N60028_002800
TREASURE ISLAND
SSIC NO. 5090.3.A

FINAL
FINAL STATUS SURVEY REPORT
Historic Avenue "N" Wood Stave Pipe
Former Naval Station Treasure Island
San Francisco, California

Contract Number: N62473-12-D-2005
Contract Task Order: 0012

Document Control Number: CBI-2005-0012-0019

July 2016

Prepared for:

Base Realignment and Closure
Program Management Office West Naval Facilities Engineering Command
33000 Nixie Way, Building 50
San Diego, California 92147

Prepared by:

CB&I Federal Services LLC
4005 Port Chicago Highway, Suite 200
Concord, California 94520-1120

FINAL
FINAL STATUS SURVEY REPORT
Historic Avenue "N" Wood Stave Pipe
Former Naval Station Treasure Island
San Francisco, California

Contract Number: N62473-12-D-2005
Contract Task Order: 0012

Document Control Number: CBI-2005-0012-0019

July 2016

Approved by _____ Date: July 12, 2016
John Hackett, CHP, PE
Project Manager

Table of Contents

List of Figures iii
List of Tables iii
List of Photographs iii
List of Appendices iii
Acronyms and Abbreviations iv

Executive Summary ES-1
1.0 Introduction 1-1
1.1 Scope of Work 1-1
1.2 Report Objectives and Organization 1-2
2.0 Site History and Description 2-1
2.1 Treasure Island History 2-1
2.2 Wood Stave Pipe Work Area History 2-1
2.3 Current Site Conditions 2-1
3.0 Characterization and Remediation Field Activities 3-1
3.1 Release Criterion and Waste Characterization 3-1
3.2 Background Reference Areas and Investigation Levels 3-2
3.3 Survey Instrumentation 3-2
3.3.1 Instrument Selection 3-2
3.3.2 Instrument Calibration 3-3
3.3.3 Instrument Operational Checks 3-3
3.3.4 Instruments for the Measurement of Gamma Surface Activity 3-3
3.3.5 Exposure Rate Surveys 3-3
3.4 Radiological Survey Performance 3-4
3.4.1 Survey Unit Design and Classification 3-4
3.4.2 Data Quality Objective Summary 3-4
3.4.2.1 Step One—State the Problem 3-5
3.4.2.2 Step Two—Identify the Decision 3-5
3.4.2.3 Step Three—Identify Inputs to the Decision 3-5
3.4.2.4 Step Four—Define the Study Boundaries 3-5
3.4.2.5 Step Five—Develop a Decision Rule 3-6
3.4.2.6 Step Six—Specify Limits on Decision Errors 3-6
3.4.2.7 Step Seven—Optimize the Design for Obtaining Data 3-6
3.4.3 Sample Preparation and Analysis 3-6
3.4.4 Mobilization 3-7
3.4.5 Site Preparation 3-7
3.4.6 Excavation of Impacted Materials and In-Process Sampling 3-8
3.4.7 Gamma Walkover Survey 3-9
3.4.8 Systematic Soil Sampling 3-9
3.4.9 Waste Management 3-9
3.4.10 Demobilization 3-9

Table of Contents (continued)

4.0 Characterization and Remediation Results 4-1
4.1 Material Characterization Surveys 4-1
4.1.1 In-Process Material Sampling Data 4-1
4.1.2 Material Survey Data 4-1
4.2 Soil Surveys 4-1
4.2.1 Gamma Walkover—Survey Results 4-2
4.2.2 Soil Sampling and Analysis 4-2
4.2.2.1 Comparison of Survey Unit Concentration Data to Background Reference Area 4-3
5.0 Compliance with Final Status Survey Requirements 5-1
5.1 Final Status Survey Objective 5-1
5.1.1 Conceptual Site Model 5-1
5.1.1.1 Initial Conceptual Site Model 5-1
5.1.1.2 Excavation and Current Conceptual Site Model 5-1
5.1.2 Future Land-Use Scenario 5-2
5.1.3 Statistical Testing 5-2
5.1.3.1 Null Hypothesis 5-3
5.1.3.2 Wilcoxon Rank Sum Test 5-3
5.1.3.3 Quantile Test 5-3
5.1.3.4 Calculating Number and Location of Soil Samples 5-4
5.1.3.5 Calculate N 5-5
5.1.4 Dose Modeling for Unrestricted Release of the Wood Stave Pipe Area 5-5
5.2 Data Quality Assessment 5-6
5.2.1 Analytical Quality Control Program 5-6
5.2.2 Analytical Quality Assurance 5-7
5.2.2.1 Data Quality Indicators 5-7
5.2.3 Data Validation and Verification 5-8
5.2.3.1 Number and Location of Soil Samples 5-9
5.2.3.2 Analytical Data Requirements 5-9
5.2.4 Data Quality Summary 5-9
6.0 Conclusions and Recommendations 6-1
6.1 Summary of Field Activities 6-1
6.2 Conclusions and Recommendations 6-1
7.0 References 7-1

List of Figures

Figure 1 Wood Stave Storm Line Project Area Location Map
Figure 2 Project Area Layout
Figure 3 TI Sitewide Background Reference Areas
Figure 4 Sampling Locations
Figure 5 RSY Pad 233A Systematic Sampling
Figure 6 Profile View of Wood Stave Pipe Excavation

List of Tables

Table 1 Sitewide Background Analytical Results
Table 2 Radiological Instrumentation
Table 3 In-Process Material Sampling Results
Table 4 Material Survey Summary
Table 5 Analytical Data from Wood Stave Pipe Impacted Soil Sampling
Table 6 Wood Stave Pipe Area Survey Unit and Number of Soil Samples Calculations
Table 7 RESRAD Dose and Risk Summary

List of Photographs (in text)

Photograph 1 Existing conditions at wood stave pipe work area prior to removal of surface drainage swale. Lift Station #22 (red fencing) and the installed swale bypass (black and white piping) are visible past the excavator.

List of Appendices

Appendix A Work Instructions
Appendix B In-Process Analytical and Survey Data
Appendix C Final Status Survey and Background Data
Appendix D Instrument Calibration and Quality Control Data
Appendix E Dose and Risk Modeling Outputs
Appendix F Photograph Log
Appendix G Radiological Investigations Within Utility Corridors 1 and 2
Appendix H Technical Basis Document, Gamma Scanning Surveys (dated March 2015)

Acronyms and Abbreviations

^{226}Ra	radium-226
bgs	below ground surface
CB&I	CB&I Federal Services LLC
CSM	conceptual site model
CSO	Caretaker Site Office
DCGL	derived concentration guideline level
DoD	U.S. Department of Defense
DQO	data quality objective
DQI	data quality indicator
EPA	U.S. Environmental Protection Agency
FSS	final status survey
GWS	gamma walkover survey
H_0	null hypothesis
H_a	alternative hypothesis
HRASTM	*Final Historical Radiological Assessment—Supplemental Technical Memorandum, Naval Station Treasure Island, San Francisco, California*
IL	investigation level
LBGR	lower boundary of the gray region
LLRW	low-level radioactive waste
MARSSIM	*Multi-Agency Radiation Survey and Site Investigation Manual*
MDC	minimum detectable concentration
mrem/yr	millirem per year
Navy	U.S. Department of the Navy
NRC	U.S. Nuclear Regulatory Commission
NSTI	former Naval Station Treasure Island
pCi/g	picocurie per gram
P_r	random shift probability
QC	quality control
QA	quality assurance
RASO	Radiological Affairs Support Office
Report	final status survey report
ROICC	Resident Officer in Charge of Construction
RSY	radiological screening yard
SAP	sampling and analysis plan
SU	survey unit
TI	Treasure Island
Work Plan	*Final Work Plan for the Removal and Final Status Survey of Historic Avenue "N" Wood Stave Pipe at Former Naval Station Treasure Island, San Francisco, California*
WRS	Wilcoxon Rank Sum
YBI	Yerba Buena Island

Executive Summary

On behalf of the U.S. Department of the Navy, CB&I Federal Services LLC (CB&I) performed the removal and final status survey of the historic Avenue N wood stave pipe at former Naval Station Treasure Island, San Francisco, California. This Final Status Survey Report describes the activities conducted, presents results and findings, and documents the final condition of the excavation. The work was performed in accordance with the project *Final Accident Prevention Plan/Site Safety and Health Plan, Removal and Final Status Survey of Wood Stave Storm Line at Former Naval Station Treasure Island, San Francisco, California* (CB&I, 2015a) and *Final Work Plan for the Removal and Final Status Survey of Historic Avenue "N" Wood Stave Pipe at Former Naval Station Treasure Island, San Francisco, California* (CB&I, 2015b).

In the *Final Historical Radiological Assessment—Supplemental Technical Memorandum, Naval Station Treasure Island, San Francisco, California* (TriEco Tt, a Joint Venture of TriEco LLC and Tetra Tech EM, Inc., 2014), storm and sewer lines downstream of former Building 233 at Naval Station Treasure Island were identified as radiologically impacted due to the potential for disposal of radium-226 down these lines during the decontamination of Building 233 due to a radium spill in 1950. While the vast majority of existing storm lines was investigated, the *Final Historical Radiological Assessment—Supplemental Technical Memorandum, Naval Station Treasure Island, San Francisco, California* confirmed the existence of a former drain line on construction drawings. The drawings had the notation "existing 30-in wood stave pipe to be abandoned in place" (Naval Facilities Engineering Command Western Division, 1974). This storm drain pipe original to the island construction was replaced by an aboveground drainage swale in the mid-1970s. During this work, upstream sections of the wood pipe were removed and a majority of the pipe was filled in place with a concrete slurry mixture. Additionally, the original outfall was removed and replaced with the present day existing structure.

Site preparation activities consisted of the installation of a stormwater bypass line for surface stormwater swale; removal of sections of the drainage swale; and excavation and stockpiling of non-impacted soil. Excavation of radiologically impacted material, defined as the historic pipe itself and soil within 1 foot of the pipe on all sides, was performed under radiological controls. Due to the presence of a high volt electrical utility line that bisected the excavation in several locations, the central portion of the historic pipe remained in place and was not disturbed.

In-process samples were collected at various points along the excavation. These samples consisted of soil adjacent to the pipe, sediment and concrete slurry material from within the pipe,

and wood from the pipe itself. In addition, radiological surveys were performed on recovered materials. All in-process sampling and survey results were below project release criteria.

Due to the presence of groundwater within the excavation, the final trench surface was inaccessible for survey. As part of the excavation process, an additional 6 inches of material representing the final trench surface were excavated along with the impacted soil and placed on a radiological screening yard pad adjacent to the excavation. The excavated impacted soil underwent a 100 percent gamma scanning survey using the RS-700 gamma scanning system and systematic sampling per the requirements for a Class 1 survey unit in accordance with the *Multi-Agency Radiation Survey and Site Investigation Manual* (U.S. Nuclear Regulatory Commission et al., 2000). Gamma scanning survey and systematic sampling results met project release criteria.

Dose modeling was performed using a conservative exposure scenario and results were within background levels. While the center pipe segment was not directly investigated, the likelihood of contamination in this area is very low due to the lack of contamination upstream and downstream of the segment. In addition, the intact condition of the pipe as found at either end suggests it is unlikely there are any breaches in the center section. Therefore, it is concluded that the dose and risk from the center portion of the historic pipe remaining in place are also within background levels.

No further investigation or remediation is warranted based on these data. The U.S. Department of the Navy respectfully requests California Department of Public Health approve a Recommendation of Radiological Unrestricted Release.

1.0 Introduction

This Final Status Survey Report (herein referred to as Report) describes the radiological work conducted to support the removal and final status survey (FSS) of the historic Avenue N wood stave pipe at former Naval Station Treasure Island (NSTI), San Francisco, California (Figure 1). This Report presents the results of the radiological surveys and sampling during the removal of the pipe that demonstrate residual radioactivity present within the boundaries of the excavation meet the requirements for radiological unrestricted release.

This work was performed for the U.S. Department of the Navy (Navy), Naval Facilities Engineering Command Southwest, under Contract No. N62473-12-D-2005, Contract Task Order 0012. The Base Realignment and Closure Program Management Office West managed the work elements under this Contract Task Order.

This Report was prepared and implemented by CB&I Federal Services LLC (CB&I). The work documented in this Report followed the provisions of the project *Final Accident Prevention Plan/Site Safety and Health Plan, Removal and Final Status Survey of Wood Stave Storm Line at Former Naval Station Treasure Island, San Francisco, California* (CB&I, 2015a) and the *Final Work Plan for the Removal and Final Status Survey of Historic Avenue "N" Wood Stave Pipe at Former Naval Station Treasure Island, San Francisco, California* (Work Plan; CB&I, 2015b).

1.1 Scope of Work

The scope of work was based on findings in the *Final Historical Radiological Assessment—Supplemental Technical Memorandum, Naval Station Treasure Island, San Francisco, California* (HRASTM; TriEco-Tt, a Joint Venture of TriEco LLC and Tetra Tech EM, Inc., 2014).

The scope of work included the excavation and radiological characterization of the historic wood stave pipe and associated activities. Project activities included the following:

- Planning
- Permitting and notifications
- Site preparation, including fencing, installation of stormwater swale bypass lines, and construction of the radiological screening yard (RSY) pad (RSY Pad 233A)
- Removal of concrete swale and non-impacted overburden soil over the wood stave excavation

- Radiological screening of excavated impacted materials including the wood stave pipe, excavated impacted soil, and other associated materials
- Staging of material (implementing best management practices)
- Radiological surveys, sampling, and analysis consistent with the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM, U.S. Nuclear Regulatory Commission [NRC] et al., 2000) methodologies
- Backfilling of excavated areas
- Loading, transport, and disposal or recycling of waste
- Site restoration and stormwater swale restoration
- Dust control
- Traffic control
- Maintenance of the fenced perimeter delineating the exclusion zone

The targeted excavation area is shown on Figure 2. Prior to excavation of the soil, approximately 120 feet of the concrete stormwater swale was removed: 18 feet length at the east end and 102 feet length at the west end. In-process samples were collected from the wood stave material (soil, concrete slurry fill, and soil within 1 foot of the pipe) at four locations along the length of the excavation. These samples, along with the 20 systematic samples collected on RSY Pad 233A that consisted of soil deeper than 5.5 feet below ground surface (bgs) to 1 foot below the pipe, were analyzed for radiological characterization as outlined in the final version of the Work Plan and its associated sampling and analysis plan (SAP; CB&I, 2015b). As radiological survey and sampling results demonstrate that residual radioactivity levels meet the project release criteria, the wood stave pipe excavation has been backfilled to grade, compacted, and the surface stormwater swale has been repaired to match pre-excavation conditions.

1.2 Report Objectives and Organization

This Report documents the results of radiological survey and sampling activities associated with the historic Avenue N wood stave pipe. The surveys and sampling were performed in accordance with the Work Plan (CB&I, 2015b).

The data described in this Report meet requirements for use in an FSS and demonstrate that the residual levels of radioactivity in the area comply with requirements for unrestricted release. The following appendices support this report:

- Appendix A presents the work instructions cited in this Report.
- Appendix B presents the analytical data from samples collected from impacted materials during the excavation process, as well as radiological survey data from removed impacted materials.
- Appendix C is the FSS data package consisting of gamma scanning data and analytical results, as well as statistical analyses.
- Appendix D provides calibration certificates and daily quality control (QC) reports for instruments used for gamma surveys of soil.
- Appendix E summarizes dose and risk modeling.
- Appendix F presents photographic log of field activities.
- Appendix G presents a map summarizing the radiological investigations in Utility Corridors 1 and 2
- Appendix H presents the calculations for minimum detectable concentrations (MDCs) for gamma scanning surveys performed during the project.

2.0 Site History and Description

The following subsections describe the general site history and previous work within the boundaries of the historic wood stave pipe work area.

2.1 Treasure Island History

Treasure Island (TI) is a 403-acre man-made island located next to a natural rock island, Yerba Buena Island (YBI), in the San Francisco Bay (Figure 1). TI was constructed of materials dredged from the San Francisco Bay from 1936 to 1937 for the Golden Gate International Exposition of 1939 and 1940. In 1940, the Navy began leasing TI from the City and County of San Francisco and later, during World War II, gained full ownership of TI. YBI, a 147-acre natural island, has been under military control since 1898. In addition to other uses, the primary function of YBI was to provide training, administration, housing, and support services to the U.S. Pacific Fleet and other entities (Kistner, et al, 1995). In 1993, the NSTI was designated for closure under the Base Realignment and Closure Act of 1990. The NSTI was closed on September 30, 1997.

2.2 Wood Stave Pipe Work Area History

In the HRASTM (TriEco-Tt, a Joint Venture of TriEco LLC and Tetra Tech EM, Inc., 2014), storm and sewer lines downstream of former Building 233 were identified as radiologically impacted due to the potential for disposal of radium-226 (^{226}Ra) down these lines during the decontamination of Building 233 due to a radium spill in 1950. While the vast majority of existing storm lines was investigated, the HRASTM confirmed the existence of a former drain line on construction drawings. The drawings had the notation “existing 30-in wood stave pipe to be abandoned in place” (Naval Facilities Engineering Command Western Division, 1974). This storm drain pipe original to the island construction was replaced by an aboveground drainage swale in the mid-1970s. During this work, upstream sections of the wood pipe were removed and a majority of the pipe was filled in place with a concrete slurry mixture. Additionally, the original outfall was removed and replaced with the present-day existing structure.

In 2013, Gilbane collected gamma scanning measurements, alpha and beta static measurements, and alpha and beta swipe samples on the surface swale structure (Gilbane, 2015). Measurements were less than the project release criteria. No previous investigation of the wood stave pipe is known to have been performed.

2.3 Current Site Conditions

The historic wood stave pipe was located within the southeast corner of TI between Avenue M, Avenue N, and 3rd Street, within Utility Corridor 2 (Appendix G). The area of investigation was

identified as being directly below the existing surface drainage swale, which handles water pumps from Lift Station #22 (Photograph 1). Neighboring facilities include several island utility houses in the direct vicinity of the investigation area and a storage facility directly to the north. As shown on Figure 2, the work site is transected by three buried high voltage electrical lines. These 12,000-volt lines supply power to TI and YBI.

According to the Treasure Island Development Authority's *Treasure Island and Yerba Buena Island Streetscape Master Plan*, the wood stave pipe work area is proposed for reuse as island mixed use and open space (Conger Moss Guillard, 2015). Land surrounding the wood stave pipe excavation area includes various commercial, government, and industrial businesses.

Photograph 1
Existing conditions at wood stave pipe work area prior to removal of surface drainage swale. Lift Station #22 (red fencing) and the installed swale bypass (black and white piping) are visible past the excavator.

3.0 Characterization and Remediation Field Activities

This section provides an overview of the survey design and the field activities implemented during this project. The results of the radiation surveys and sample analyses supporting waste characterization and remediation decisions at the wood stave pipe work area are provided in Section 4.0. The work was performed in accordance with the Work Plan (CB&I, 2015b).

3.1 Release Criterion and Waste Characterization

The release criterion for the wood stave pipe work area is based on the ^{226}Ra concentration in soil samples collected from the NSTI sitewide background reference area (Figure 3). The investigation and remediation process has been designed to demonstrate that ^{226}Ra concentrations in soil samples from the project site meet the U.S. Environmental Protection Agency (EPA) dose limit of 12 millirem per year (mrem/yr) (EPA, 2014) above background.

The background reference area is a geographical area from which representative radioactivity measurements are performed for comparison with measurements performed in an impacted area. The selected reference area is an area with similar physical, chemical, radiological, and biological characteristics as the impacted area(s) being investigated but has not been identified as impacted.

The concentration of naturally occurring radionuclides at NSTI is variable because the island is man-made with materials brought in from multiple, and not always documented, areas. The variability in the concentration of the naturally occurring radionuclides results in highly variable gamma walkover survey (GWS) and gamma static survey count rates in areas that are not contaminated with ^{226}Ra. Based on information obtained from previous efforts to identify a suitable background reference area, it was determined that investigation of multiple potential reference background areas would be necessary. Therefore, reference area surveys and surface soil samples were collected from 20 potential background locations at NSTI (Figure 3). Collectively, these locations are designated the sitewide background reference areas. These 20 samples were analyzed at an off-site U.S. Department of Defense (DoD)-approved laboratory for ^{226}Ra using gamma spectroscopy. The details of the NSTI soil background investigation are provided in the *Analysis of Gamma Survey and Radium-226 Soil Concentration Data at the Treasure Island Sitewide Background Areas and the Area 7 Background Reference Area* (Shaw Environmental, Inc., 2012a).

