26							

DCGLw:	7200	dpm/100cm2
		Co-60

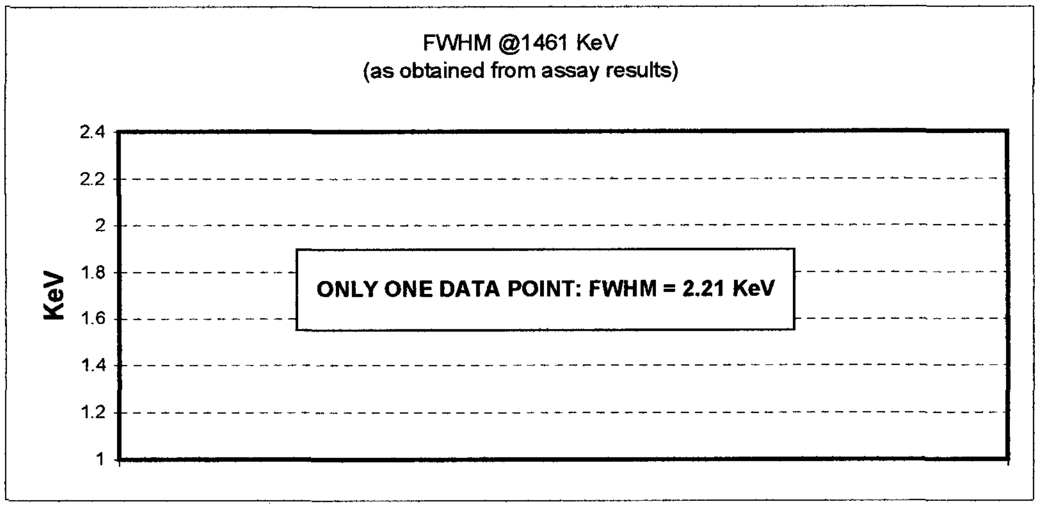
Maximum Value	1524
Minimum Value	-268
Mean	660
Median	642
Estimated Stdev	277
Number of Samples	20