The mean ^{226}Ra concentration in these 20 surface soil samples is 0.69 picocuries per gram (pCi/g). A screening criterion of 1 pCi/g of ^{226}Ra above the mean background concentration in the background reference area soil (equal to 1.69 pCi/g ^{226}Ra) was used as a screening tool to determine if soil remediation was necessary. Release of soil is based on the

requirements of the California Code of Regulations, Title 17, Section 30256 for radiological release.

The ^{226}Ra release criteria from Table 1 of Regulatory Guide 1.86 (U.S. Atomic Energy Commission, 1974) and provided in Table 4 of the Work Plan (CB&I, 2015b) were used to support initial waste characterization and material handling requirements for non-soil materials excavated and removed from the project site. The criteria for unrestricted use provided in Table 4 of the Work Plan include limits for alpha and beta-gamma total and removable surface contamination.

3.2 Background Reference Areas and Investigation Levels

The investigation level (IL) is the instrument-specific gamma survey count rate used to identify locations that warrant further investigation during gamma scan and static surveys. The scan and gamma static survey count rates are not used to quantify radionuclide concentrations. An a priori IL count rate is defined specifically for each ratemeter/scaler detector pair, for each media (soil or asphalt), and for each type of survey (GWS or gamma static). The IL is an estimate of the 99.7 percentile count rate for a survey of the background reference area and is calculated as the mean count rate plus three standard deviations of a survey performed at the background reference area. There are two background reference areas: Area 7 is the background reference area for soil and Area 9 is the background reference area for asphalt. Prior to collection of gamma survey measurements at the wood stave pipe work area, instrument- and media-specific ILs were determined using each area.

3.3 Survey Instrumentation

The following subsections provide details on the radiation detection instruments used for this project.

3.3.1 Instrument Selection

Radiological survey instruments selected are suitable for the physical and environmental conditions at the wood stave pipe work area. The instruments and measurement methods selected are able to detect ^{226}Ra and are, in relation to the survey or analytical technique, capable of measuring levels sufficient to support the data quality objectives (DQOs) described in Section 3.4.2. All radiological instruments were calibrated at least annually using appropriate National Institute of Standards and Technology-traceable standards. Specific instruments used during the radiological characterization activities during the wood stave pipe removal project are listed in Table 2.

3.3.2 Instrument Calibration

Portable survey instrument calibration is completed on an annual frequency. Instrument calibration is also performed after repairs or modifications have been performed on the instrument. The instruments were calibrated in accordance with the manufacturer's recommended method. Instrument calibration records for instruments used during the wood stave pipe radiological characterization activities are presented in Appendix D.

3.3.3 Instrument Operational Checks

Prior to use of the portable survey instruments, calibration verification, physical inspection, battery check, and a source response QC check were performed daily in accordance with *Treasure Island Work Instruction,* TIWI-12-01, "Operation and Use of Portable Instruments at Treasure Island" (Shaw Environmental, Inc., 2012b) (Appendix A). Daily QC checks for the instruments used during this survey are provided in Appendix C. Only those instruments that met the response check requirements and were found to be free of physical damage, had appropriate battery voltage levels, and had current calibrations were used in the field. Each of the selected instrument types in the following sections has been evaluated, and its response to ^{226}Ra has been calculated when the response check source is cesium-137.

3.3.4 Instruments for the Measurement of Gamma Surface Activity

Surveys for gamma radiation were performed with two instruments. In-process gamma scans were performed using a Ludlum Model 44-20 3-inch by 3-inch sodium iodide gamma scintillation detector coupled with a Ludlum Model 2221 ratemeter/scaler. This detector was also used for static gamma count rate measurements collected from soil on RSY Pad 233A.

Gamma scanning measurements on RSY Pad 233A were collected with the Radiation Solutions, Inc., RS-700 256-cubic-inch sodium iodide detector. Scanning measurements were collected at a speed of 0.25 meters per second with the detectors a height of 6 inches above the surface of the soil.

A detailed discussion of the scanning MDCs for both detectors is presented in Appendix H. The scan MDC for ^{226}Ra is equal to 1.42 pCi/g for the 44-20 and a 6-inch soil depth and 0.91 pCi/g for the RS-700 system and a 9-inch soil depth.

3.3.5 Exposure Rate Surveys

Exposure rate surveys were performed using a Ludlum Model 19, and survey results were recorded in units of microroentgen per hour. Surveys included general area dose rates, measured at approximately waist level (1 meter), to assess worker exposure levels. Weekly perimeter surveys around the site boundary were also performed to assess dose rates in areas accessible to the public.

3.4 Radiological Survey Performance

Specific details regarding the performance of radiological surveys during the wood stave pipe removal are presented in the following subsections.

3.4.1 Survey Unit Design and Classification

Investigation of the historic wood stave pipe was based on excavating the pipe and adjacent soil in approximately 12-foot long sections. Given the saturated soil conditions and sidewalls sloughing into the center of the excavation, tracking soil from its original location and stockpiling the soil in discrete piles allowed for easy identification of potential radiological contamination location. A site layout of the pipe excavation is found on Figure 4.

The Work Plan (CB&I, 2015b) noted impacted soil (defined as soil within 1 foot of the historic pipe) was to be excavated followed by an additional 6 inches of sidewall and bottom. Due to observed sloughing of trench surfaces from the infiltration of groundwater, the additional 6 inches of soil were excavated at the same time as the impacted soil. All impacted soil was radiologically screened using the FSS screening process on RSY Pad 233A. Material from each excavation section was tracked to its approximate location on the RSY pad.

Due to the saturated conditions within the excavation, radiological surveys and sampling inside the completed excavation were not feasible. To obtain radiological data for the impacted material, the excavated impacted material was transported to an adjacent RSY pad and surveyed in a manner consistent with a Class 1 survey unit (SU) in a MARSSIM framework (NRC et al., 2000). Per MARSSIM, a typical Class 1 SU consists of 2,000 square meters of material with a 6-inch depth equal to approximately 397 cubic yards of material. The excavation described above for the planned excavation areas calculates to approximately 90 cubic yards of excavated impacted soil resulting in one Class 1 SU.

3.4.2 Data Quality Objective Summary

DQOs are qualitative and quantitative statements developed as follows:

- To define the purpose of the data collection effort
- To clarify what the data should represent to satisfy this purpose
- To specify the performance requirements for the quality of information to be obtained from the data

These outputs are used to develop a data collection design that meets all performance criteria and other design requirements and constraints. EPA has specified a seven-step process to develop DQOs (2006), which was adapted for use in the MARSSIM (NRC et al., 2000). The DQOs

identified in the SAP (Appendix F of CB&I, 2015b) have been refined for the wood stave pipe radiological survey in the following subsections.

3.4.2.1 Step One—State the Problem

The historic wood stave pipe area is being investigated due to the following:

- ^{226}Ra may be present at concentrations and locations that potentially result in unacceptable dose or risk to human receptors.
- ^{226}Ra contamination may be present in the soil or wood stave pipe material without appropriate controls.

3.4.2.2 Step Two—Identify the Decision

The decision to be made for the FSS and unrestricted free radiological release is as follows: "Determine whether or not ^{226}Ra concentrations exceed project criteria for radiological free release."

3.4.2.3 Step Three—Identify Inputs to the Decision

The primary inputs to the decision include the following information:

- Analytical data from systematic soil samples from RSY Pad 233A used for radiological surveys of excavated impacted soil
- Analytical data from an appropriate reference area (Table 1)
- Data from GWS and gamma count rate static surveys of RSY Pad 233A
- Data from soil, wood, and concrete samples collected during the excavation process for radiological characterization
- Surface contamination data from excavated impacted materials
- Results from statistical testing performed on analytical and field measurement data
- QC data from the analytical laboratory and field activities

3.4.2.4 Step Four—Define the Study Boundaries

The lateral boundary for this study is the wood stave pipe and approximately 1 foot on all sides of the pipe plus an additional 6 inches. The vertical spatial boundary is 5.5 feet below ground surface to 1 foot below the bottom of the wood stave pipe, plus an additional 6 inches.

3.4.2.5 Step Five—Develop a Decision Rule

The decision rule is:

> If the soil ^{226}Ra concentration exceeds the screening criterion of 1.69 pCi/g, the soil will be remediated and disposed as low-level radioactive waste. If the ^{226}Ra concentrations from a SU are demonstrated to meet project release criteria, no further assessment is required.

3.4.2.6 Step Six—Specify Limits on Decision Errors

Acceptable decision errors were established to enable statistical testing of the data if required. Types I and II decision errors for statistical tests were conservatively established at 2.5 and 5 percent, respectively.

3.4.2.7 Step Seven—Optimize the Design for Obtaining Data

The following actions are taken to optimize the design for obtaining data:

- A 100 percent GWS is performed on radiologically impacted soil placed on RSY Pad 233A.
- If the GWS count rate or a gamma static count exceeds the instrument-specific IL indicating the potential presence of ^{226}Ra contaminated soil, additional surveys in the area are conducted; detected contamination is removed; remedial action support surveys are conducted to ensure ^{226}Ra contamination has been removed; and bias soil samples are collected and analyzed at a DoD-approved off-site laboratory for ^{226}Ra using gamma spectroscopy to bound the potential contaminated area.
- Prompt down loading, evaluation, and analysis of gamma count rate and position data to allow for timely follow-up in the event gamma count rates exceed the IL.
- The number and location of soil samples are calculated using the methods specified in MARSSIM Sections 5.5.2.2 and 5.5.2.5, respectively (NRC et al., 2000).
- Soil sampling is based on a triangular grid with a random starting point.
- Survey and soil sampling design will meet the limits on decision errors.
- Step-out soil sampling locations may be implemented if a prescribed soil sampling location cannot be sampled or if the gamma count rate exceeds the gamma survey IL.
- Assumptions involved in the sampling design are evaluated throughout the FSS process.

3.4.3 Sample Preparation and Analysis

Project radiological samples were submitted for off-site analysis to TestAmerica St. Louis, which is accredited by the DoD Environmental Laboratory Accreditation Program. Samples were dried

and canned according to standard laboratory procedures to allow for ingrowth of ^{226}Ra progeny. Radiological samples were analyzed by gamma spectroscopy for ^{226}Ra using the 609-kiloelectron volt gamma emission from bismuth-214 following both a 7-day and 21-day ingrowth. Data obtained following the 21-day ingrowth serve as the final project data in this Report.

The analytical MDC requirement for the analysis of ^{226}Ra by gamma spectroscopy is 0.5 pCi/g per the SAP (Appendix F of CB&I, 2015b). Analysis of TestAmerica St. Louis MDCs using gamma spectroscopy analysis for ^{226}Ra for radiological soil samples demonstrates the maximum sample-specific ^{226}Ra MDC for a wood stave pipe area soil sample is 0.176 pCi/g, which meets the required MDC.

3.4.4 Mobilization

Mobilization activities included site preparation, utility location, movement of equipment and materials to the site, and orientation and training of field personnel. Prior to field mobilization, representatives from the Resident Officer in Charge of Construction (ROICC), Caretaker Site Office (CSO), Radiological Affairs Support Office (RASO), and the Navy Remedial Project Manager were notified regarding the planned schedule for mobilization and excavation activities.

Training of field personnel included site-specific health and safety training and CB&I Radiation Worker Training. Upon receipt of the appropriate records and authorizations, field personnel, temporary facilities, and required sampling equipment and materials were mobilized to the job site. The temporary facilities included restrooms and a hand-washing station.

3.4.5 Site Preparation

To allow for continued operation of the stormwater lift station at the western end of the project site after removal of segments of the concrete drainage swale, a bypass line was installed and tested. The line allowed for stormwater to flow along the inner perimeter of the work area fence and out to the rip-rap adjacent to San Francisco Bay. This bypass line was left in place until the drainage swale was fully reconstructed.

Prior to excavation of soil, two sections of concrete drainage swale were removed at the west and east ends of the planned excavation area. Due to the presence of a high volt electrical utility line that bisected the excavation in several locations (Figure 2), the central portion of the swale remained in place and was not disturbed. No other surface features besides the swale were removed to facilitate excavation activities.

The top 5.5 feet of non-impacted overburden soil was excavated from each excavation section; radiologically screened using the 44-20 to verify radiological conditions; and stockpiled along the south side of the excavation (clean area). This soil was radiologically screened by the

bucketful prior to being placed in the stockpile staging area and was also radiologically screened after stockpiling. The excavation was probed for utilities and was surface surveyed on each 1-foot lift down to a depth of 4 feet. Several abandoned metal utility lines were discovered, surveyed, and removed for disposal at the completion of the project. The overburden material was tracked by excavation section and covered with plastic when stockpiled.

3.4.6 Excavation of Impacted Materials and In-Process Sampling

Once the historic pipe was vertically and horizontally located via probing and overburden soil was removed to a depth of 1 foot above the pipe, the excavation of impacted materials was performed starting at the at the west end of the planned excavation area and proceeding east. Excavated impacted materials were radiologically controlled and were segregated according to excavation section and material type (e.g., wood, concrete, soil). Significant water infiltration in the impacted area was observed due to heavy recent rains. Prior to transport to RSY Pad 233A, saturated soil was staged on the side of the excavation on plastic to allow for water to drain back into the excavation. Excavated soil was tracked to specific locations on RSY Pad 233A (Figure 5).

At the west end of the excavation, concrete fill was observed to be present in only a small portion of the pipe. The thickness of the fill was observed to increase to the east. In Section 4W (Figure 4), remnants of a riser and manhole were excavated. Concrete fill materials were thickest within the pipe in the vicinity of this location and were observed to continue at this thickness and gradually taper off to the east. Based on these observations, it is believed a concrete slurry fill was pumped into the pipe from the manhole; due to the slope of the pipe, the fill was unable to completely fill the pipe to the west.

At the east end of the excavation, the historic wood stave pipe that was originally believed to continue under the west side of Avenue N was observed to end at the Avenue N catch basin (Figure 6). Excavation did not continue into the Avenue N right of way; however, based on the infrastructure installed as noted in the 1974 plan (including the concrete catch basin, four 14-inch concrete drain pipes, new outfall, and original outfall backfilled), it is unlikely the original wood stave pipe remains below Avenue N.

Radiological in-process samples were collected during the excavation of impacted materials from wood pipe materials, concrete, sediment collected from within the pipe, and soil immediately adjacent to the pipe. These samples were tracked by excavation section. The samples were sent for off-site gamma spectroscopy analysis at TestAmerica St. Louis. Results from the in-process sampling are described in Section 4.0.

3.4.7 Gamma Walkover Survey

In addition to the gamma screening measurements for excavated overburden soil described in Section 3.4.5, GWS was performed over 100 percent of RSY Pad 233A in February 2016 using the RS-700 system. Data from these surveys were used to identify areas with potential for ^{226}Ra concentrations in soil that exceeded background. Any areas that exceeded the instrument-specific IL were further investigated via gamma static measurements as discussed in Section 4.1. Gamma static measurements were also collected at each systematic soil sampling location.

3.4.8 Systematic Soil Sampling

Systematic soil samples were collected from RSY Pad 233A in February 2016. Samples were collected using hand tools through the entire depth of the pad (9 inches). Following sampling, non-disposable sampling tools and associated equipment were surveyed for gross alpha contamination with a Ludlum Model 2360 with a 43-93 detector to verify the absence of radioactivity that would require additional contamination controls. Consistent with the *Sitewide Radiation Protection Plan, Naval Station Treasure Island, San Francisco, California* (CB&I, 2014), dry decontamination techniques were used on the sampling equipment between each location. Visible dirt or debris was removed from the sampling equipment with a brush and a masselin wipe. The equipment and wipe were frisked to confirm the absence of activity above control levels.

Per the Work Plan (CB&I, 2015b), systematic samples were collected using a random-start triangular grid. Twenty samples were collected for off-site analysis and static readings were collected at each location. The locations of the systematic samples are shown on Figure 5. The soil samples were submitted for off-site analysis to TestAmerica St. Louis, which is accredited by the DoD Environmental Laboratory Accreditation Program. Samples were dried and canned according to standard laboratory procedures. Results of the soil sampling are described in Section 4.0.

3.4.9 Waste Management

Used personal protective equipment was generated and conservatively managed as low-level radioactive waste (LLRW). No other radioactive waste materials were generated during the surveys.

3.4.10 Demobilization

Demobilization will include downposting the radiologically restricted areas of the work site, removing all tools, and equipment from the site, cleaning the project site, inspecting the study area, and completing a final inspection. Demobilization will occur once the site has been backfilled and the swale has been restored. A pre-final inspection will be performed by the CB&I Construction Manager and Project QC Manager with the ROICC and CSO. A final inspection

will be performed by the ROICC and CSO. A final inspection form will be signed after the final inspection has been completed.

4.0 Characterization and Remediation Results

This section provides a summary of the radiation surveys and sample analysis results supporting waste characterization and remediation decisions for radiologically impacted materials at the wood stave pipe excavation.

4.1 Material Characterization Surveys

Radiological characterization surveys were performed during excavation activities at the historic wood stave pipe site. For tracking purposes, the planned excavation was divided into nine excavation sections: numbered 1 West through 8 West on the west excavation and numbered 1 East on the east excavation (Figure 4). Samples were collected from wood, soil adjacent to the pipe, concrete, and sediment soil within the pipe within four of the excavation sections.

Soil and pipe material excavated below approximately 5.5 feet bgs were managed as potentially radiologically impacted material. Debris was removed from the excavated soil and placed into stockpiles based on material type and location from which they were excavated, so material and its characterization could be tracked throughout field activities. Soil deeper than 5.5 feet bgs and within 18 inches of the wood stave pipe was placed on RSY Pad 233A for radiological screening. Soil removed from each section was placed generally in the same area, so if any anomalies or items were found during the GWS of the pad, the location of their origin would be known.

4.1.1 In-Process Material Sampling Data

A total of 13 material samples were collected from four locations during the excavation. Results are listed in Table 3. None of the results exceeded the project screening criterion.

4.1.2 Material Survey Data

Material characterization activities included radiological screening of excavated impacted wood and concrete prior to final disposition. Surveys followed procedures for unrestricted radiological release noted in the *Sitewide Radiation Protection Plan, Naval Station Treasure Island, San Francisco, California* (CB&I, 2014). Data from alpha and beta material surveys performed on wood and concrete are summarized in Table 4. All measurements were below project release criteria.

4.2 Soil Surveys

As noted in Section 3.4.6, excavated impacted soil was placed on RSY Pad 233A to allow for radiological surveys and sampling. Radiological surveys consisted of gamma scan and gamma

static measurement surveys. The gamma scan survey of soil was performed in two stages. The first stage was conducted over 100 percent of the soil placed on RSY Pad 233A using the RS-700 system (shown on Figure 5). If the count rate exceeded the IL or otherwise required follow-up investigation, the second stage required an additional survey of the location where the count rate exceeded the gamma scan IL and nearby areas to assess if the elevated reading was the result of a point source or distributed radioactive material.

Gamma scan surveys are strictly used to identify areas of elevated gamma counts in comparison to background. Locations identified during gamma scan surveys that exceeded the instrument-specific IL required further investigation. Initial investigation consisted of reacquiring the elevated location and conducting a one-minute gamma static count. The radiological control technician rescanned the nearby area to assess if the elevated reading was the result of a point source or distributed radioactive material. If the static (one-minute) count was less than the detector-specific static IL and there was no evidence of a point source, further investigation was not required. If the static IL was exceeded or there was evidence of distributed contamination at or above either IL, the soil was sampled and analyzed as appropriate to confirm designation as LLRW or low-level mixed waste (i.e., waste containing both ^{226}Ra greater than the project screening criterion and levels of chemicals of concern triggering a hazardous waste designation). As discussed in the following subsections, no point sources or distributed radioactive contamination in soil prompting additional testing were identified during the wood stave pipe investigation activities.

4.2.1 Gamma Walkover—Survey Results

The GWS count rate data collected using the RS-700 system were evaluated to ensure potential small areas of elevated count rates were identified. This evaluation included review of the time series peaks observed in the gamma scan data and statistical evaluation to determine the Z-scores (i.e., the number of standard deviations a data point is from the data set mean) for each measurement. The RSY Pad 233A plots are presented in the FSS data package in Appendix C. Nine locations were selected for follow-up static surveys using the 44-20; none of the static measurements collected at those locations exceeded the instrument-specific IL.

4.2.2 Soil Sampling and Analysis

Following sample collection, the soil samples were shipped to TestAmerica St. Louis for ^{226}Ra analysis. TestAmerica is accredited in the DoD Environmental Laboratory Accreditation Program. The gamma spectroscopy library included all naturally-occurring radionuclides. Following initial review of 7-day ingrowth results, samples were counted following a full 21-day ingrowth period and were reported using the 609-kiloelectron volt gamma emission from bismuth-214. Data from the 21-day ingrowth analysis are reported as the final data.

Following receipt of the final gamma spectroscopy data after a 21-day ingrowth period, a data package consisting of the gamma scan data, analytical data, and background comparison was compiled and submitted to RASO for concurrence that the soil could be disposed as non-LLRW. The data packages and RASO concurrence for RSY Pad 233A are provided in Appendix C.

4.2.2.1 Comparison of Survey Unit Concentration Data to Background Reference Area

Analytical data were evaluated following the general process described in Section 8 of the MARSSIM (NRC et al., 2000). Data review included preparation of summary statistics and graphical analysis. Sample results and summary statistics are presented in Appendix C.

Summary Statistics

Summary statistics were prepared to summarize ^{226}Ra results for RSY Pad 233A (Table 5). A total of 20 systematic samples were analyzed by gamma spectroscopy for ^{226}Ra using the 609-kiloelectron volt gamma emission from bismuth-214 following 21-day ingrowth.

All results were below the project ^{226}Ra screening criterion of 1.69 pCi/g. The average concentration for the excavated impacted soil is below the sitewide background average, and other naturally-occurring radionuclides were detected within expected ranges for background. The statistical evaluation of SU ^{226}Ra data as compared to background is presented in Appendix C.

Graphical Plots

The primary graphical tool used to evaluate the wood stave pipe excavation ^{226}Ra data was the histogram. A histogram comparing the data from each SU to the sitewide background data set was prepared and is presented in Appendix C. The histograms demonstrate the ^{226}Ra data collected from RSY Pad 233A were consistent with sitewide background levels.

5.0 Compliance with Final Status Survey Requirements

The radiological characterization sampling for soil excavated from the wood stave pipe work area was conducted to meet sampling frequency and data quality requirements for an FSS. This section provides additional discussion regarding the FSS and justification no additional data are required.

5.1 Final Status Survey Objective

As noted in Section 2.2, the wood stave pipe would have been in use during active Navy operations at the former Building 233. Therefore, the pipe, filling material used to abandon the pipe in place, and the soil immediately surrounding the pipe (i.e., soil located within 1 foot of the pipe) are considered radiologically impacted and require investigation for potential radiological contamination. If present, contaminants in soil within the wood stave pipe work area represent a potential risk for current and future TI residents and utility workers on the site.

5.1.1 Conceptual Site Model

The following subsections describe the assumptions of the initial wood stave pipe area conceptual site model (CSM), how the investigation and remediation performed at the wood stave pipe area validated or refuted the assumptions, and the current CSM following excavation activities.

5.1.1.1 Initial Conceptual Site Model

The initial CSM assumed the only radionuclide of concern was ^{226}Ra. As noted in Section 2.2, the wood stave pipe was active when the historical ^{226}Ra spill in Building 233 occurred. Therefore, contamination of the pipe and adjacent soil may have resulted due to ^{226}Ra contamination from Building 233 entering the system as a result of stormwater runoff.

5.1.1.2 Excavation and Current Conceptual Site Model

Surveys of soil and debris from the wood stave pipe area demonstrated ^{226}Ra contamination from the historical spill was not present. Soil ^{226}Ra concentrations were similar to background, and radiological surveys did not identify any elevated activity. The excavation included both a 1-foot thick layer of soil immediately adjacent to the historic pipe as well as an additional 6 inches of soil from the trench sidewalls and bottom.

The center section of the historic pipe was left in place due to the safety hazard in excavating adjacent to the high voltage electrical lines running through the area. While this pipe segment was not investigated, the likelihood of contamination in this area is very low due to the lack of contamination upstream and downstream of the segment. In addition, the intact condition of the

pipe as found at either end suggests it is unlikely there are any breaches in the center section where contamination may have accumulated.

Potential conservative exposure mechanisms for current and future human receptors include external exposure to gamma radiation associated with ^{226}Ra and its decay progeny, inhalation of ^{226}Ra and decay progeny associated with particulates, and inadvertent ingestion of soil contaminated with ^{226}Ra and its decay progeny. Receptors under a future resident farmer land-use scenario may also be exposed via ingestion of ^{226}Ra contaminated produce, meat, milk, and eggs. The groundwater is saline and cannot be used to irrigate crops, to water livestock, or for household uses.

5.1.2 Future Land-Use Scenario

The hypothetical future land-use scenario is a residential farmer. This land use is not necessarily a planned future land use but is a standard conservative default and is considered protective of all likely future land uses. There is no regulatory basis for the definition of "resident farmer." The term "resident farmer" is conservatively assumed to include the raising of livestock, grains, fruits, and vegetables for food even though these activities will not be part of the planned future land use for this portion of TI. The exposure pathways include the following:

- External exposure assuming the dose receptor is on site 24 hours per day, 365 days per year
- Inhalation of airborne ^{226}Ra contaminated particulates
- Inadvertent soil ingestion
- Ingestion of produce and meat raised on the land

The near-term anticipated future land-use scenario is the residential suburban and includes use as public land. However, for calculating the dose to residents, a resident farmer land-use scenario is assumed.

Transport mechanisms include downward migration of any residual activity through the surface soil. The present depth of the downward migration is expected to be minimal and less than 0.15 meter based on fall-out studies and the asphalt and concrete ground cover in the area. Future vertical migration to the surface is expected to be minimal. Clean soil will be used to backfill the excavation to the original soil surface.

5.1.3 Statistical Testing

The sample design was prepared with the objectives of demonstrating ^{226}Ra soil concentrations within the wood stave pipe work area meet the project release criteria and performing a comparison of site ^{226}Ra concentrations to background. Based on these survey objectives, the

process described as “Scenario B” in the MARSSIM (NRC et al., 2000) was used as the basis for evaluation of the data collected from the excavated soil on RSY Pad 233A (the SU).

5.1.3.1 Null Hypothesis

The null hypothesis (H_0) describes the default assumption that the statistical test will either accept or reject in favor of an alternative hypothesis (H_a). For Scenario B, the hypotheses may be described as follows (from NUREG-1505; NRC, 1998):

- H_0: The difference in the median concentration of radioactivity in the SU and in the reference area is less than the lower boundary of the gray region (LBGR).
- H_a: The difference in the median concentration of radioactivity in the SU and in the reference area is greater than the derived concentration guideline level (DCGL).
- H_0 and H_a are tested by the Wilcoxon Rank Sum (WRS) Test described in Section 5.1.3.2.

5.1.3.2 Wilcoxon Rank Sum Test

The WRS Test is a nonparametric two-sample test used when the contaminant is present in background. For the wood stave pipe work area, ^{226}Ra is present in background; therefore, use of the WRS Test is appropriate. The WRS Test was performed using the spreadsheet formulas for Scenario B provided in NUREG-1505 Section 6 (NRC, 1998) and with the following parameters:

- LBGR: Based on the discussion in Section 13 of NUREG-1505, the standard deviation of the sitewide background data set (0.161 pCi/g) multiplied by 3 (equal to 0.483 pCi/g).
- Type I error rate, α_W, equal to $\alpha/2$, or 0.025.

Spreadsheets with the WRS Test conducted for the wood stave pipe data are presented in Appendix C. As expected from the summary statistics and histograms, H_0 was accepted for the wood stave pipe data.

5.1.3.3 Quantile Test

In Scenario B, the Quantile Test must also be performed if the WRS Test accepts H_0. The Quantile Test looks for localized groups of sample results that exceed the LBGR. Using the Quantile Test in tandem with the WRS Test in Scenario B results in higher power to detect sample results exceeding background than either test has individually.

The Quantile Test was performed for the wood stave pipe data (Appendix C). The results of the Quantile Tests demonstrate there are no isolated areas of activity within the wood stave pipe data.

5.1.3.4 Calculating Number and Location of Soil Samples

The number of samples estimated during the survey design for each SU was 20 samples per 1,000 square meters. During the data quality assessment phase, the estimated number of samples determined during the survey design was compared to the actual minimum number of samples required for the appropriate statistical test using actual SU data to determine if the survey design assumptions were adequate. The following calculations are shown using the actual wood stave pipe data for ^{226}Ra soil concentrations. The results for the wood stave pipe data are presented in Table 6.

Calculate the Relative Shift

The relative shift (Δ/σ) is calculated first by determining the width of the gray region or in other words, the difference (Δ) between the DCGL and the LBGR. The standard deviation (σ) from the sitewide background data set was greater than the standard deviations observed for solid waste disposal area Bigelow Court site SU 1. Therefore, for this evaluation, the LBGR is set to the value used for the Scenario B WRS Test, or 0.483 pCi/g, and the standard deviation from the sitewide background data set is used. Therefore, the relative shift can be calculated for ^{226}Ra for the wood stave pipe data using the following equation:

$$\frac{\Delta}{\sigma} = \frac{DCGL - LBGR}{\sigma} = \frac{1 - 0.483}{0.161} = 3.21$$

Where:

DCGL	=	1 pCi/g (Section 3.1)
LBGR	=	0.483 pCi/g
σ	=	0.161 pCi/g; standard deviation of ^{226}Ra in the reference area that was greater than the observed data standard deviation of 0.075 pCi/g

Determine P_r

The probability a random measurement from the SU exceeds a random measurement from the background reference area by less than the DCGL when the SU median is equal to the LBGR above background is defined as random shift probability (P_r). MARSSIM Table 5.1 lists relative shift values and the corresponding values for P_r (NRC et al., 2000). When the actual value of the relative shift was not listed in MARSSIM Table 5.1, the next lower value that appeared in the table was used. For the evaluation of ^{226}Ra in the wood stave pipe data and a relative shift of 3.21, the corresponding $P_r = 0.983039$.

5.1.3.5 Calculate N

Using the P_r determined above and the Type I (α) and Type II (β) decision error percentiles, the total number of samples from the SU plus the reference area (N) is calculated using MARSSIM Equation 5-1 (NRC et al., 2000) as follows:

$$N = \left\{ \frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{3\left(P_r - 0.5\right)^2} \right\}(1.2) = \left\{ \frac{\left(1.960 + 1.645\right)^2}{3\left(0.983039 - 0.5\right)^2} \right\}(1.2) = 22.3$$

Where:

N	=	number of combined samples from the SU and reference area
$Z_{1-\alpha}$	=	Type I decision error level (1.960 as determined from MARSSIM Table 5.2 and α=0.025)
$Z_{1-\beta}$	=	Type II decision error level (1.645 as determined from MARSSIM Table 5.2 and β=0.05)
P_r	=	random shift probability, determined in MARSSIM Section 5.1.4.4.2
1.2	=	factor for over-sampling to account for missing or unusable data

The total number of samples (N) is divided between SU and the reference area as the minimum number required for the WRS Test based on the parameters for ^{226}Ra. This is done by rounding up N to the next even number and dividing by two (N/2). Therefore, 22.3 is rounded up to 24 total samples and divided in half to equal 12. The actual number of samples taken at RSY Pad 233A for ^{226}Ra was 20, which exceeds the required minimum number of samples.

As noted in Section 3.3.4, the scan MDC for ^{226}Ra equals 1.42 pCi/g using the 44-20, and 0.91 pCi/g using the RS-700 system. As this value is below the project screening criterion of 1.69 pCi/g, no additional samples are required to compensate for the scan MDC.

Statistical Power Evaluation

The statistical power associated with the data collected from RSY Pad 233A was evaluated using a retrospective power analysis. The power analysis was performed consistent with the guidance in Section 10 of NUREG-1505 (NRC, 1998) using the actual number of samples collected and the observed standard deviation from the sitewide background data set to generate retrospective power curves (Appendix C).

5.1.4 Dose Modeling for Unrestricted Release of the Wood Stave Pipe Area

To translate the soil concentration data into a measure of potential dose, it is necessary to develop a dose model. A conservative dose model was performed using *RESRAD*, Version 7.0 (Argonne National Laboratory, 2014). The modeling uses the residential farmer scenario, which assumes a full-time resident that grows crops in the modeled area.

Using the typical dose modeling approach for NSTI, site-specific inputs to the model included only the maximum wood stave pipe area ^{226}Ra concentration corrected for background (0.69 pCi/g) and the total surface area of RSY Pad 233A. As the background-corrected concentration is a negative value, dose evaluation using the background-corrected maximum ^{226}Ra concentration is not required.

Although additional dose modeling is not required, the average observed ^{226}Ra concentration of 0.381 pCi/g was used to determine a conservative estimate of dose from the wood stave pipe area. Equilibrium of ^{226}Ra with its progeny lead-210 was also assumed. The inputs for the RESRAD dose model are shown in Table 7. This model resulted in a dose of 3.14 mrem/yr and a maximum excess lifetime cancer risk of 6.27E-05. As noted above, these results are conservative and are calculated only to demonstrate the minimal contribution of the observed naturally-occurring ^{226}Ra levels in soil to the average reported exposure to terrestrial sources of background radiation of 19 mrem/yr (National Council on Radiation Protection and Measurements, 2009). The *RESRAD* output reports for dose and risk are presented in Appendix E.

In *Decommissioning Health Physics* (2014), Abelquist presents an approach for conducting a hazard assessment for contaminated underground pipe. In that approach, data collected from the accessible ends of the pipe are used as representative inputs to determine inhalation, ingestion, and external radiation dose to a future construction worker from the pipe as a whole. Based on the data collected from the west and east ends of the excavated wood stave pipe and associated material, it is concluded using the same reasoning that the dose and risk from the center portion of the historic pipe remaining in place are also within background levels.

5.2 Data Quality Assessment

A review of the project analytical data quality requirements is provided in the following subsections.

5.2.1 Analytical Quality Control Program

Details on the off-site laboratory quality assurance (QA) program requirements are established in the SAP (Appendix F of CB&I, 2015b). The salient topics addressed in the QA program are as follows:

- Laboratory accreditation
- Measurement system and standard operating procedure requirements
- Certification of operator competence
- Internal QC checks, such as recovery of known additions through use of standards and laboratory control samples

- Analysis of externally supplied standards
- Analysis of reagent blanks
- Calibration with standards using internal or external standard procedures
- Calibration verification with second-source standard
- Analysis of duplicates
- Maintenance of control charts
- Strict adherence to good laboratory practices
- Consistent use of written and approved standard operating procedures
- Calibration requirements
- Calibration standards
- Preventive maintenance
- Training supplies and consumables
- Software QA and validation
- Software security
- Laboratory corrective action

The assigned Project Chemist reviewed the laboratory data packages.

5.2.2 Analytical Quality Assurance

Criteria for the FSS, as stated in the DQOs (except where noted), require valid quality data be used for making critical decisions (CB&I, 2015b). Rigorous QA/QC is implemented for all laboratory samples including documentation, data verification and validation of analytical results, and an assessment of data quality indicators (DQIs) as they relate to laboratory analysis.

Validated data will be assessed to determine if they meet the DQO requirements of the investigation and the performance criteria for the DQIs. If the DQOs are not met, impact to the remediation objective decision will be evaluated. Based on the evaluation, no additional sampling, surveys, or remediation will be required.

5.2.2.1 Data Quality Indicators

DQIs are quantitative and qualitative descriptors used in determining the degree of acceptability or usability of data. The DQIs established to evaluate the quality of the survey and sampling data are precision, accuracy, representativeness, comparability, completeness, and sensitivity and are

used to evaluate the entire measurement system, the laboratory measurement processes (i.e., analytical method performance), and individual analytical results (i.e., parameter performance).

Representativeness and comparability are qualitative measures. Completeness, accuracy, and precision are quantitative measurements. Precision and accuracy are used to assess the overall analytical method and field sampling performance as well as to assess the need to qualify the usability of individual parameter results when corresponding QC sample results are not within established control limits. Therefore, performance metrics have been established for both analytical methods and individual analytical results. Worksheet #19 and Worksheets #23 through 25 in the SAP provide the established analytical method/measurement system performance criteria for each of the DQIs and the potential impacts to the decision if the criteria are not met (Appendix F of CB&I, 2015b).

The MARSSIM requires conditions that adversely affect data quality (i.e., nonconformance), both in the field and the laboratory, be documented (NRC et al., 2000). Corrective actions required to mitigate adverse field conditions are tracked to verify successful implementation. All DQI performance criteria deficiencies will be evaluated for data usability and impacts to the DQO decisions. These evaluations are discussed in the following subsections.

5.2.3 Data Validation and Verification

The details on the data validation and verification are in Worksheets #35 and #36 of the SAP (Appendix F of CB&I, 2015b). The validation and verification requirements address the following.

- Definition of each step in the validation and verification process
- Input to each step
- Individual responsible for performing each step
- Criteria for each step in the data validation and verification process

The data validation Project Manager reviews the off-site laboratory reports for compliance with applicable methods and the approved SAP (Appendix F of CB&I, 2015b), applies validation qualifiers to analytical data, and prepares a data validation report.

The Project Chemist is the point of contact for laboratory issues. The Project Data Manager is the point of contact for electronic data deliverables. If laboratory issues are not resolved with the Project Chemist or Data Manager, then the issues are elevated to the Program Chemist. Upon resolution, the Project Chemist oversees the documentation, notification, and corrective actions

associated with the laboratory issues in writing. There were no significant data quality issues with analytical data from the historic wood stave pipe area.

5.2.3.1 Number and Location of Soil Samples

When determining compliance with the FSS goals, the survey data were examined. Compliance reviews considered the following:

- Did the GWS and static survey count rates exceed the IL?
- Did the number and location of soil samples meet the requirements of the DQOs?
- Did sample results identify the maximum ^{226}Ra concentration in the soil samples?
- Is the maximum ^{226}Ra concentration in soil less than the release criterion?
- Does the statistical evaluation of the reported analytical ^{226}Ra sample results compare favorably with background levels of ^{226}Ra in soil?

5.2.3.2 Analytical Data Requirements

The analytical data requirements for the calibration of the gamma spectroscopy program, including calibration procedure, frequency, acceptance requirement, and corrective actions, are defined in TestAmerica Procedure No. ST-RD-0102, Rev. 13 (included in the SAP [Appendix F of CB&I, 2015b]). The requirements for the maintenance, testing, and inspections of the gamma spectroscopy system, including procedures, frequency, acceptance requirements, and corrective actions, are defined in SAP Worksheet #25. The QC requirements for method blanks, laboratory duplicates, and laboratory control samples for gamma spectroscopy of soil samples are defined in SAP Worksheet #28.

5.2.4 Data Quality Summary

Analytical data were provided by TestAmerica St. Louis in five separate analytical batches. No data were identified as rejected. Specific analytical details from the case narratives for each data report are noted as follows (analytical data reports are presented in Appendices B and C):

- 160-15772-2 (FSS Section 1W Soil and Wood Final Data):
  - Sample was prepped as received rather than the project specified dry/grind: TITO12-WSTAVE-WOOD (160-15772-2). The detection goal for ^{226}Ra was not met for the following sample due to insufficient sample available for analysis: TITO12-WSTAVE-WOOD (160-15772-2). The sample is low-density wood splinters. Analytical results are reported with the detection limit achieved.

- 160-15883-2 (FSS Section 4W Soil and Wood Final Data):
  - Sample was prepped as received rather than the project specified dry/grind: TITO12-WSTAVE-WOOD012516 (160-15883-1). The ^{226}Ra detection goal was not met for the following sample due to the low density of the sample: TITO12-WSTAVE-WOOD012516 (160-15883-1). Analytical results are reported with the detection limit achieved.
- 160-15947-2 (FSS Section 1W and 4W Concrete Final Data):
  - No difficulties were noted.
- 160-16018-2 (FSS Section 8W and 1E Soil, Wood, and Concrete Final Data):
  - Due to the matrix, the samples were not dried and ground as per the project requirements.
- 160-16133-2 (FSS Systematic Sampling of RSY Pad 233A Final Data):
  - No difficulties were noted.

6.0 Conclusions and Recommendations

This section includes the summary of field activities and conclusions.

6.1 Summary of Field Activities

A radiological survey consisting of GWS, gamma static surveys, and soil sampling was conducted on radiologically impacted soil excavated from at the wood stave pipe area and placed on RSY Pad 233A in January and February 2016. The survey objective was to provide sufficiently robust data to support the requirements of a FSS and for the results to support radiologic unrestricted release.