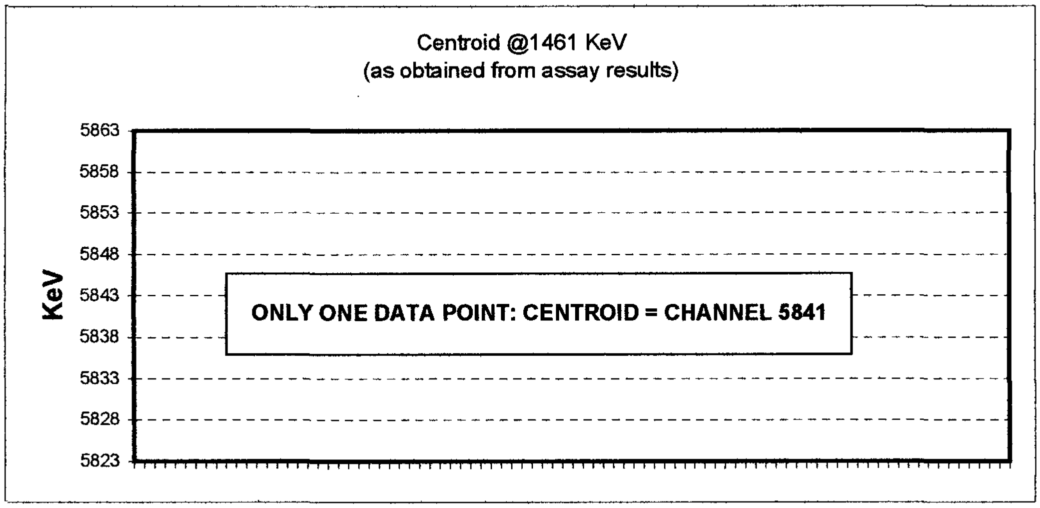


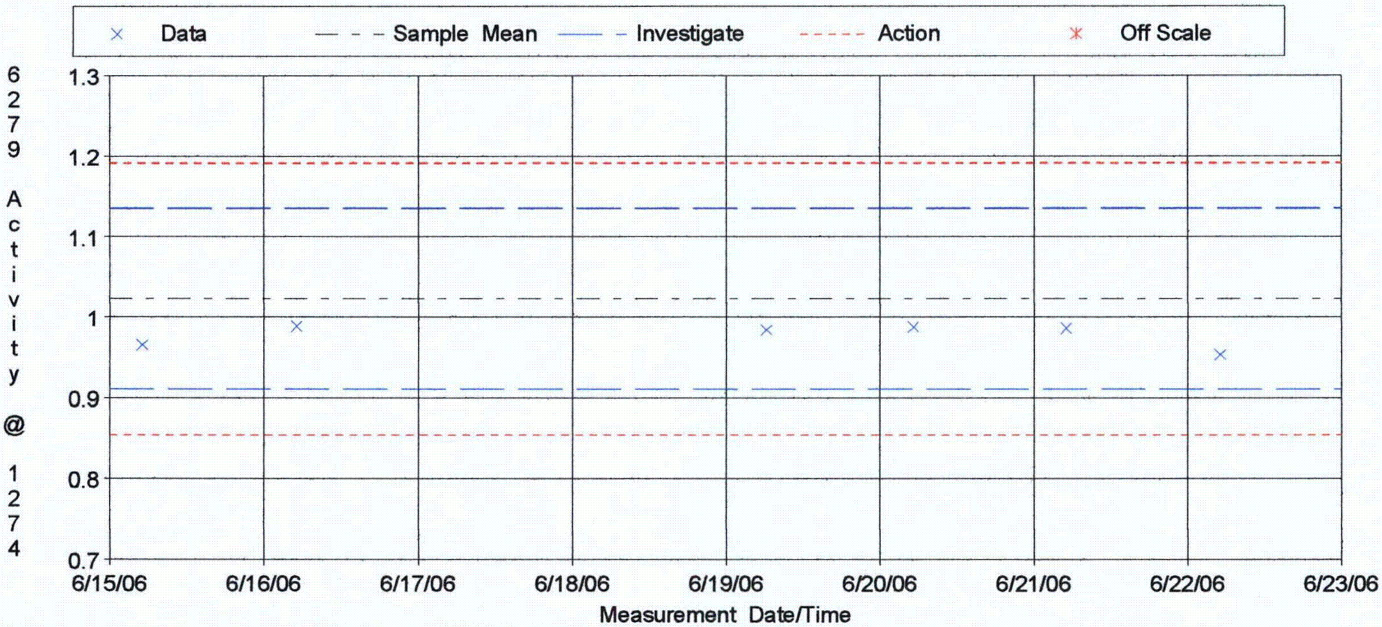


QA Filename : S:\2RedRover (6264)\Archived QC Files\6264.QAF
Parameter Description : 6264 Activity @ 1274 keV (uCi)
Selection Dates : 6/15/06 12:00:00 AM - 6/21/06 12:00:00 AM
Sample Mean +/- Std Dev : 1.013 +/- 0.017

AUX-02
ISOCS DETECTOR 6264

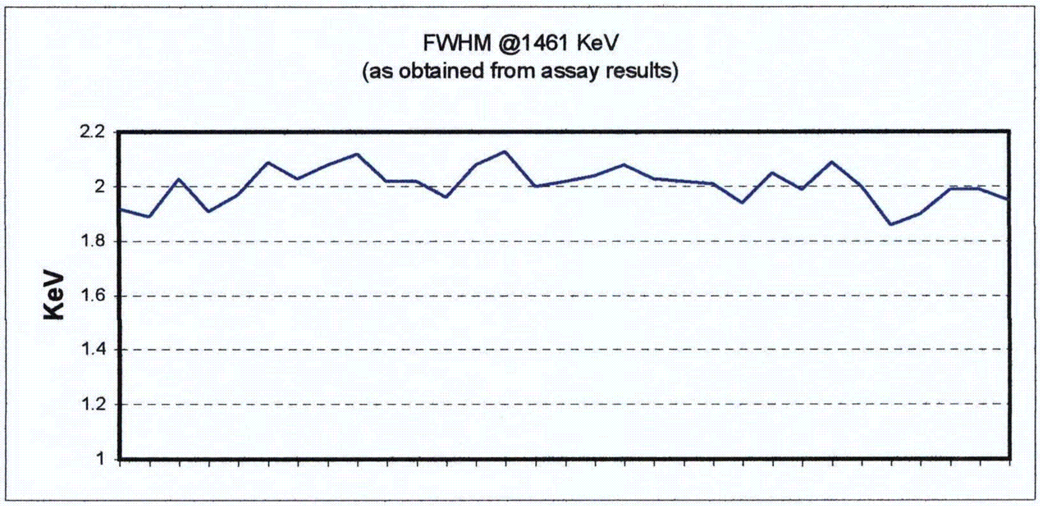


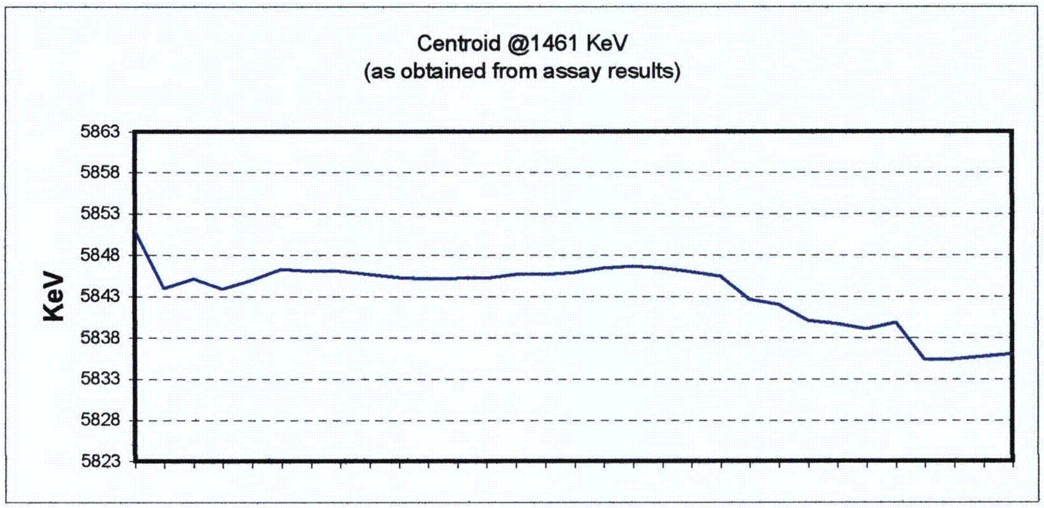




QA Filename	:	S:\1BlueRover (6279)\Archived QC Files\6279.QAF
Parameter Description	:	6279 Activity @ 1274 keV (uCi)
Selection Dates	:	6/15/06 12:00:00 AM - 6/23/06 12:00:00 AM
Sample Mean +/- Std Dev	:	1.023 +/- 0.056

AUX-02
ISOCS DETECTOR 6279





Daily Survey Journal

Survey Area Unit No.: AUX-02-01			Survey Date: 06/21/06
Survey Plan #: YNPS-FSSP-AUX-02-01-00			
Supervisor: Neel / Sprucinski Crew: Pennock / J. White			
Instruments:			
Model:	ISOCS (Blue)	ISOCS (NA)	* SEE SURVEY
Serial #:	6279		
Cal. Due.	03/07		
Pre-op source check :	Sat. ☐	Sat. ☐	Sat. ☐
Pre-op source check :	Sat. ☐ Date:	Sat. ☐ Date:	Sat. ☐ Date:

TIME	NOTES FOR SURVEY DATE
0700	Conducted daily safety briefing and plan for today's FSS activities.
0800	Background survey being conducted IAW FSSP direction.
0830	Direct measurement survey being conducted IAW FSSP direction, DP-8534, and
	DP-8535 by FSS technician James White.
1300	Direct measurements are complete in this survey unit.
1615	Blue rover set up with 90 degree collimator at 2 meters from surface of concrete
	wall. Starting scans IAW DP-8871. FSS technician James White positioning
	rovers and FSS technician Gary Jennings controlling counts from truck monitor.
1700	ISOCS scans completed. Field work for survey unit complete.