Investigation areas were identified during the GWS conducted to support the excavation and FSS. Follow-up investigation static gamma count rate measurements did not exceed the instrument-specific IL. Twenty systematic soil samples were collected on RSY Pad 233A, and no samples exceeded the project screening criterion of 1.69 pCi/g. A total of 33 radiological samples were collected and analyzed by gamma spectroscopy in support of the radiological characterization of excavated impacted wood stave soil and materials.

Results and the FSS statistical calculations for the excavated impacted soil demonstrated that the project release criterion of 12 mrem/yr was achieved. In addition, analytical data from the excavated impacted soil was evaluated with the sitewide background dataset and found to be comparable.

6.2 Conclusions and Recommendations

The results from the characterization and remediation activities support the conclusion no further data collection is required to meet the requirements of an FSS, and the historic wood stave pipe site is suitable for radiological unrestricted release based on the following lines of evidence:

- GWS and subsequent follow-up surveys of measurements did not identify elevated ^{226}Ra levels.
- Radiological screening of impacted soil excavated during the wood stave pipe removal demonstrated ^{226}Ra concentrations in excavated soil were comparable to the TI sitewide background data set.
- Radiological surveys of impacted wood and concrete excavated during the wood stave pipe removal showed no evidence of ^{226}Ra contamination.
- Concentrations of ^{226}Ra measured in the wood stave pipe material (wood and concrete) and in soil excavated from the investigation area at 5.5 feet bgs to 1 foot

below the wood stave pipe were compared with the TI sitewide background data set and concluded to be indistinguishable from background.

- A conservative model demonstrates the potential dose to a worst-case receptor from the naturally-occurring ^{226}Ra levels in the wood stave pipe area soil is within the expected background exposure from naturally-occurring terrestrial sources.

The final inspection of the excavation area identified no visual evidence of buried solid waste or signs of contamination that extended horizontally or vertically beyond the target excavation boundaries. The segment of the wood stave pipe left in place due to the adjacent high voltage lines was fully bounded by excavations on either end with no contamination found. Therefore, it is concluded the remaining wood stave pipe does not pose a future exposure risk.

No further investigation or remediation is warranted based on these data. The Navy respectfully requests California Department of Public Health approve a Recommendation of Radiological Unrestricted Release.

7.0 References

Abelquist, Eric W., 2014. *Decommissioning Health Physics: A Handbook for MARSSIM Users*, 2nd Edition, CRC Press, New York.

Argonne National Laboratory, 2014, *RESRAD, Version 7.0*.

CB&I, 2014, *Sitewide Radiation Protection Plan, Naval Station Treasure Island, San Francisco, California.*

CB&I, 2015a, *Final Accident Prevention Plan/Site Safety and Health Plan, Removal and Final Status Survey of Wood Stave Storm Line at Former Naval Station Treasure Island, San Francisco, California*.

CB&I, 2015b, *Final Work Plan for the Removal and Final Status Survey of Historic Avenue "N" Wood Stave Pipe at Former Naval Station Treasure Island, San Francisco, California*, December.

Conger Moss Guillard, 2015, *Treasure Island and Yerba Buena Island Streetscape Master Plan*, February.

Gilbane, 2015, *Internal Draft Report, Scoping Survey of Wastewater Lines Downstream from Former Building 233, Former Naval Station Treasure Island, San Francisco, California*, September.

Kistner, J., Hice, E., and D. Schierling, 1995, *Historical Study of Yerba Buena Island and Treasure Island and Their Buildings*, Mare Island Naval Shipyard, Base Realignment and Closure.

Naval Facilities Engineering Command Western Division, 1974, "U.S. Naval Station Treasure Island, California Storm Drain Lift Station Plan & Profile Vicinity Map," August.

National Council on Radiation Protection and Measurements, 2009, *Ionizing Radiation Exposure of the Population of the United States*, Report No. 160.

Shaw Environmental, Inc., 2012a, Internal Memorandum from Steve Adams, Certified Health Physicist, to Christine Donahue, Project Radiation Safety Officer, *Analysis of Gamma Survey and Radium-226 Soil Concentration Data at the NSTI Sitewide Background Areas and the Area 7 Background Reference Area*, April 23.

Shaw Environmental, Inc., 2012b, *Treasure Island Work Instructions*, most recent version.

TriEco-Tt, a Joint Venture of TriEco LLC and Tetra Tech EM, Inc., 2014, *Final Historical Radiological Assessment—Supplemental Technical Memorandum, Naval Station Treasure Island, San Francisco, California*, July 1.

U.S. Atomic Energy Commission, 1974, *Termination of Operating Licenses for Nuclear Reactors,* U.S. Atomic Energy Commission Regulatory Guide 1.86, June.

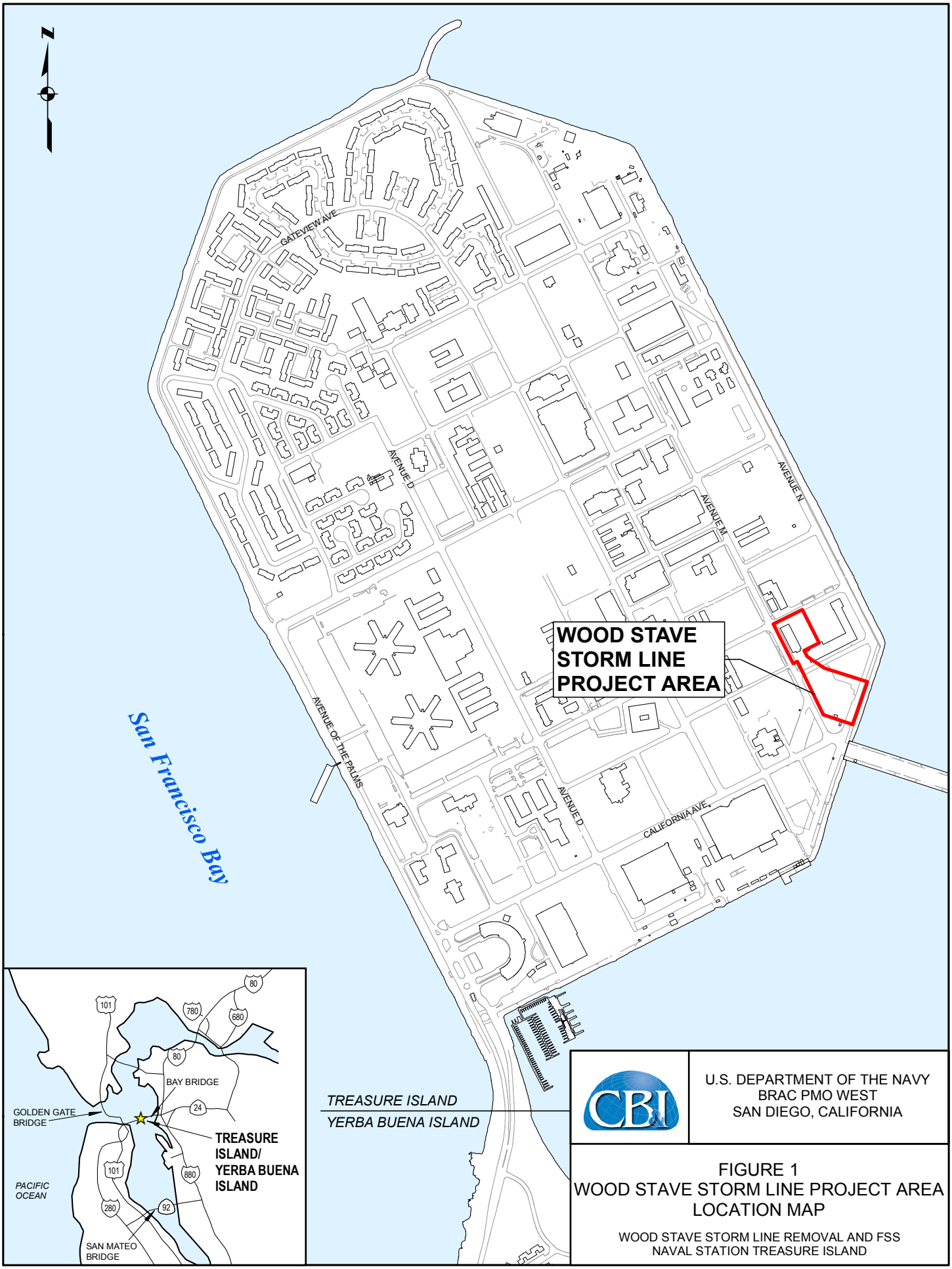
U.S. Environmental Protection Agency, 2006, *Guidance on Systematic Planning Using the Data Quality Objectives Process*, EPA QA/G-4, EPA/240/B-06/001, February.

U.S. Environmental Protection Agency, 2014, *Radiation Risk Assessment at CERCLA Sites: Q&A*, Directive 9200.4-40, EPA 540-R-012-13, May.

U.S. Nuclear Regulatory Commission, 1998, *A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys, NUREG-1505*, Revision 1, June.

U.S. Nuclear Regulatory Commission, U.S. Environmental Protection Agency, and U.S. Department of Energy, 2000, *Multi-Agency Radiation Survey and Site Investigation Manual*, NUREG-1575, EPA 402-R-97-016, DOE/EH-0624, Revision 1, Washington, D.C.

Figures



U.S. DEPARTMENT OF THE NAVY
BRAC PMO WEST
SAN DIEGO, CALIFORNIA

FIGURE 1
WOOD STAVE STORM LINE PROJECT AREA
LOCATION MAP

WOOD STAVE STORM LINE REMOVAL AND FSS
NAVAL STATION TREASURE ISLAND

C:\GIS\Treasure_Island\GIS_Documents\Project_Maps\CTO12EMAC_WoodStave\TI_CTO12_100_WoodStave_Loc.mxd 4/1/2016

Legend

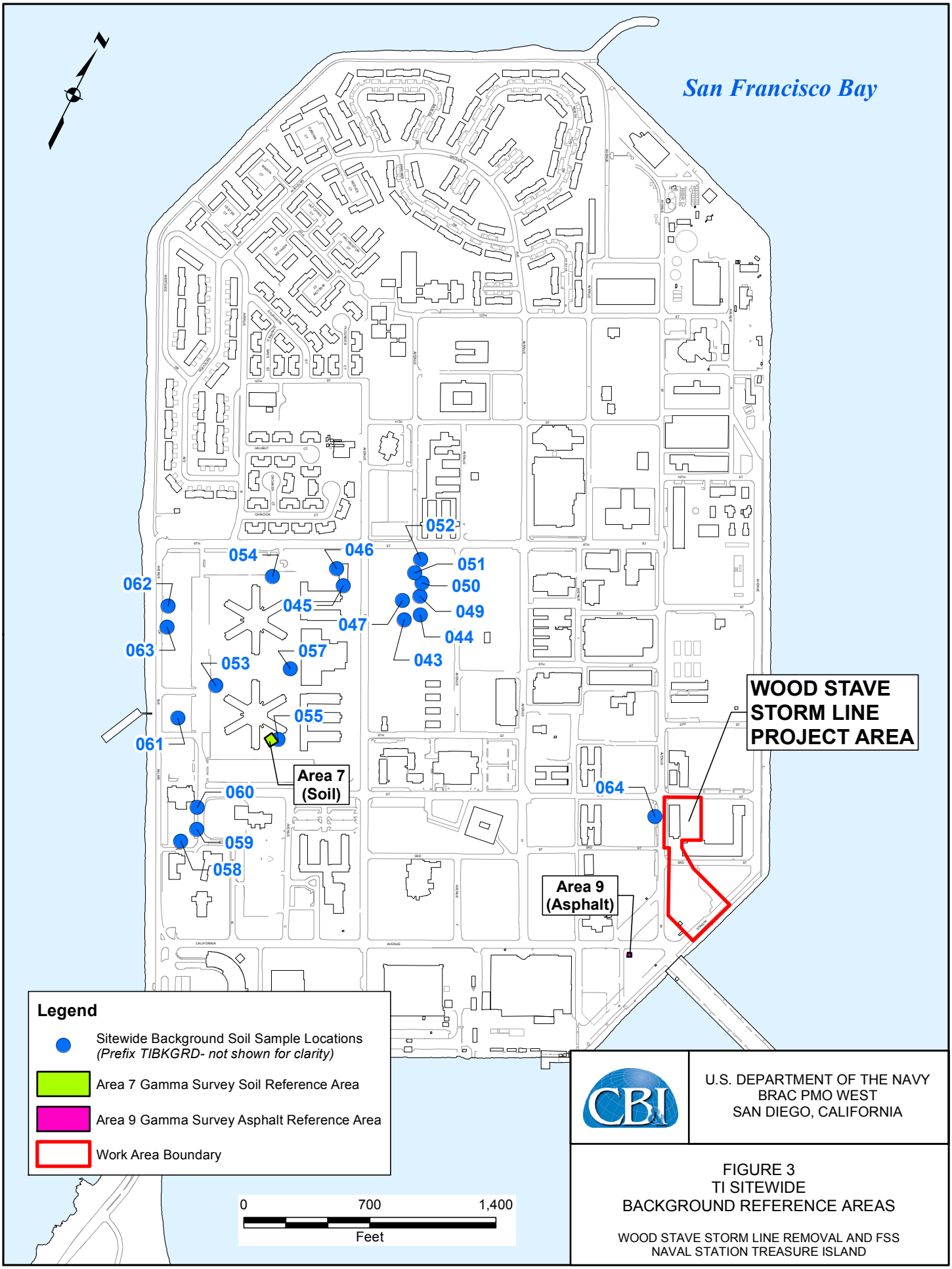
- Excavation Area
- Stockpile Area
- Swale Bypass
- RSY Pad
- Project Work Area (fenced)
- RCA
- Traffic Control Barricade
- Water Line
- Buried Power Line

U.S. DEPARTMENT OF THE NAVY
BRAC PMO WEST
SAN DIEGO, CALIFORNIA

FIGURE 2
PROJECT AREA LAYOUT

WOOD STAVE STORM LINE REMOVAL AND FSS
NAVAL STATION TREASURE ISLAND

C:\GIS\Treasure_Island\GIS_Documents\Project_Maps\CTO12EMAC_WoodStave\TI_CTO12_102_WoodStave_Site.mxd 3/30/2016

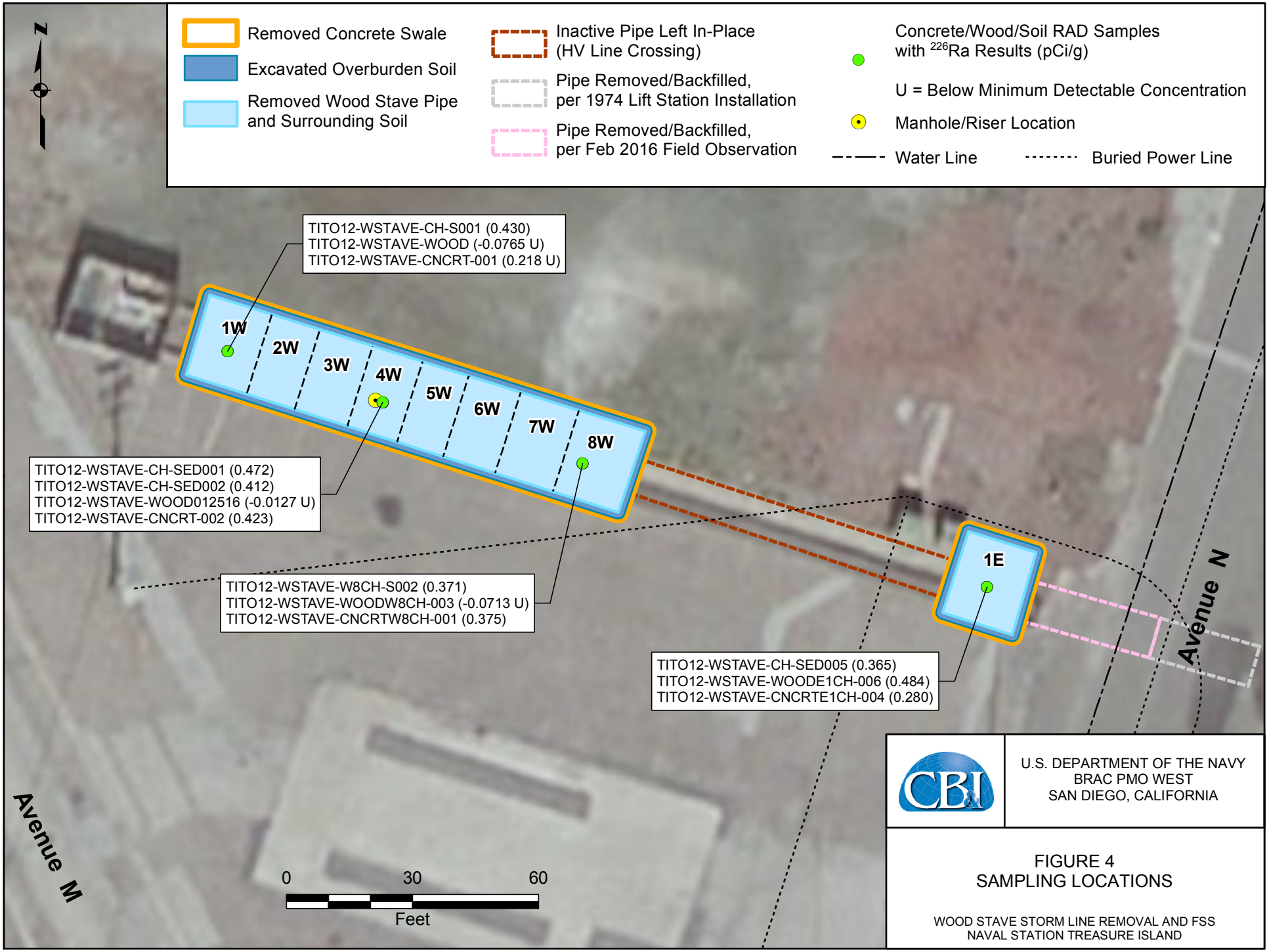


U.S. DEPARTMENT OF THE NAVY
BRAC PMO WEST
SAN DIEGO, CALIFORNIA

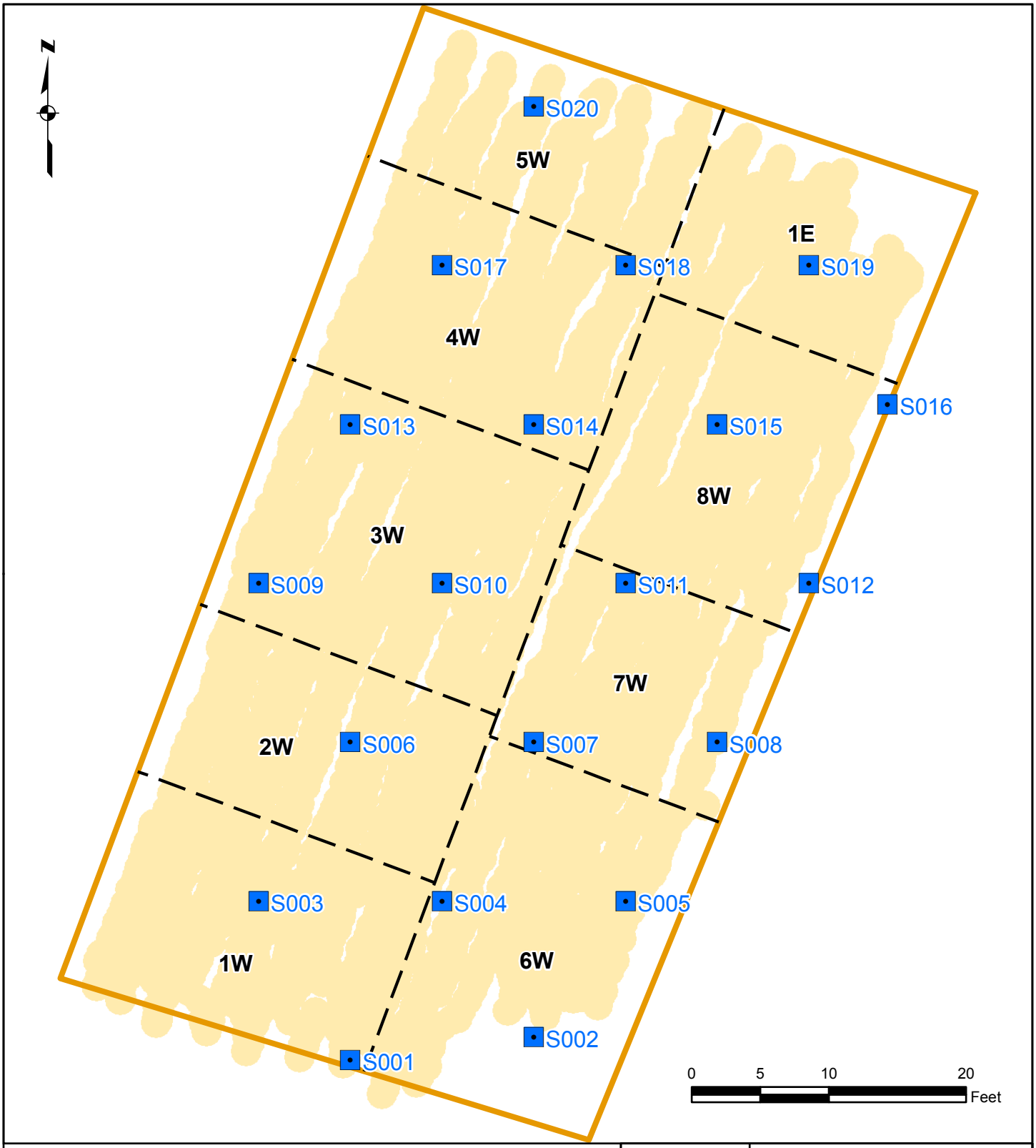
FIGURE 3
TI SITEWIDE
BACKGROUND REFERENCE AREAS

WOOD STAVE STORM LINE REMOVAL AND FSS
NAVAL STATION TREASURE ISLAND

C:\GIS\Treasure_Island\GIS_Documents\Project_Maps\CTO12EMAC_WoodStave\TI_CTO12_101_WoodStave_BkgdRef.mxd 4/1/2016



C:\GIS\Treasure_Island\GIS_Documents\Project_Maps\CTO12EMAC_WoodStave\TI_CTO12_108_WoodStave_Samples.mxd 5/25/2016



Legend

- Sample Location
- RSI Coverage
- RSY Pad Boundary

NOTES:

Survey Number: TIRS-02152016-WSP-JSS-052

Instrument Number: 97290

Coordinate System: CSP Zone III, NAD83, US Survey Foot

100% of the soil on the RSY Pad was surveyed by the RSI unit.