Completed by [signature] Date 06-21-2006
FSS Field Supervisor

Reviewed by [signature] N. TOZZIE Date 6/29/06
FSS Radiological Engineer

CONTROL POINT

PORTABLE INSTRUMENT ACCOUNTABILITY FORM

Instrument Type & YAEC or DE&S #	Batt ✓	Cal Due ✓	Src ✓ Out	Location and/or Reason For Use	Date and Time Out	Tech Name	Data and Time In	Srce ✓ In
E-600 # 01625 SPA-3 # 726328	✓	✓	✓	BOP	6-21-06 0915	Moyers	6-21-06 1100	✓
E-600 # 02482 SPA-3 # 51847	✓	✓	✓					NOT USED
E-600 # 5141 SPA-3 # 725329	✓	✓	✓	WEST Drain	06.21.06 0635	Miskimen	6.21.06 1355	✓
E-600 # 01622 SPA-3 # 726554	✓	✓	✓	1/2	6/21/06 1420	[illegible]	6-21-06 1650	✓
E-600 # 02491 SHP-180 # 55296	✓	✓	✓	FSS/06-02/Survey	06/21/06 08:15	MAXWELL	6-21-06 1705	✓
E-600 # 5073 43-37 # 59026	✓	✓	✓					NOT USED
E-600 # 02490 43-37 # 60079	✓	✓	✓	B-25 Tr	6-21-06 0720	MacDonald	6-21-06 1600	Note 1

RP Supervisor Review [signature] (1)

(1) If any post-use source check failures occur, ensure that the condition is documented by a Condition Report.

Note 1 Nail Damaged mylar. 1400 - PB MacDonald

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Rev. 17

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PORTABLE/GAMMA F[illegible] SOURCE CHECK FORM

E-600	HP-100C	55896	E-21	19401	29102
Meter Type	Detector Type	Detector Number	Source ID	Net Acceptance Criteria - 20%	Net Acceptance Criteria + 20%

PRE USE CHECKS								POST USE CHECKS							
Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int	Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int
4-13-06	0950	SAT	N/A	140	23600	23460	[illegible]	4-13-06	1635	SAT	N/A	129	23000	22871	[illegible]
4-27-06	0820	SAT	N/A	139	24000	23861	[illegible]	4-27-06	1435	SAT	N/A	146	22000	21854	[illegible]
5-8-06	0930	SAT	N/A	88	21000	20912	[illegible]								*
5-15-06	0920	SAT	N/A	120	21900	21780	[illegible]	5-16-06	0525	SAT	N/A	126	22400	22274	[illegible]
5-16-06	0525	SAT	N/A	126	22400	22274	[illegible]								*
5-17-06	1410	SAT	N/A	131	22900	22769	[illegible]	5-17-06	[illegible]	SAT	N/A	103	20700	20597	[illegible]
5-18-06	0725	SAT	N/A	165	23300	23135	[illegible]	5-19-6	1615	SAT	NA	149	22900	22751	cjc
6-21-06	0600	SAT	N/A	133	22800	22667	[illegible]	6-21-6	1705	SAT	NA	133	23000	22867	cjc
6-22-06	0600	SAT	N/A	134	22900	22764	[illegible]								*
6-27-06	0745	SAT	N/A	106	22800	22694	[illegible]	6-28-6	0640	SAT	NA	130	23100	22970	cjc
6-28-6	0640	SAT	NA	130	23100	22970	cjc								*
7-7-6	0645	SAT	NA	122	22200	22078	cjc	7-7-6	1620	SAT	NA	135	23600	23465	cjc
						NO FURTHER ENTRIES THIS PAGE									

* NOT USED

RP Supervisor Review: [illegible] (1)

(1) If any post-use source check failures occur, ensure that the condition is documented by a Condition Report.

DPF-8504.5
Rev. 17

Daily Survey Journal

Survey Area Unit No.: AUX-02-02			Survey Date: 06/21/06
Survey Plan #: YNPS-FSSP-AUX-02-02-00			
Supervisor: Neel / Sprucinski Crew: Pennock / J. White			
Instruments:			
Model:	ISOCS (Blue)	ISOCS (NA)	* SEE SURVEY
Serial #:	6279		
Cal. Due.	03/07		
Pre-op source check :	Sat. □	Sat. □	Sat. □
Pre-op source check :	Sat. □ Date:	Sat. □ Date:	Sat. □ Date:

TIME	NOTES FOR SURVEY DATE
0700	Conducted daily safety briefing and plan for today's FSS activities.
0800	Background survey being conducted IAW FSSP direction.
0830	Direct measurement survey being conducted IAW FSSP direction, DP-8534, and
	DP-8535 by FSS technician James White.
1040	Blue rover set up with 90 degree collimator at 2 meters from surface of concrete
	wall. Starting scans IAW DP-8871. FSS technician Steve Pennock positioning
	rovers and FSS technician Gary Jennings controlling counts from truck monitor.
1300	Direct measurements are complete in this survey unit.
1310	FSS technician James White is taking over positioning of ISOCS rovers.
1700	Turnover of ISOCS scans given to nightshift with two scans remaining to be
	done.

Completed by [signature] Date 06-21-2006
FSS Field Supervisor

Reviewed by [signature] Date 6/22/06
FSS Radiological Engineer

CONTROL POINT

PORTABLE INSTRUMENT ACCOUNTABILITY FORM

Instrument Type & YAEC or DE&S #	Batt ✓	Cal Due ✓	Src ✓ Out	Location and/or Reason For Use	Date and Time Out	Tech Name	Date and Time In	Srce ✓ In
E-600 # 01625 SPA-3 # 726328	✓	✓	✓	BOP	6-21-06 0915	Moyers	6-21-06 1100	✓
E-600 # 02483 SPA-3 # 51847	✓	✓	✓					NOT USED
E-600 # 5141 SPA-3 # 725329	✓	✓	✓	WEST Drain	06.21.06 0635	Riskimen	6.21.06 1355	✓
E-600 # 01622 SPA-3 # 726554	✓	✓	✓	1/2	6/21/06 1420	[illegible]	6-21-06 1650	✓
E-600 # 02491 SHP-100 # 55296	✓	✓	✓	FSS/06-02/Survey	06/21/06 08:15	MAXWELL	6-21-06 1705	✓
E-600 # 5073 43-37 # 59026	✓	✓	✓					NOT USED
E-600 # 02490 43-37 # 60079	✓	✓	✓	B-25 Trl	6-21-06 0720	MacDonald	6-21-06 1600	Note 1

RP Supervisor Review [signature] (1)

(1) If any post-use source check failures occur, ensure that the condition is documented by a Condition Report.

Note 1 Nail Damaged mylar. 1400 - PS MacDonald

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PORTABLE/GAMMA F[illegible] SOURCE CHECK FORM

E-600	HP-100C	55896	E-21	19401	29102
Meter Type	Detector Type	Detector Number	Source ID	Net Acceptance Criteria - 20%	Net Acceptance Criteria + 20%

PRE USE CHECKS								POST USE CHECKS							
Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int	Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int
4-13-06	0950	SAT	N/A	140	23600	23460	[illegible]	4-13-06	1635	SAT	N/A	129	23000	22871	[illegible]
4-~~13~~ 27-06	0820	SAT	N/A	139	24000	23861	[illegible]	4-27-06	1435	SAT	N/A	146	22000	21854	[illegible]
5-8-06	0930	SAT	N/A	88	21000	20912	[illegible]								*
5-15-06	0920	SAT	N/A	120	21900	21780	[illegible]	5-16-06	0525	SAT	N/A	126	22400	22274	[illegible]
5-16-06	0525	SAT	N/A	126	22400	22274	[illegible]								*
5-17-06	1410	SAT	N/A	131	22900	22769	[illegible]	5-17-06	1715	SAT	N/A	103	20700	20597	[illegible]
5-18-06	0725	SAT	N/A	165	23300	23135	[illegible]	5-19-6	1615	SAT	NA	149	22900	22751	cjc
6-21-06	0600	SAT	N/A	133	22800	22667	[illegible]	6-21-6	1705	SAT	NA	133	23000	22867	cjc
6-22-06	0600	SAT	N/A	134	22900	22764	[illegible]								*
6-27-06	0745	SAT	N/A	106	22800	22694	[illegible]	6-28-6	0640	SAT	NA	130	23100	22970	cjc
6-28-6	0640	SAT	NA	130	23100	22970	cjc								*
7-7-6	0645	Sat	NA	122	22200	22078	cjc	7-7-6	1620	SAT	NA	135	23600	23465	cjc
						NO FURTHER ENTRIES		THIS PAGE							

* NOT USED

RP Supervisor Review: [illegible] [1]

[1] If any post-use source check failures occur, ensure that the condition is documented by a Condition Report.

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