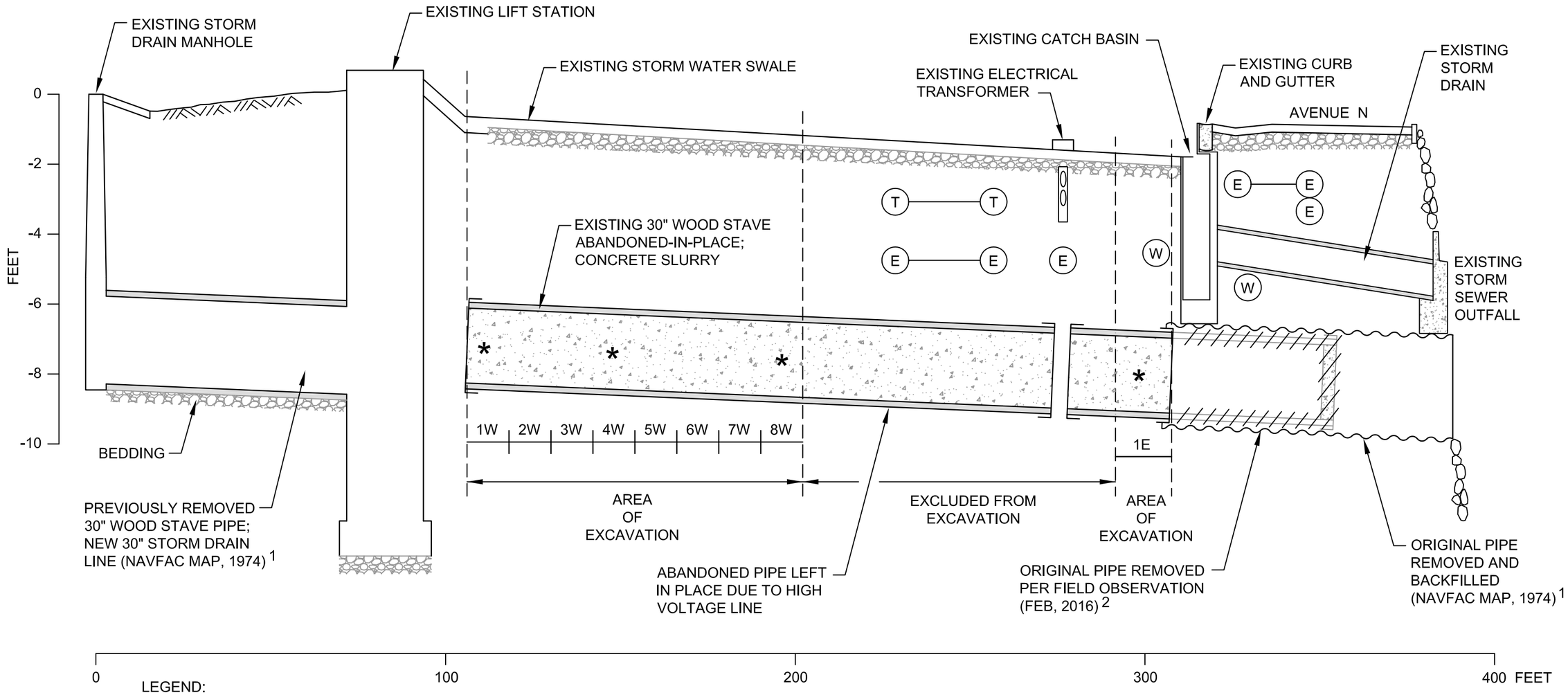
Approximate locations for soil excavated are shown on the RSY Pad.

U.S. DEPARTMENT OF THE NAVY
BRAC PMO WEST
SAN DIEGO, CALIFORNIA

FIGURE 5
RSY PAD 233A
SYSTEMATIC SAMPLING

WOOD STAVE STORM LINE REMOVAL AND FSS
NAVAL STATION TREASURE ISLAND

C:\GIS\Treasure_Island\GIS_Documents\Project_Maps\CTO12EMAC_WoodStave\TI_CTO12_107_RSY233A_Report.mxd 3/14/2016



LEGEND:

- * SAMPLE COLLECTED FOR LAB ANALYSIS (IN PROCESS)
- (E) HIGH VOLTAGE ELECTRICAL LINE; RUNS PERPENDICULAR TO EXCAVATION AREA
- (E)—(E) HIGH VOLTAGE ELECTRICAL LINE; RUNS DIAGONALLY THROUGH EXCAVATION AREA
- (T)—(T) TELECOMMUNICATION LINE; RUNS DIAGONALLY THROUGH EXCAVATION AREA
- (W) WATER LINE

HORIZONTAL SCALE

0 30 60 FEET

VERTICAL SCALE

0 3 6 FEET

NOTES:

1. NAVFAC WEST, "STORM DRAIN LIFT STATION PLAN & PROFILE VICINITY MAP, TREASURE ISLAND, SAN FRANCISCO, CALIFORNIA. 1974

2. FIELD ACTIVITIES PERFORMED BY CB&I UNDER N62473-12-0-2005, CTO 0012 IN FEBRUARY 2016

U.S. DEPARTMENT OF THE NAVY
BRAC PMO WEST
SAN DIEGO, CALIFORNIA

FIGURE 6
PROFILE VIEW OF
WOOD STAVE PIPE EXCAVATION

WOOD STAVE STORM LINE REMOVAL AND FSS
NAVAL STATION TREASURE ISLAND

DRAWING NUMBER	APPROVED BY	CHECKED BY	DRAWN BY	OFFICE	X-REF	IMAGE
500475-B3			2/18/16 KB	Concord	---	---

Tables

Table 1
Sitewide Background Analytical Results

Sample	^{226}Ra	
	Result [a]	MDC
TIBKGRD-043	0.49	0.13
TIBKGRD-044	0.98	0.16
TIBKGRD-045	0.83	0.19
TIBKGRD-046	0.54	0.08
TIBKGRD-047	0.57	0.13
TIBKGRD-049	0.55	0.12
TIBKGRD-050	0.57	0.14
TIBKGRD-051	0.46	0.11
TIBKGRD-052	0.50	0.11
TIBKGRD-053	0.66	0.10
TIBKGRD-054	0.75	0.08
TIBKGRD-055	0.70	0.10
TIBKGRD-057	0.86	0.15
TIBKGRD-058	0.51	0.14
TIBKGRD-059	0.91	0.14
TIBKGRD-060	0.83	0.11
TIBKGRD-061	0.79	0.16
TIBKGRD-062	0.90	0.10
TIBKGRD-063	0.66	0.13
TIBKGRD-064	0.69	0.09
Average	0.69	Not Applicable
Standard Deviation	0.16	Not Applicable
Minimum	0.46	Not Applicable
Maximum	0.98	Not Applicable
Median	0.68	Not Applicable

Notes:

[a] All values are reported in units of picocuries per gram.

^{226}Ra radium-226

MDC minimum detectable concentration

Table 2
Radiological Instrumentation

Gamma Exposure Rate Surveys—Ludlum Model 19		
Meter Serial Number	Calibration Due Date	Background Exposure Rates (µR/h)
267085	11/4/2016	5
267096	7/16/2016	4
138426	1/27/2016	5

Gamma Scan and Static Surveys—Ludlum Model 2221 (3-inch by 3-inch NaI Probe)				
Meter Serial Number	Detector Serial Number	Calibration Due Date	Asphalt Investigation Level (cpm)[a]	Soil Investigation Level (cpm)
282966	PR262403	9/29/2016	21,087 (scan)	22,399 (scan)
			18,022 (static)	20,154 (static)
97290	PR295572	4/28/2016	21,087 (scan)	22,399 (scan)
			18,022 (static)	20,154 (static)
262337	PR337255	1/27/2016	19,099 (scan)	21,105 (scan)
			17,214 (static)	19,608 (static)

Alpha/Beta Scan and Static Surveys						
Meter	Meter Serial Number	Calibration Due Date	Efficiency		Background (cpm)	
			Alpha	Beta	Alpha	Beta
43-93	268506	9/28/2016	42.6%	30.8%	0.2	118.7

Alpha/Beta Smear Surveys						
Meter	Meter Serial Number	Calibration Due Date	Efficiency		Background (cpm)	
			Alpha	Beta	Alpha	Beta
3030	224340	4/21/2016	32.5%	32.6%	0.3	32.7
3030	265985	3/24/2016	32.9%	30.5%	0.2	31.2

Table 2 (continued)
Radiological Instrumentation

Gamma Scanning Surveys—RS-700 with RSX-1 Detectors		
Component	Serial Number	Calibration Date[b]
RS-701 Console	7236	2/26/2014
RSX-1 Detector	5447	
RSX-1 Detector	5448	

Notes:

[a] *For gamma surveys on concrete, the asphalt investigation level was conservatively used.*

[b] *Manufacturer recommendation is system calibration every two years.*

µR/hr	*microroentgen per hour*
%	*percent*
cpm	*count per minute*
NaI	*sodium iodide*

Table 3
In-Process Material Sampling Results

Description	Excavation Section[a]	Material Type	^{226}Ra			
			Result[b]	Flag[c]	MDL	≥ MDL[d]
TITO12-WSTAVE-CH-S001	1W	Soil (Adjacent to Pipe)	0.430		0.119	0.430
TITO12-WSTAVE-WOOD	1W	Wood	-0.077	U	0.668	0.668
TITO12-WSTAVE-CNCRT-001	1W	Concrete	0.218	U	0.220	0.220
TITO12-WSTAVE-CH-SED001	4W	Sediment (Within Pipe)	0.472		0.146	0.472
TITO12-WSTAVE-CH-SED002	4W	Sediment (Within Pipe)	0.412		0.110	0.412
TITO12-WSTAVE-WOOD012516	4W	Wood	-0.013	U	0.604	0.604
TITO12-WSTAVE-CNCRT-002	4W	Concrete	0.423		0.161	0.423
TITO12-WSTAVE-W8CH-S002	8W	Soil	0.371		0.088	0.371
TITO12-WSTAVE-WOODW8CH-003	8W	Wood	-0.071	U	0.460	0.460
TITO12-WSTAVE-CNCRTW8CH-001	8W	Concrete	0.375		0.046	0.375
TITO12-WSTAVE-CH-SED005	1E	Sediment (Within Pipe)	0.365		0.103	0.365
TITO12-WSTAVE-WOODE1CH-006	1E	Wood	0.484		0.295	0.484
TITO12-WSTAVE-CNCRTE1CH-004	1E	Concrete	0.280		0.140	0.280
Project Screening Criterion			1.690			
Number of Samples			13			13
Average			0.282			0.428
Standard Deviation			0.205			0.119
Minimum			-0.077			0.220
Maximum			0.484			0.668
Median			0.371			0.423

Notes:

[a] Excavation section shown on Figure 4.

[b] Units are picocuries per gram (pCi/g).

[c] "U" indicates "Result is less than the sample detection limit."

[d] If the reported result is less than the method detection limit, the method detection limit is reported in this column.

≥	*greater than or equal to*
^{226}Ra	*radium-226*
MDL	*method detection limit*

Table 4
Material Survey Summary

Survey Type	Static Measurements						
	Count	(dpm/100 cm^2)				Release Limit	Measurements > Release Limit
		Average	Std Dev	Min	Max		
Wood—Alpha	62	9	7	-2	26	100	0
Wood—Beta	62	249	135	-118	463	5,000	0
Concrete—Alpha	99	16	15	-2	64	100	0
Concrete—Beta	99	366	96	129	626	5,000	0

Survey Type	Smear Measurements						
	Count	(dpm/100 cm^2)				Release Limit	Measurements > Release Limit
		Average	Std Dev	Min	Max		
Wood—Alpha	42	-1	1	-1	2	20	0
Wood—Beta	42	4	17	-24	44	1,000	0
Concrete—Alpha	53	0	1	-1	5	20	0
Concrete—Beta	53	0	20	-39	53	1,000	0

Notes:

>	*greater than*
dpm/100 cm^2	*disintegration per minute per 100 centimeters squared*
Max	*maximum*
Min	*minimum*
Std Dev	*standard deviation*

Table 5
Analytical Data from Wood Stave Pipe Impacted Soil Sampling

Description[a]	^{226}Ra			
	Result[b]	Flag	MDL	≥ MDL[c]
TITO12-RSY233A_1CH-S001	0.393		0.170	0.393
TITO12-RSY233A_1CH-S002	0.358		0.118	0.358
TITO12-RSY233A_1CH-S003	0.465		0.116	0.465
TITO12-RSY233A_1CH-S004	0.364		0.136	0.364
TITO12-RSY233A_1CH-S005	0.295		0.138	0.295
TITO12-RSY233A_1CH-S006	0.184		0.176	0.184
TITO12-RSY233A_1CH-S007	0.360		0.111	0.360
TITO12-RSY233A_1CH-S008	0.338		0.114	0.338
TITO12-RSY233A_1CH-S009	0.403		0.135	0.403
TITO12-RSY233A_1CH-S010	0.400		0.145	0.400
TITO12-RSY233A_1CH-S011	0.413		0.101	0.413
TITO12-RSY233A_1CH-S012	0.347		0.147	0.347
TITO12-RSY233A_1CH-S013	0.492		0.136	0.492
TITO12-RSY233A_1CH-S014	0.309		0.129	0.309
TITO12-RSY233A_1CH-S015	0.403		0.115	0.403
TITO12-RSY233A_1CH-S016	0.478		0.132	0.478
TITO12-RSY233A_1CH-S017	0.404		0.156	0.404
TITO12-RSY233A_1CH-S018	0.298		0.100	0.298
TITO12-RSY233A_1CH-S019	0.448		0.158	0.448
TITO12-RSY233A_1CH-S020	0.472		0.116	0.472
Project Screening Criterion	1.690			
Number of Samples	20			20
Average	0.381			0.381
Standard Deviation	0.075			0.075
Minimum	0.184			0.184
Maximum	0.492			0.492
Median	0.397			0.397

Table 5 (continued)
Analytical Data from Wood Stave Pipe Impacted Soil Sampling

Notes:

[a] *Sample locations and associated excavation sections are shown on Figure 5.*

[b] *Units are picocuries per gram (pCi/g).*

[c] *If the reported result is less than the method detection limit, the method detection limit is reported in this column.*

≥	*greater than or equal to*
^{226}Ra	*radium-226*
MDL	*method detection limit*

Table 6
Wood Stave Pipe Area Survey Unit and Number of Soil Samples Calculations

SU	Total Area (m^2)	σ (higher of background vs. SU data)	LBGR	Δ/σ	P_r	N	N/2	Actual N (Systematic Locations)	Number of Biased Locations	Total Number of Samples
233A-1	247	0.161	0.483	3.21	0.983039	22.3	12	20	0	20
Total:										20

Notes:

Δ	*delta*
σ	*sigma*
LBGR	*lower bound of gray region*
m^2	*square meter*
N	*number of samples*
P_r	*probability value from Table 5.1 of MARSSIM (NRC et al., 2000)*
SU	*survey unit*
vs.	*versus*

Table 7
RESRAD Dose and Risk Summary

Survey Unit	Survey Area	Maximum Activity	Net Maximum Activity[a]	Dose	Excess Cancer Risk
	(m^2)	(pCi/g)	(pCi/g)	(mrem/yr)	
		^{226}Ra	^{226}Ra		
RSY 233A	247	0.492	N/A	N/A	N/A
RSY 233A—gross ^{226}Ra	247	0.381[b]	N/A	3.136	6.267E-05

Notes:

[a] Net maximum activity is determined by subtracting the average background concentration of 0.69 pCi/g from the maximum activity.

[b] For the gross ^{226}Ra dose model, the average observed concentration was used as the model input.

^{226}Ra	*radium−226*
mrem/yr	*millirem per year*
m^2	*square meter*
N/A	*not applicable*
pCi/g	*picocurie per gram*
SU	*survey unit*

Appendix A
Work Instructions

UNCONTROLLED
WHEN REPRODUCED

1.1 PURPOSE

This Treasure Island Work Instruction provides direction to radiological control personnel for the performance and documentation of radiological surveys to detect, quantify, and document the following:

- Total/removable alpha and/or beta-gamma emitting radioactive contamination on work surfaces, work areas, vehicles, equipment, and personnel
- Exposure and dose rates from beta and gamma for posting requirements and control of radiation exposure to workers

Radiological surveys are conducted for routine work area monitoring and for those activities associated with job-specific tasks authorized by the radiological work permit (RWP) process (Ref. 1.3.1).

Radiological Control personnel conduct surveys to:

- Demonstrate compliance with the requirements of Code of Federal Regulations (CFR) Title 10, Part 20, *Standards for Protection Against Radiation* (Ref. 1.3.2) and incorporated by reference into Title 17 of the California Code of Regulations
- Detect changes in radiological conditions
- Determine the location of radioactive material and/or radiation fields in the workplace
- Determine the effectiveness of engineering and process controls

1.2 SCOPE AND APPLICABILITY

This work instruction provides the requirements for determining and documenting routine survey frequencies, defines the steps required to detect, quantify, and document radiation exposure and dose rates, total contamination, and removable contamination. This work instruction also specifies the measurements that must be made for:

- Routine surveys
- Posting verification surveys
- Unrestricted release surveys
- Sealed sources leak tests
- Personnel frisking

This work instruction does not address the performance and documentation of gamma walk-over surveys or U.S. Department of Transportation surveys. Refer to the applicable work instruction for specific instructions relating to these types of radiological surveys.

This document, including certain of its background information, contains proprietary and confidential information of Shaw and is to be returned upon request. Its contents may not be copied, disclosed to third parties, or used for other than the express purpose for which it has been provided without the prior written consent of Shaw. This document does not constitute a "Work for Hire."

1.3 REFERENCES

1.3.1 Shaw Environmental, Inc. (Shaw), Current Revision, *Radiological Work Permits*, TIWI-19, Concord, California.

1.3.2 CFR, Title 10, Part 20, Standards for Protection against Radiation, U.S. Government Printing Office, Washington, D.C., January 1, 2011, available online at 10CFR20 (December 2011).

1.3.3 U.S. Nuclear Regulatory Commission (NRC), Regulatory Guide 1.86, *Termination of Operating Licenses for Nuclear Reactors*, Table 1.1.

1.3.4 Shaw, Current Revision, *Radiological Control Technician Training and Qualification*, TIWI-11, Concord, California.

1.3.5 Shaw, Current Revision, *Operation and Use of Radiation Detection Instruments at Treasure Island*, TIWI-12, Concord, California.

1.3.6 Shaw, Current Revision, *Radiological Incident Emergency and Response*, TIWI-21, Concord, California.

1.4 DEFINITIONS

TERM (ACRONYM)	DEFINITION
Contamination Survey	The use of smears or direct portable instrument surveys to identify and/or quantify radioactive material on personnel, on equipment, or in an area.
Contamination Area (CA)	An area, accessible to individuals, in which surface contamination levels on equipment or solid surface materials are equal to or exceed the values provided in NRC Regulatory Guide 1.86, Table 1.1, but do not exceed 100 times those values (Ref. 1.3.3).
General Area (GA)	Radiological reading collected at a height of approximately 1 meter from ground surface (approximately waist level) to determine an area's general radiation levels.
High Contamination Area (HCA)	An area, accessible to individuals, in which surface contamination levels on equipment or solid surface materials exceed 100 times the values provided in NRC Regulatory Guide 1.86, Table 1.1 (Ref. 1.3.3).

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

UNCONTROLLED
WHEN REPRODUCED

TERM (ACRONYM)	DEFINITION
High Radiation Area (HRA)	An area, accessible to individuals, in which radiation levels from radiation sources external to the body could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 milliSievert) in 1 hour at 30 centimeters from the radiation source or any surface that the radiation penetrates.
Job Safety Analysis (JSA)	A Job Safety Analysis identifies hazards associated with job-specific tasks and provides appropriate safety controls for the identified hazards.
Radiation Area (RA)	An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 milliSievert) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.
Radioactive Materials Area (RMA)	Any area or room where quantities of radioactive materials in excess of 10 times the 10 CFR 20, Appendix C (Ref. 1.3.2) quantities are used or stored, or any area designated by the project radiation safety officer.
Radiological Work Permit (RWP)	A document prepared by radiological controls to inform workers of the radiological conditions, which exist in the work area and the radiation safety precautions and requirements for the job.
Routine Survey	Surveys conducted on a scheduled basis to monitor or detect changes in radiological conditions, confirm postings, determine the location of radioactive material and/or fields in the work area, and verify effectiveness of engineering and process controls.

1.5 RESPONSIBILITIES

1.5.1 Project Radiation Safety Officer

The project radiation safety officer (PRSO) implements this procedure and approves all radiological protective measures incorporated into each RWP. Specifically, the PRSO, or designee shall:

- Review the planned work and associated hazards
- Ensure an as low as reasonably achievable (ALARA) review has been performed and documented, as appropriate
- Formally approve the RWP and any subsequent revisions

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

1.5.2 Radiological Control Supervisor

The radiological control supervisor (RCS) supervises the radiological control technicians (RCT) and oversees the daily activities within all radiologically-controlled areas. The RCS ensures compliance with the requirements of this work instruction. At the direction of the PRSO, the RCS shall:

- Review the planned work
- Identify hazards
- Establish radiological controls
- Ensure ALARA review is completed, documented, and requirements are satisfied
- Prepare and formally approve the RWP and any subsequent revisions

1.5.3 Lead Radiological Control Technician

The lead RCT is assigned supervision of the RCTs at a specific work location and oversees the daily activities within all radiologically-controlled areas. The lead RCT ensures compliance with the requirements of this work instruction. At the direction of the RCS, the lead RCT shall:

- Establish radiological controls
- Ensure ALARA review is completed, documented, and requirements are satisfied
- Provide on-going review of work activities to ensure compliance with applicable RWP

1.5.4 Radiological Control Technician

The RCT conducts radiation and contamination surveys, accurately documents required survey reports, and routinely monitors worker compliance with RWP requirements. The assigned RCT shall:

- Assist in the RWP preparation as directed by the RCS
- Perform and document a pre-job radiological survey of the work area as required by a PRSO or RCS
- Make specific recommendations for radiological controls
- Perform radiological surveys as required by the approved RWP or when requested by a project manager with concurrence from the RCS
- Routinely review the RWP and perform compliance reviews of work activities during on-going surveys and support activities

1.6 PRECAUTIONS AND LIMITATIONS

Do not enter any area where the expected exposure rates are greater than the measurement capability of the survey instrument. Immediately leave the area when continued exposure could lead to the RWP control limit (if applicable) being exceeded.

Maintain exposure ALARA (e.g., use of extending probe instruments and remote area monitoring, pre-staging equipment, and review of survey maps/photographs prior to entry).

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

When performing a direct survey of an area or item in a posted contamination area, be careful to prevent contamination of the probe or instrument. Do not cover the active surface of the detector with protective material. An increase in detector background may indicate a contaminated probe/instrument. If the probe/instrument is suspected to be contaminated, it must be surveyed to verify its radiological status.

Surfaces that have films of grease, oil, or water can trap or mask contamination. If a survey of these areas is required, contact the RCS or lead RCT for assistance.

Porous surfaces, such as wood or cardboard, can be difficult to survey for contamination. If a contamination survey of a porous material is required, contact the RCS or lead RCT for assistance in deciding if special survey techniques are necessary.

1.7 PREREQUISITES

Staff performing this procedure must be trained and qualified per TIWI-11, *Radiological Control Technician Training and Qualification* (Ref. 1.3.4).

In collaboration with the RCS or lead RCT, choose the most appropriate instrument based on the radiation environment to be surveying. TIWI-12, *Operation and Use of Radiation Detection Instruments at Treasure Island* (Ref. 1.3.5) provides uses and limitations of survey instruments typically employed at Treasure Island.

Gather appropriate information and supplies, such as the following:

- Historical survey data, recent survey information, if available, and any other information that would be useful to perform a proper survey.
- Form FRM TI-01-1, “Survey Report – Example” or Form FRM TI-01-2, “Sealed Source Leak Test – Report – Example,” map of the area to be surveyed, gloves, appropriate smears and instruments, plastic bags and labels (as needed), and a marker or pen.

Required personal protective equipment must be in accordance with the RWP and Job Safety Analysis document covering the specific work or area.

Check instruments for operability, such as battery check and high voltage check, in accordance with TIWI-12 (Ref. 1.3.5). Verify that the instrument calibration is current.

Review and sign applicable RWP(s) for the specific work area, task, or job.

Comply with general industrial safety standards, including those found in the Job Safety Analysis while conducting surveys. For example, never place your body in harm’s way when performing surveys on suspended loads. Use long handled meters to reach under the load. Never place your body beneath suspended loads exceeding 50 pounds. Do not perform surveys near exposed wiring, pressurized lines, cryogen lines, or dewars, unless they have been proven to be safely de-energized.

1.8 WORK PROCESS

The following sections describe the frequency for performing surveys and the work process for completing exposure/dose rate surveys, direct contamination surveys, removable contamination surveys, leak source test surveys, and personnel surveys.

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

1.8.1 Survey Frequency

Surveying work areas provides the basis for posting and labeling, developing RWPs and other work authorizations, implementing ALARA measures, issuing individual monitoring devices, and verifying the efficacy of design measures and engineering controls.

Survey frequencies are based on potential and actual radiological conditions, probability of change in conditions, and area occupancy factors.

Table 1 provides guidelines for establishing routine and job-specific survey frequencies. Survey locations, frequencies, and additional requirements are documented in the appropriate RWP.

Table 1
Guidelines for Establishing Survey Frequency

Activity	Guideline Frequency
Survey Type – Routine – No Active Work	
Exposure rates and surface contamination of select items and equipment stored in posted Contamination Area.	Monthly
Exposure rates and surface contamination in uncontrolled areas directly adjacent to Radioactive Material Storage Areas (main building)	Monthly
Exposure rates and/or surface contamination of clean trash bins, office areas, break room.	Monthly
Exposure/dose rate surveys of posted Restricted Area and posted Radiation Area boundaries.	Weekly
Survey Type – Active Work	
Exposure rates and surface contamination of inside cab of Shaw truck	Monthly
Exposure rates and surface contamination in posted Restricted and Radiological Areas (contamination area, high contamination area, radiation area)	Daily
Leak test of sealed sources – all	Quarterly

1.8.2 Exposure/Dose Rate Surveys

Exposure/dose rate surveys are conducted to determine the potential dose rates to personnel entering or working in general areas, verify current radiological postings, and characterize sources of radiation.

Survey documentation shall include dose rates in the units reported on the instrument (e.g., microroentgens per hour [μR/h], milliroentgens per hour [mR/h]). However, for beta-gamma radiation, 1 R ≈ 1 rem ≈ 1 rad, therefore, it is acceptable to use values measured in R or rad (or fractions thereof) to verify posting requirements stated in rem or rad.

The exposure rate meters in use at Treasure Island include those listed in Table 2.

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

Table 2
Exposure Rate Meters Used at Treasure Island

Meters	Detector Type	Use
Ludlum 9-3	Ion Chamber	Beta/gamma exposure rate surveys; mR/h
Ludlum 19	1-inch by 1-inch Sodium Iodide Scintillator	Gamma exposure rate surveys; µR/h

The instruments will be pre-operationally inspected and response checked prior to use in accordance with TIWI-12 (Ref. 1.3 5).

The following steps outline the process for completing an exposure or dose rate survey:

Step	Action
1	Take and record on the survey report (Form FRM-TI-01-1), a background measurement in an area representative of the area to be surveyed, but unlikely to be impacted by radiation sources or contamination in the area of interest.
2	Take general area exposure rate measurements at waist-level (approximately 1 meter height), unless otherwise specified. • Move the detector around to verify that it is exposed to all sources of radiation without your body providing inadvertent shielding, allowing sufficient time for stable instrument response. • Record actual dose rates (e.g., µR/h, mR/h, milli rad/hour). *Note: If a source or radiation-emitting surface is located in overhead areas or near the ground, then also measure and record the dose rate at the nearest part of the body (e.g., head, feet).* *Survey points other than waist level (approximately 1 meter height) must be clearly denoted on the survey documentation (Form FRM-TI-01-1). Record dose rates in the units reported on the instrument (e.g., µR/h, mR/h).*
3	Take exposure rate measurements at a distance of 30 centimeters from known sources of radiation or surfaces of interest to evaluate potential whole-body exposures and posting requirements. *Note: Measurement distance (e.g., 30 centimeters from source, equipment, etc.) must be clearly denoted on the survey documentation (Form FRM-TI-01-1).*
4	Take dose rate measurements on contact with potential sources of radiation if direct source handling is anticipated. *Note: Measurement distance must be clearly denoted on the survey documentation (Form FRM-TI-01-1) (i.e., "contact").* **CAUTION:** The size of the source to be surveyed can greatly affect survey results. If concerns or questions arise, contact the RCS or PRSO.

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

Step	Action
5	For mixed beta/gamma radiation fields use Ludlum 9-3: • Take a measurement with the window open to determine the combined beta and gamma contribution. The window must be directed toward the source. • Take a measurement with the window closed to determine the gamma-only contribution. *Note: Survey documentation (Form FRM-TI-01-1) must clearly identify that window open and window closed measurements were made and state the survey distance.* **CAUTION:** If the open window reading is greater than double the closed window reading it may be necessary to apply an energy-dependent beta correction factor – contact the RCS or PRSO for further instruction.

1.8.3 Direct Contamination Surveys

Direct surveys are conducted with portable instruments to detect and quantify total alpha and beta contamination on surfaces of equipment, material, and items.

The instruments listed in Table 3 are used at Treasure Island for performance of total (direct) contamination surveys.

Table 3
Instruments Used at Treasure Island for Performance of Total (Direct) Contamination Surveys

Detectors	Meters	Detector Type	Typical Efficiencies		Uses
Ludlum 43-68	Ludlum 2360 Ludlum 2224	126 square centimeters (cm^2) Gas flow proportional	21%	30%	Alpha/beta surface contamination surveys
Ludlum 43-93	Ludlum 2360 Ludlum 2224	100 cm^2 ZnS scintillator	20%	32%	Alpha/beta surface contamination surveys
Ludlum 43-37	Ludlum 2360 Ludlum 2224	584 cm^2 Gas-flow proportional (Floor monitor)	15%	18%	Alpha/beta surface contamination surveys

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

UNCONTROLLED
WHEN REPRODUCED

The following steps outline the process for completing a direct contamination survey:

Step	Action
1	Survey for direct contamination prior to surveying for removable contamination so that the direct measurement includes the amount of removable contamination, that is, the total of both fixed and removable.
2	Take and record (Form FRM-TI-01-1) a minimum of a 1-minute background measurement in an area representative of the area to be surveyed, but unlikely to be impacted by radiation sources or contamination in the area of interest. *Note: Acceptable area background count rates for each of the direct survey instruments are provided on the label affixed to each instrument. If the background threshold is exceeded, the instruments cannot be used for direct surveys of items being considered for release. If possible, move to a lower background area, repeat the background measurement, and, if acceptable, conduct surveys of items at that location.*
3	Use the predetermined scan speed of 1.25 centimeters per second as outlined in TIWI-12 (Ref 1.3.5). Move the probe over the surface as close as possible (approximately 3 millimeters) to the surface without touching the surface. • For large items (greater than 1 square meter [m^2]), conduct separate scans for each 1 m^2 of surface area. • While performing the scan, observe the count rate audibly and visibly (optional). • If an audible or visual increase above background is observed, consider the location as a potential hot spot, but continue the scan until complete. • Record the results (counts per minute [cpm]) for each 1 m^2 area. Each scan result represents the "average" total residual surface contamination. *Note: Higher scanning speeds may be appropriate in certain situations, such as surveys in areas of known contamination.* *Surfaces prone to static electricity (i.e., Herculite™, plastic hard hats, and polyvinyl chloride pipe) can cause unattached radon daughter products to congregate, resulting in elevated direct readings.*
4	Perform a stationary, "static," survey for a minimum of 1 minute at each "hot spot" identified during the scan to determine the count rate. • Record the reading (cpm) for all "hot spots". The 1-minute survey of each "hot spot" represents the "maximum" total residual surface contamination. *Note: The assessment of radiological conditions must include a sufficient number of survey points to characterize the radiological conditions present, verify boundaries, and confirm radiological posting.*
5	Take a background survey at the completion of the area/equipment survey to confirm that the meter is free of contamination and functioning properly. Conduct this end-of-survey background measurement in the location where the pre-survey background measurement was taken. *Note: If these readings differ significantly (e.g., twice pre-survey background reading) notify the lead RCT or RCS.*

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

1.8.4 Removable Contamination Surveys

Removable contamination levels are determined via the use of smear surveys to determine the removable or loose contamination on an item, equipment, or an area. Smears are counted on site using a Ludlum Model 3030, or equivalent, or other industry accepted.

The survey procedure for smear surveys is provided in Section 1.8.4.1, the survey procedure for a large area smear (LAS) is outlined in Section 1.8.4.2, and the procedure for performance of sealed source leak tests is detailed in Section 1.8.4.3.

1.8.4.1 Removable Contamination Surveys – Smear Surveys

The following steps outline the process for completing a removable contamination survey using smears:

Step	Action
1	Prepare for the survey by collecting the following: • A survey map of the area of interest or graphical representation of the area or item to be monitored. • Appropriate smear sample media and smear envelopes or baggies. Prior to use, write on the envelope, baggie, or directly on the smears to identify sampling location. Smears with individual "fold-over" covers do not require separate envelopes. Mark locations of smears on a map, drawing, or picture. • Gloves, appropriate anti-contamination clothing, and other personal protective equipment as required by the associated RWP. • Survey Report forms (Form FRM-TI-01-1), as appropriate. • The previous surveys of the area of interest have been checked, if available, to determine radiation and contamination types and levels in the areas to be surveyed and to determine whether conditions of safety have changed since the last survey.
2	Determinations of removable contamination must be based on 100 cm^2 taken in the following manner: • Locations of smears must be identifiable – prior to use, write on the holder, envelope, or directly on the smears to identify sampling location. Mark locations on a map, drawing, or picture. • Evaluate removable surface contamination in areas by smearing, in an S-shaped pattern, an area of 100 cm^2, using a circular filter paper, manufactured disc smear, or other appropriate smear media. • Take the swipe using moderate pressure. Apply enough pressure to be representative of personnel spreading contamination by brushing past the surface. • Confirm that wet smears are dry before counting. *Note: For items less than 100 cm^2, smear the entire surface and note item was less than 100 cm^2.*

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

Step	Action
3	Field check the smears taken in contamination and high contamination areas with a direct survey instrument prior to counting on the Ludlum 3030. **CAUTION:** To avoid contaminating the instrument DO NOT place smears with count rates greater than 500 cpm alpha or 2,000 cpm beta in the Ludlum 3030. Surfaces prone to static electricity can cause unattached radon daughter products to congregate, resulting in elevated direct readings. If smears are found to be greater than these levels, count the high activity smear using an appropriate portable direct survey instrument and indicate as such on the survey report. *Note: Results of field counts are not required to be recorded on the survey documentation, unless field counts are required due to high smear activity.*
4	Complete the Chain of Custody (COC) form (Form FRM-TI-01-3, "Chain of Custody – Example"). Secondarily contain the smears for transport to the counting station located in Building 570. *Note: When carrying potentially contaminated smears, enter the back door of the Treasure Island Shaw office building, unless otherwise instructed.*
5	Count smears individually, for 1 minute each (or for required count time to meet minimum detectable activity). At the completion of the count, record the gross count result (cpm). Bag and label any smears with unexpected high readings for potential radionuclide analysis. Notify the RCS or lead RCT. *Note: Surfaces prone to static electricity can cause unattached radon daughter products to congregate and be available for smear sampling. When suspected, recount smears after some period of time (typically overnight). Record results of the "recount" on the survey documentation to discriminate radon daughters from "long-lived" contamination.*
6	Prepare survey documentation as detailed in Section 1.9.

1.8.4.2 Removable Contamination Surveys – Large Area Smear

The LAS surveys are qualitative evaluations, designed to quickly indicate the presence of contamination. The LAS surveys cannot be used for posting determinations or release decisions. Quantitative determination of removable contamination must be based on 100 cm^2 smears taken as specified in Section 1.8.4.1.

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

The following steps outline the process for completing a removable contamination survey using large area smears:

Step	Action
1	To perform an evaluation of gross activity for a large area use a large area media (e.g., 9 inch by 4 inch filter paper, Masslin, disc smear greater than100 cm^2) or "sticky roller" survey **prior to** performing disc smears of 100 cm^2 areas.
2	Each LAS area to be surveyed must be less than 2 m^2.
3	Count LAS smears using the appropriate portable direct counting instrument and record LAS results in the field activity daily log. *Note: Do not include results of LAS surveys on the final survey documentation.*
4	If the survey requires determination of removable contamination levels, LAS surveys must be followed by a sufficient number of 100 cm^2 smears to characterize the area of interest as instructed in Section 1.8.4.1.

1.8.4.3 Removable Contamination Surveys – Sealed Source Leak Tests

Techniques and equipment used for leak tests shall be capable of detecting the leakage of activity from sealed sources at a value equal to or exceeding 0.005 millicuries (11,000 disintegrations per minute [dpm]) as required by 10 CFR 20 (Ref. 1.3.2). This is a minimum acceptable detection limit and is not intended to be a decision basis for whether a source is leaking. The leakage criteria established for Treasure Island are the applicable removable contamination equal to or greater to the free release limits in Table 1.1 of Regulatory Guide 1.86 (Ref. 1.3.3) for the size of the source smeared, typically 10 cm^2.

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

The following steps outline the process for completing a removable contamination survey for a sealed source leak test:

Step	Action
1	Review the sealed source inventory record for the source to be surveyed and dose rate information, if available. Confirm that the sealed source being surveyed matches the description in the inventory record and that the source and container are properly labeled.
2	Wear gloves while performing the leak test of the source.
3	Mark each smear paper with an identifying number or character and smear the sealed source. • For encapsulated sources, smear the entire surface of the source • For electroplated or deposited/covered sources, smear the source container and smear around the perimeter of the source *Note: Do not smear the active surface of an electroplated or deposited source as it may cause damage and subsequent leakage.*
4	Take an initial contamination measurement of each smear using an approved portable contamination monitor.
5	If no removable activity is detected, fold the smear or place the smear in an envelope and proceed to Step 6. If removable activity is detected, then: • Immediately suspend further surveys of the source or others in the location • Survey the area and self to determine the extent of any contamination • Secure the area and contact the RSC or PRSO
6	Measure activity of the smear with the low-level counting system, typically Ludlum 3030 or 2929. Compare the results to the II leak test criterion (applicable Regulatory Guide 1.86, Table 1 value [Ref. 1.3.3]).
7	If the leak test criterion is not satisfied, the source is considered leaking and must be removed from service. • Notify the RSC or PRSO immediately • Secondarily contain the sealed source for proper disposal as radioactive waste • Document that the source has been removed from service • Perform an area survey and decontaminate, as necessary
8	If the leak test criterion is satisfied complete the sealed source survey documentation per instruction provided in Section 1.10.

1.8.5 Personnel Surveys

Perform whole body frisk surveys of individuals exiting a contamination area per RWP or as requested by the RCS or lead RCT. Surveys of hands and feet *only* may be required per the RWP upon exit from a Restricted Area.

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

The following steps outline the process for completing a personnel survey:

Step	Action
1	Hold the probe over the person's outer clothing as close as possible (approximately 3 millimeters) without touching the surface area being surveyed and move at the 1.25 centimeters per second scan speed.
2	Survey the individual starting at their head and carefully survey around nose, mouth, eyes, and ears. Carefully survey the entire body, front and back, paying particular attention to the cuffs of pants, soles of shoes, and wrist and ankle area. *Note: completion of whole body frisk should take approximately 4 minutes.*
3	If the worker is found to be contaminated, follow instructions detailed in TIWI-21, *Radiological Incident Emergency Response* (Ref. 1.3.6). *Note: Survey documentation is not required unless skin or personal clothing contamination is identified.*

1.9 SURVEY DOCUMENTATION REQUIREMENTS

All required survey results must be documented on the electronic survey form, FRM-TI-01-1, or equivalent. All applicable data fields must be accurately completed and legibly recorded. If survey reports are written upon, use black or blue permanent ink. All changes must be struck (one-line), initialed, and dated.

1.9.1 General

All blank blocks require an "NA" or a line thru the box entry. Complete survey documentation within 2 days of performance of the survey, unless unexpected conditions occur, such as absence due to illness. When supplemental information is required, such as additional analytical analysis, submission may be delayed until the necessary information is available. Revise and resubmit surveys returned for revisions within 1 day.

Survey report assembly:

- Survey report
- Continuation sheet(s), as applicable
- Maps/drawing(s)
- Analytical results, as applicable

Electronic copies of final survey records are maintained on site for the duration of project activities. Original final survey records are periodically transmitted to the Shaw Concord, California office for storage in the central file system. Pending transfer to the Concord office, all original survey documents shall be filed by the work area designation in the radiological control department central files.

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

1.9.2 **Survey Report**

The numbered boxes on the survey report example, Form FRM-TI-01-1, correspond to each of the following:

1. Survey number: All survey numbers will start with TIRS (Treasure Island Radiological Survey) and will be typed on each page of the survey.

   The format is MM DD YYYY AREA CODE SEQ, example: TIRS 12112011 233 RSW 1

   Where:

   - MM: Two digit month
   - DD: Two digit day
   - YYYY: Four digit year
   - AREA: 233, 033, 031, 012, or other work area designation
   - CODE:
     - SUR – Requested Survey
     - RSD – Routine Survey Daily
     - RSW – Routine Survey Weekly
     - RSM – Routine Survey Monthly
     - RSQ – Routine Survey Quarterly
     - RTS – Routine Trash/Building Survey
     - JSS – Job Specific Survey (RWP)
     - URS – Unrestricted Release Survey
     - DOT – On-Site and Off-Site Transportation Survey
     - 911 – Incident Response

   SEQ: Enter the next sequential number obtained from the work area survey log.

2. Survey description: A summary description of the survey, including the type of survey, must be written in a manner that clearly defines the purpose of the survey and the work supported.

3. Instrument block: All information must be provided for each instrument used for the survey. Select the appropriate instrument from the 'pull-down' list provided. All backgrounds for the instruments will be the backgrounds established during the initial set-up of the instrument.

4. Surveyor, date, and time: Enter the date the survey was performed and enter the start and end time of the survey. If the survey extends to the next day, include the different end date. Include printed name and signature of individual performing and documenting the survey and the date survey paperwork was completed by surveyor.

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

5. Survey location: Enter the location of the sample, smear, or where the exposure rate reading was performed in the form of a number corresponding to a map location or a brief description (e.g., front left tire, auger handle, etc.).
6. Removable contamination: Record the observed counts (counts per minute) for alpha and beta/gamma for smears counted on the sample counter (typically Ludlum Model 3030). These results may be provided via the COC form (Form FRM-TI-01-3). The Electronic Survey Report, Form FRM-TI-01-1, and the data will be used to populate the activity column (dpm/100 cm^2) using the appropriate instrument efficiency or the activity (dpm/100 cm^2) will be provided directly, via the COC form.
7. Direct (total contamination): Record the observed counts for beta/gamma and alpha for each static contamination measurement. The Electronic Survey Report, Form FRM-TI-01-1, will populate the activity column (dpm/100 cm^2) using the appropriate instrument efficiency.
8. Gamma static: Record the observed counts for gamma static measurement.
9. Exposure rates: Record the observed instrument reading and select the appropriate distance the detector is from the surface or object being surveyed. Indicate the appropriate units.
10. Additional comments: Enter additional information specific to each sample location. Other relevant information may include a surface or depth of sample or additional readings.
11. Approval: Upon completion of the survey report and supplemental information, provide the packet to the designated individual, typically the RCS, for review and approval. The approver will review the document for accuracy, approve, and ensure that the final survey is saved as an electronic copy on the Treasure Island server.

1.9.3 Continuation Sheet

The survey report continuation sheet information shall include the information noted on the cover sheet or enter 'see page 1' for any information that is identical.

1.9.4 Maps and Drawings

Include the same information as listed on the Survey Report form. Form FRM-TI-01-4, "Survey Report Map/Details – Example," or equivalent, shall be used to include maps, drawings, or photographs of the item, equipment, area, or other.

1.10 LEAK TEST DOCUMENTATION REQUIREMENTS

All required leak test results must be documented on the electronic sealed source leak test survey form, FRM-TI-01-2, or equivalent. All applicable data fields must be accurately completed and legibly recorded. If survey reports are written upon, use black or blue permanent ink. All changes must be struck (one-line), initialed, and dated.

1.10.1 General

All blank blocks require an "NA" or a line thru the box entry. Complete survey documentation within 2 days of performance of the survey, unless unexpected conditions occur, such as, absence due to illness. When supplemental information is required, such as additional analytical analysis,

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

submission may be delayed until the necessary information is available. Revise and resubmit surveys returned for revisions within 1 day.

Survey report assembly:

- Survey report
- Continuation sheet(s), as applicable
- Analytical results, as applicable

Electronic copies of final survey records are maintained on site for the duration of project activities. Original final survey records are periodically transmitted to the Shaw Concord, California office for storage in the central file system. Pending transfer to the Concord office, all original survey documents shall be filed by the work area designation in the radiological control department central files.

1.10.2 Leak Test Report

The numbered boxes on the leak test form, FRM-TI-01-2, correspond to each of the following:

1. Survey number: All survey numbers will start with TIRS (Treasure Island Radiological Survey) and will be typed on each page of the survey.

   The format is MM DD YYYY AREA CODE SEQ, example: TIRS 12112011 570 SSS 1

   Where:

   - MM: Two digit month
   - DD: Two digit day
   - YYYY: Four digit year
   - AREA: 570 or other
   - CODE: SSS – Sealed Source Survey
   - SEQ: Enter the next sequential number obtained from the work area survey log
2. Survey description: A summary description of the survey, including the type of survey, must be written in a manner clearly defines the purpose of the survey and the work supported.
3. Instrument block: All information must be provided for each instrument used for the survey. Select the appropriate instrument from the 'pull-down' list provided. All backgrounds for the instruments will be the backgrounds established during the initial set-up of the instrument.
4. Surveyor, date, and time: Enter the date the survey was performed, by entering the start and end time of the survey. If survey extends to next day, make sure to include the different end date. Include printed name and signature of individual performing and documenting the survey and the date survey paperwork was completed by surveyor.
5. Source ID #: List the source identification number for each source.
6. Nuclide: Enter the sealed source radionuclide.

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

7. Activity: List the current source activity level (microcuries)
8. Removable contamination: Record the observed counts for alpha and beta/gamma for smears counted on the sample counter (typically Ludlum Model 3030). These results may be provided via the COC form (Form FRM-TI-01-3). The electronic Survey Report, FRM-TI-01-1, will populate the activity column (dpm/smear) using the appropriate instrument efficiency or the activity (dpm/smear) will be provided directly via the COC form.
9. Less than 5 nanocuries: If results are less than 11,000 dpm/smear, enter "Yes" in the column. If not, enter "No." Also, note if the activity exceeds the Treasure Island leak test criteria (Regulatory Guide 1.86 [Ref. 1.3.3]) and the actions taken in the comments column.
10. Exposure rates: Record the observed instrument reading and select the appropriate distance the detector is from the surface or object being surveyed. Indicate the appropriate units.
11. Additional comments: Enter additional information specific to each sample location. Other relevant information may include a surface or depth of sample or additional readings.
12. Approval: Upon completion of the survey report and supplemental information, provide the packet to the designated individual, typically the RCS, for review and approval. The approver will review the document for accuracy, approve, and ensure that the final survey is saved as an electronic.

Electronic copies of final survey records are maintained on site for the duration of project activities. Original final survey records are periodically transmitted to the Shaw Concord, California office for storage in the central file system. Pending transfer to the Concord Office, all original survey documents shall be filed by the work area designation in the Radiological Control department central files.

1.11 FORMS

- Form FRM-TI-01-1, Survey Report – Example
- Form FRM-TI-01-2, Sealed Source Leak Test – Report – Example
- Form FRM-TI-01-3, Chain of Custody – Example
- Form FRM-TI-01-4, Survey Report Map/Details – Example

1.12 ATTACHMENTS

None.

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

UNCONTROLLED
WHEN REPRODUCED

1.13 REVISION HISTORY AND APPROVAL

Rev Level	Rev Date	Rev Description	Approver
0	04/05/2010	Initial Issue	
1	08/03/2011	Revised to clarify appropriate units and clarify the types of surveys to be documented in accordance with this work instruction. Added additional information for completion of dose rate columns.	
2	01/20/2012	Entire procedure revision.	01/24/12 Mark Somerville, License Radiation Safety Officer 01/20/12 Christine Donahue, Project Radiation Safety Officer 1/23/12 William Bishop, Radiological Control Supervisor

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

UNCONTROLLED
WHEN REPRODUCED

Form FRM-TI-01-1
Survey Report – Example

SURVEY REPORT

Page ___ of ___

RADIOLOGICAL SURVEY FORM

Survey Number: TIRS- 01012012 1319 RSQ 03 (1)

Survey Description: (2)

RWP: 2011 233 RT 01

Survey Date: **Start Time:** **End Time:**

(Printed Name) **Surveyor:** (4)

(Signature) **Surveyor:** **Date:**

Smear Counter (Inst. #1) (3)

Model:		Efficiency:	*Alpha* *Beta/gamma*
Serial #:		Bkgd. CPM:	
Probe / #:		MDA (dpm/100cm²):	
Cal. Due:		Count Time:	

Survey Meter (Inst. #2)

Model:		Efficiency:	*Alpha* *Beta/gamma*
Serial #:		Bkgd. CPM:	
Probe / #:		MDA (dpm/100cm²):	
Cal. Due:		Count Time:	
Probe Area:		Area BkgCPM:	
		Sat/Unsat:	

Survey Meter (Inst. #3)

Model:			
Serial #:			
Cal. Due:		Background:	
Reference Area Bkg		Area Bkg	
Site		Sat/Unsat:	

Exposure Rate Meter (Inst. #4)

Model:			
Serial #:			
Cal. Due:		Background:	
		Area Bkg	
		Sat/Unsat:	

Survey Location	Removable Contamination #1				Total Contamination #2				Gamma #3		Exposure Rate #4		Comments
	α	β/γ	α	β/γ	α	β/γ	α	β/γ	Gross	Net	μR/hr		
	cpm/100cm2		dpm/100 cm2		cpm/100cm2		dpm/100cm2		cpm	cpm	Contact	30cm	
(5)		(6)			(7)				(8)		(9)		(10)

Approved By: (11) Print Name Signature Title Date

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

UNCONTROLLED
WHEN REPRODUCED

Form FRM-TI-01-2
Sealed Source Leak Test – Report – Example

SEALED SOURCE LEAK TEST – REPORT

Page ___ of ___

RADIOLOGICAL SURVEY FORM

Survey Number: TIRS- 01012012 233 RSQ 03 (1)

Survey Description: Source Leak Test (2)

RWP: 2011 233 RT 01

5 nanocuries equals 11,000 dpm.

Survey Date: **Start Time:** **Completion Time:**

Surveyor: (4) (Printed Name)

Surveyor: (Signature)

Smear Counter (Inst. #1) (3)

	Alpha	Beta/gamma
Model:		
Serial #:		
Probe / #:		
Cal. Due:		
Efficiency:		
Bkgd. CPM:		
MDA (dpm/100cm²):		
Count Time:		

Exposure Rate Meter (Inst. #2)

Model:
Serial #:
Cal. Due:
Background:

Source ID #	Nuclide	Activity (µCi)	Removable Contamination (Inst 1) cpm per smear: Alpha	Beta/Gamma	dpm per smear: Alpha	Beta/Gamma	< 5 nCi Yes / No	Exposure Rates (Inst 2) All exposure rates recorded in µrem/hr unless noted: Contact	30 cm	Additional Comments
5	6	7			8		9	10		11

Approved By: _____ Print Name _____ Signature _____ Title _____ Date

FRM-TI-1-2 (01/2012)

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

UNCONTROLLED
WHEN REPRODUCED

Form FRM-TI-01-3
Chain of Custody – Example

Shaw
950 Avenue M, Building 570, Treasure Island
San Francisco, California 94130

Page ___ of ___

Project Number:

RCT(s)		**Collection Information**		
Survey Number	**Smear/Sample Description**	**Date**	**Time**	**Site/Bldg**

Relinquished By:	Date: Time:	Received By:	Date: Time
Relinquished By:	Date: Time:	Received By:	Date: Time
Relinquished By:	Date: Time:	Received By:	Date: Time

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

UNCONTROLLED
WHEN REPRODUCED

Form FRM-TI-01-4
Survey Report Map/Details – Example

SURVEY REPORT MAP/DETAILS

Page ___ of ___

Survey No.: _____

Legend

Smear Location

Static Location

Dose Rate microR/hr

Soil Sample Location

Commodity Location

FRM-TI-1-4 (01/2012)

Shaw Proprietary and Confidential-Copyright © 2012 by Shaw. All Rights Reserved.

1. PURPOSE

This Work Instruction (WI) provides specific direction for the use of portable radiological instruments at TI and demonstrates the suitability of the selected instruments to adequately detect the radionuclide of concern, radium-226 (^{226}Ra).

2. SCOPE

This WI provides standard practices and operating procedures for the instruments listed in Table 1 and equivalent instruments. This document provides the minimum required steps and quality checks that all employees and subcontractors are to follow when operating these instruments. Proper control, calibration, and daily checks of these instruments ensure that operating parameters demonstrate compliance with applicable data quality requirements and/or regulations. Also provided in this WI are instructions for the documentation of instrument performance and survey data. Use of these detectors is for performance of surveys to identify potential ^{226}Ra in the environment, on materials, or on equipment in excess of instrument specific investigation levels or project release criteria.

Table 1: Portable Instruments

DETECTORS	DETECTOR TYPE	TYPICAL METERS		USE
Ludlum 43-68	126 cm^2 Gas-flow proportional	Ludlum 2360	Ludlum 2224	Alpha/beta surface contamination surveys
Ludlum 43-93	100 cm^2 ZnS scintillator	Ludlum 2360	Ludlum 2224	Alpha/beta surface contamination surveys
Ludlum 43-37	584 cm^2 Gas-flow proportional	Ludlum 2360	Ludlum 2224	Alpha/beta surface contamination surveys
Ludlum 44-10	2-in x 2-in NaI scintillator	Ludlum 2221	Ludlum 2350-1	Gamma investigation surveys
Ludlum 44-20	3-in x 3- in NaI scintillator	Ludlum 2221	Ludlum 2350-1	Gamma investigation surveys
Ludlum 43-10-1	ZnS adhered to plastic scintillator	Ludlum 2929	NA	Alpha/beta sample counting
Integral internal detector	ZnS adhered to plastic scintillator	Ludlum 3030	NA	Alpha/beta sample counting
Integral internal detector	Ion Chamber	Ludlum 9-3	NA	Beta/gamma exposure rate surveys; mR/hr

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

DETECTORS	DETECTOR TYPE	TYPICAL METERS		USE
Integral internal detector	1-in x 1-in NaI scintillator	Ludlum 19	NA	Gamma exposure rate surveys; µR/hr

3. REFERENCES

3.1 U.S. Nuclear Regulatory Commission, 2011, Code of Federal Regulations, 10 CFR 20, *Standards for Protection Against Radiation*.

3.2 U.S. Nuclear Regulatory Commission, NUREG-1757, Vol. 2, Rev. 1 "Consolidated Decommissioning Guidance, Characterization, Survey, and Determination of Radiological Criteria"

3.3 U.S. Nuclear Regulatory Commission, NUREG-1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions"

3.4 Shaw applicable Site Radiation Protection Plan (RPP).

3.5 Shaw Environmental, Inc., 2011, *Radiation Monitoring Instrumentation*, SPL-SOP-8.10.2.

3.6 Shaw Environmental, Inc., 2011, *Surveys and Monitoring*, SPL-SOP-8.10.7.

3.7 Manufacturers' Operating Manuals

3.8 Shaw Environmental, Inc., 2012, *Project Technical Basis Document, Instrumentation Program (Treasure Island)*, July.

4. DEFINITIONS

TERM/ACRONYM	DEFINITION
Alpha Radiation (α)	Alpha particles (He^{+2}) emitted by some radionuclides while undergoing radioactive decay. While Alpha radiation does not pose an external exposure threat, alpha emitters may also emit photons (gamma or X-ray) during decay or attenuation. Alpha particles can pose an internal hazard if ingested or inhaled.
Background Radiation	Radiation that occurs naturally in the environment. Background radiation consists of cosmic radiation from outer space, or radioactive elements in geological media, building material, or other natural sources, including radon and its decay products in air and global fallout as it exists in the environment from the testing of nuclear explosive devices or from past nuclear accidents such as Chernobyl that contribute to background radiation and are not under the control of the licensee. "Background" radiation does not include radiation from source, byproduct, or special nuclear material regulated by the Nuclear Regulatory Commission (NRC).

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

TERM/ACRONYM	DEFINITION
Beta Radiation	Beta particles (β) emitted by some radionuclides while undergoing radioactive decay. With few exceptions, beta-emitting radionuclides also emit photons (gamma or X-ray) during decay. Beta particles cannot penetrate human skin but do pose a hazard to the skin and lenses of the eye.
Gamma Radiation	Photons emitted from the nucleus of most atoms during the radioactive decay process. Gamma rays do not have mass or electrical charge and can be very penetrating depending on their energy level. Gamma rays pose an external hazard.
Ionizing Radiation	Alpha particles, beta particles, gamma rays, neutrons, energetic electrons or protons, and other particles capable of producing ions when interacting with matter.
Mylar	Biaxial-oriented polyethylene terephthalate (boPET) is a polyester film made from stretched polyethylene terephthalate (PET) and is used for its high tensile strength, chemical dimensional stability, transparency, reflectivity, gas and aroma barrier properties and electrical insulation.
Photomultiplier Tube (PMT)	A sensitive detector of light in the ultraviolet, visible, and near-infrared ranges of the electromagnetic spectrum. These detectors multiply the current produced by incident light by as much as 100 million times in multiple dynode stages, enabling individual photons to be detected when the incident flux of light is very low.
Scintillator	Detector or scintillation counter is used when a scintillator counter is coupled to an electronic light sensor such as a photomultiplier tube (PMT) or a photodiode. PMTs absorb the light emitted by the scintillator and reemit it in the form of electrons via the photoelectric effect. The subsequent multiplication of those electrons (sometimes called photo-electrons) results in an electrical pulse which can then be analyzed and yield information about the ionizing radiation that originally struck the scintillator.
Sodium Iodide (NaI)	An inorganic alkali halide salt grown into a crystal with specific geometry used to detect gamma radiation via scintillation, when coupled with a photomultiplier tube.
Zinc Sulfide (ZnS)	ZnS is utilized as a scintillation detector, because it emits light on excitation by x-rays or electron beam, making it useful for x-ray screens and cathode ray tubes. It also exhibits phosphorescence due to impurities on illumination with blue or ultraviolet light. Silver activated zinc sulfide (ZnS(Ag)) has a very high scintillation efficiency but is only available as a polycrystalline powder and is thus used in thin screens for alpha particle detection.

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

5. RESPONSIBILITIES

5.1 Project Radiation Safety Officer

The Project Radiation Safety Officer (PRSO) is responsible for the maintenance and management of the instrumentation. The PRSO is also responsible for making sure Radiological Control Technicians (RCTs) are following this procedure as described herein.

5.2 Radiological Controls Supervisor

The Radiological Controls Supervisor (RCS) is responsible for the oversight of the RCTs operating these instruments.

5.3 Radiological Control Technician

The Radiological Control Technicians (RCT) are responsible for compliance with this WI, recognizing instrumentation problems and notifying the RCS or PRSO of malfunctioning instruments. RCTs shall understand project investigation levels and release criteria and know how to compare instrument response to the applicable investigation levels or release criteria.

6. PROCEDURE

Instruments are calibrated and operated in accordance with manufacturers' instructions and Reference 3.3, are set-up and function checked each day of use in accordance with this WI.

Table 2 compares the energies of the check sources in use to ^{226}Ra and demonstrates that instrument specific responses based on these check sources will result in satisfactory detection of ^{226}Ra activity.

Table 2: Source Energy Comparison For Treasure Island

RADIONUCLIDE	ALPHA ENERGY (MeV)	BETA MAX ENERGY (MeV)	GAMMA ENERGY (MeV)
^{226}Ra	4.78 (95% abun)	^{214}Bi, 1.5 (40% abun) ^{214}Pb, 0.65 (40% abun)	^{226}Ra, 0.18 (4% abun) ^{214}Bi, 0.69 (47% abun) ^{214}Pb, 0.35 (36% abun)
^{230}Th[1,2]	4.68 (76% abun)		
^{99}Tc[1,3]		^{99}Tc, 0.29	
^{137}Cs[1,4]		^{137}Cs, 0.51	^{137}Cs, 0.662 (85% abun)

[1] The check sources in use include one of these radionuclides.
[2] ^{230}Th compares well with the alpha energy of ^{226}Ra and is slightly lower in energy so it is a conservative calibration source.
[3] ^{99}Tc is lower in energy than the significant daughter products of ^{226}Ra so it is a conservative calibration source.
[4] ^{137}Cs has a gamma which is similar to the ^{214}Bi daughter and the response of the NaI detectors has been specifically calculated to ^{226}Ra and its daughter energies using the method of NUREG-1507.

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

6.1 Exposure Rate Meters

Exposure rate meters (Model 19, Model 9-3) will be pre-operationally inspected and response checked in accordance with the following steps. Both background and source response shall be verified to be within the +/-20% daily variability at the beginning of each work day the instrument is used.

6.1.1 Calibration Verification

All portable radiological instruments shall have an approved, current calibration label (Reference 3.3). Calibration verification shall be performed prior to the use of the instrument.

6.1.2 Physical Check

A physical check of radiological instruments is an inspection of the general physical condition of each instrument and detector. A physical check shall be performed prior to using a radiological instrument.

The physical check should include inspecting the instrument for loose or damaged knobs, buttons, cables, and connectors; broken/damaged meter movements/displays; dented or corroded instrument cases; punctured/deformed probe/probe window(s), cables, etc.; and any other physical impairments that may affect the proper operation of the instrument or detector. Any instrument or detector having a questionable physical condition shall not be used until the condition is properly corrected.

The instrument, cable, and detector as calibrated should be kept together as a unit. Do not swap components.

6.1.3 Battery Check

A battery check is performed to help ensure that there is sufficient voltage being supplied to the detector and instrument circuitry for proper operation. This check shall be performed in accordance with the instrument's technical manual.

6.1.4 High Voltage Check (HV)

The HV is adjusted during instrument calibration; additional adjustment for normal operation is not required. However, an HV check is required prior to each use in accordance with the specific instrument technical manual. For some instruments a HV check in the field is not possible. An instrument with suspected HV problems shall be immediately reported to the PRSO.

6.1.5 Response Source Check

A response source check is performed to ensure that the instrument will accurately respond to a known source of radiation. Obtain a check source of the proper size, type, and activity for the instrument/detector being used and perform the response source check as follows:

1. Determine the background radiation level. It must be low enough to allow a measurable response to the check source being used. Careful monitoring of changing background levels is necessary to obtain accurate instrument readings.
2. Begin with the instrument on the highest range/scale and energize the audible device, if applicable.
3. Slowly move the detector towards the check source and check the instrument for an increase in audible and/or visual response.

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

4. If appropriate check source(s) are available, change the range/scale of the instrument to obtain a visual indication and to check each of the meter ranges/scales. If an appreciable response cannot be obtained (even in the lowest range), evaluate instrument performance by comparison to previous source check data for the instrument. Notify the Project RSO of any instrument/detector response problems. Document the response on the Ratemeter Daily Instrument Check Sheet. Plot the response on the Control Graph at the bottom of the Ratemeter Daily Instrument Check Sheet.
5. The Project RSO or designee shall set up the control graph for background and source response on the Ratemeter Daily Instrument Check Sheet such that lines indicate when an instrument is outside of the +/- 20% variability.
6. Instruments with day-to-day background or source responses that vary by more than 20% under identical conditions shall be removed from service and the Project RSO shall be notified.

Ratemeter instrument inspections, performance verifications, and corrective actions shall be recorded on the Ratemeter Daily Instrument Check Sheet prior to use.

6.2 Sample Counters

Sample counters (Model 2929, Model 3030) will be prepared for use in accordance with the following steps:

6.2.1 Sample Counter Pre-operational Requirements

Prior to the use of sample counters, the following inspections/operational verifications shall be performed in addition to those required in Section 6.1 for ratemeter-type instruments (i.e., calibration verification, physical check, battery check, HV check).

6.2.2 Background Measurement (Initial Project Set-up)

1. Ensure that the sample holder tray is empty and clean. The detector/sample holder geometry should be set up in the same configuration as that to be used when counting samples to produce the most accurate results.
2. Select the desired counting time. The selected time must be consistently used to perform all source and sample/swipe counting operations. The counting time directly influences the Minimum Detectable Concentration (MDC) obtained for the instrument. Although the counting time must be long enough to obtain the desired MDC, it must be short enough to be practical. The background measurements should be performed in conjunction with the MDC calculations.
3. Perform the background measurement for the selected time period (t) and record the total counts measured on the Scaler Instrumentation Check Sheet.
4. Repeat the background measurement ten times. Record the total counts observed for each measurement on the Scaler Instrumentation Check Sheet.

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

5. Calculate the average background counts ($\overline{C_b}$) and the standard deviation (SD_b):

$$\overline{C_b} = \frac{\sum_{i=1}^{N} C_{b_i}}{N} \qquad SD_b = \sqrt{\frac{\sum_{i=1}^{N} (C_{b_i} - \overline{C_b})^2}{N - 1}}$$

Where:

$\sum_{i=1}^{N}$	=	Summation of item 1,2,3…N
$\overline{C_b}$	=	Average number of background counts
SD_b	=	Standard deviation of the background counts
N	=	Number of measurements
C_{b_i}	=	Background counts 1, 2, 3 … N

6. Record the average background ($\overline{C_b}$), background count time (t_b), and the standard deviation (SD_b) on the Scaler Instrumentation Check Sheet.

7. Divide $\overline{C_b}$ by t_b to determine the average background count rate in cpm ($\dot{C}_b$), and record the result on the Scaler Instrumentation Check Sheet.

Background is checked at the beginning of each work day the instrument is used. Acceptable background response is assessed using the following equation:

$$C_b = \overline{C_b} \pm 3SD_b$$

Where:

$\overline{C_b}$	=	Average background counts.
SD_b	=	Standard deviation of the average background counts.

If the background measurement is satisfactory, continue. If the background measurement does not meet this criterion, immediately notify the PRSO. Record the background measurement on the Scaler Daily Instrument Check Sheet.

6.2.3 Source Response

Determine the detector source response with a source of known activity of a nuclide with energy decay products similar to those of the nuclide to be monitored (Table 2), as follows:

1. Correct the 4 pi source activity for radioactive decay (when necessary) as follows:

$$A = A_o e^{-\lambda T} \quad Where: \lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

Where:

A	=	Present source activity.
A_o	=	Source activity at initial assay.
λ	=	Decay constant for the source isotope.
T	=	Time elapsed since initial source assay.
$t_{1/2}$	=	Source isotope half-life.

NOTE: Time units must be consistent (days, hrs, mins., etc.)

2. Count the source for the same time period (t_s) selected during the background measurements (See Section 6.2.2, step 2).

Initially: At project set-up or as otherwise directed by the project specific work plans or instructions, or the Project RSO , count the source ten times and calculate the average net counts ($\overline{C_n}$), the standard deviation of the average gross counts (SD_g), and the standard deviation of the average net source counts (SD_n):

$$\overline{C}_g = \frac{\sum_{i=1}^{N} C_{g_i}}{N} \qquad \overline{C}_n = \overline{C}_g - \overline{C}_b$$

$$SD_g = \sqrt{\frac{\sum_{i=1}^{N} (C_{g_i} - \overline{C}_g)^2}{N - 1}} \qquad SD_n = \sqrt{(SD_g)^2 + (SD_b)^2}$$

Where:

C_{g_i}	=	Gross source counts (total counts observed including background) 1 through N
$\overline{C_b}$	=	Average background counts.
$\overline{C_g}$	=	Average gross counts.
$\overline{C_n}$	=	Average net counts.
SD_n	=	Standard deviation of the average net counts.
SD_g	=	Standard deviation of the average gross counts.
N	=	Number of measurements.
SD_b	=	Standard deviation of the average background counts.
$\sum_{i=1}^{N}$	=	Summation of item 1,2,3…N.

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

Record the gross counts (C_{g_i}, where i =1 to N), $\overline{C_n}$ and the standard deviations (SD_n and SD_g) on the Scaler Instrumentation Check Sheet.

3. Divide $\overline{C_n}$ by t_s to determine the average net count rate ($\dot{C}_n$) and record the rate on the Scaler Instrumentation Check Sheet.

Source response is checked daily prior to instrument use. Acceptable source response is assessed using the following equation:

$$C_g - C_b = C_n = \overline{C_n} \pm 3SD_n$$

Where:

$\overline{C_n}$	=	Average net counts
C_g	=	Gross source counts
C_n	=	Net source counts
C_b	=	Daily background counts
SD_n	=	Standard deviation of the average net counts

$$SD_n = \sqrt{(SD_g)^2 + (SD_b)^2}$$

6.2.4 Instrument Efficiency (ε)

Record the 4 pi detector efficiency (ε) from the instrument Calibration Certificate on the Scaler Instrumentation Check Sheet

6.2.5 Calculation of Minimum Detectable Concentrations (MDC)

The calculated MDC is determined to ensure that the detector being used will detect the presence of activity at or above the allowable limit under a given set of counting conditions. The MDC is the concentration that a specific instrument and technique can be expected to detect 95 percent of the time under actual conditions of use. MDC is based on the estimated detector efficiency, background, and the counting time.

MDC of each instrument shall be determined upon initial set-up of the counting system and as needed following modification, calibration, repair, or replacement (i.e., new detector, cables, calibration, etc.). An MDC may be required to be adjusted based on specific materials that exhibit a different background than at initial set-up.

For measurements of surface concentrations by a smear sample, the MDC_{static} should be determined using the equation from NUREG-1507. The sample collection times should be the same as the selected background times in Section 6.2.2, step 2, if practical. The PRSO shall consult with the License RSO for all other conditions.

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

1. Calculate the beta MDC for smears in dpm/100cm^2:

$$MDC = \frac{3 + 4.65\sqrt{\overline{C_b}}}{(\varepsilon)(t)}$$

Where:

$\overline{C_b}$	=	Average background counts during time interval *t*
t	=	Sample counting time, time interval in minutes
ε	=	Efficiency for the emitted radiation

2. Calculate the alpha MDC for smears in dpm/100cm^2:

$$MDC = \frac{3 + 4.65\sqrt{\overline{C_b}}}{(\varepsilon)(0.8)(t)}$$

Where:

$\overline{C_b}$	=	Average background counts during time interval *t*
t	=	Sample counting time, time interval in minutes
ε	=	Efficiency for the emitted radiation
0.8	=	Alpha absorption factor for air and smear sample media

3. Calculate the alpha air sample MDC in µCi/mL:

$$MDC = \frac{3 + 4.65\sqrt{\overline{C_b}}}{(\varepsilon)(Vol)(0.8)(t)(2.22E6)}$$

Where:

$\overline{C_b}$	=	Average background counts during time interval *t*
t	=	Sample counting time, time interval in minutes
ε	=	Efficiency for the emitted radiation
Vol	=	The volume of air collected in mL
0.8	=	Alpha absorption factor for air sample media
2.22E6	=	Converts dpm to µCi

4. Record the calculated MDC values on the Scaler Instrumentation Check Sheet.

If the desired MDC cannot be attained, then inspect the instrument for equipment problems (contaminated detector or sample holder, loose cables/connectors, etc.) and notify the PRSO. If no equipment problems are found, parameters such as sample quantity, count time, or background radiation levels may have to be adjusted appropriately to obtain an acceptable MDC. An MDC that reliably satisfies the project release criteria, airborne activity requirements or remediation goals may be used. If reasonable adjustment of these parameters (as directed by the PRSO) does not result in an acceptable MDC, a more suitable instrument/detector shall be required.

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

Smear sample results are reported in disintegrations per minute per 100 centimeters squared (dpm/100 cm^2); 2.22 dpm = 1 picocurie.

Air sample results are reported in microCuries per milliliter (µCi/ml).

Spreadsheet software is used to calculate instrument parameters (average background, source response, and MDC) and to track daily instrument performance checks. The PRSO or RCS will provide the instrument parameters to the RCTs via a printout or a label affixed to the meter.

6.3 SURFACE CONTAMINATION SURVEY INSTRUMENTS

Ludlum Model 2360 or Model 2224 meters with either Ludlum 43-68, Ludlum 43-93 or Ludlum 43-37 detectors will be prepared for use in accordance with the following steps:

6.3.1 Surface Contamination Survey Instrument Pre-operational Requirements

Prior to the use of these instruments and detectors, the following inspections/operational verifications shall be performed in addition to those required in Section 6.1 for ratemeter-type instruments (i.e., calibration verification, physical check, battery check, HV check). Where a calculator Standard Deviation Function is used or when a spreadsheet program is used in the pre-operational checks, it should be noted on the affected paperwork.

6.3.2 Background Measurement (Initial Project Set-up)

1. Select the desired counting time. The selected time must be consistently used to perform all source and sample counting operations. The counting time directly influences the Minimum Detectable Concentration (MDC) obtained for the instrument. Although the counting time must be long enough to obtain the desired MDC, it must be short enough to be practical. The background measurements should be performed in conjunction with the MDC calculations.
2. Perform the background measurement for the selected time period (t_b) and record the total counts measured on the Scaler Instrumentation Check Sheet.
3. Repeat the background measurement ten times. Record the total counts observed for each measurement on the Scaler Instrumentation Check Sheet.
4. Calculate the average background counts ($\overline{C_b}$) and the standard deviation (SD_b):

$$\overline{C_b} = \frac{\sum_{i=1}^{N} C_{b_i}}{N} \qquad SD_b = \sqrt{\frac{\sum_{i=1}^{N} (C_{b_i} - \overline{C}_b)^2}{N - 1}}$$

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

Where:

$\sum_{i=1}^{N}$	=	Summation of item 1,2,3…N
$\overline{C_b}$	=	Average number of background counts
SD_b	=	Standard deviation of the background counts
N	=	Number of measurements
C_{b_i}	=	Background counts 1, 2, 3 … N

5. Record the average background ($\overline{C_b}$), background count time (t_b), and the standard deviation (SD_b) on the Scaler Instrumentation Check Sheet.

6. Divide $\overline{C_b}$ by t_b to determine the average background count rate in cpm ($\dot{C}_b$), and record the result on the Scaler Instrumentation Check Sheet.

Background is checked at the beginning of each work day the instrument is used. Acceptable background response is assessed using the following equation:

$$C_b = \overline{C_b} \pm 3SD_b$$

Where:

C_b	=	Background counts
$\overline{C_b}$	=	Average background counts.
SD_b	=	Standard deviation of the average background counts.

If the background measurement is satisfactory, continue. If the background measurement does not meet this criterion, immediately notify the PRSO. Record the background measurement on the Scaler Daily Instrument Check Sheet.

6.3.3 Source Response

Determine the detector source response with a source of known activity of a nuclide with energy decay products similar to those of the nuclide to be monitored (Table 2), as follows:

1. Correct the source activity for radioactive decay (when necessary) as follows:

$$A = A_o e^{-\lambda T} \quad Where: \lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

Where:

A	=	Present source activity.
A_o	=	Source activity at initial assay.
λ	=	Decay constant for the source isotope.
T	=	Time elapsed since initial source assay.
$t_{1/2}$	=	Source isotope half-life.

NOTE: Time units must be consistent (days, hrs., mins., etc.)

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

2. Count the source for the same time period (t_s) selected during the background measurements (See Section 6.3.2, step 2).

   Initially: At project set-up or as otherwise directed by the project specific work plans or instructions, or the Project RSO , count the source ten times and calculate the average net counts ($\overline{C_n}$), the standard deviation of the average gross counts (SD_g), and the standard deviation of the average net source counts (SD_n):

$$\overline{C}_g = \frac{\sum_{i=1}^{N} C_{g_i}}{N} \qquad \overline{C}_n = \overline{C}_g - \overline{C}_b$$

$$SD_g = \sqrt{\frac{\sum_{i=1}^{N} (C_{g_i} - \overline{C}_g)^2}{N - 1}} \qquad SD_n = \sqrt{(SD_g)^2 + (SD_b)^2}$$

Where:

C_{g_i}	=	Gross Source Counts (total counts observed including background) 1 through N
$\overline{C_b}$	=	Average background counts.
$\overline{C_g}$	=	Average gross counts.
$\overline{C_n}$	=	Average net counts.
SD_n	=	Standard deviation of the average net counts.
SD_g	=	Standard deviation of the average gross counts.
N	=	Number of measurements.
SD_b	=	Standard deviation of the average background counts.
$\sum_{i=1}^{N}$	=	Summation of item 1,2,3…N.

Record the gross counts (C_{g_i}, where i =1 to N), $\overline{C_n}$ and the standard deviations (SD_n and SD_g) on the Scaler Instrumentation Check Sheet.

3. Divide $\overline{C_n}$ by t_s to determine the average net count rate ($\dot{C}_n$) and record the rate on the Surface Contamination Instrumentation Check Sheet.

Source response is checked at the beginning of each work day the instrument is used. Acceptable source response is assessed using the following equation:

$$C_g - C_b = C_n = \overline{C_n} \pm 3SD_n$$

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

Where:

$\overline{C_n}$ = Average net counts

C_g = Gross source counts

C_n = Net source counts

C_b = Daily background counts

SD_n = Standard deviation of the average net counts

$$SD_n = \sqrt{(SD_g)^2 + (SD_b)^2}$$

6.3.4 Instrument Efficiency (ε)

Record the 4 pi instrument efficiency (ε) from the instrument Calibration Certificate on the Scaler Instrumentation Check Sheet.

6.3.5 Calculation of Minimum Detectable Concentrations (MDC)

The calculated MDC is determined to ensure that the detector being used will detect the presence of activity at or above the allowable limit under a given set of counting conditions. The MDC is the concentration that a specific instrument and technique can be expected to detect 95 percent of the time under actual conditions of use. MDC is based on the estimated detector efficiency, background, and the counting time.

MDC of each instrument shall be determined upon initial set-up of the counting system and as needed following modification, calibration, repair, or replacement (i.e., new detector, cables, calibration, etc.). An MDC may be required to be determined on specific materials that exhibit a different background than at initial set-up. The Project RSO shall be contacted to determine if an MDC determination is necessary for specific materials.

For scanning building surfaces, the MDC_{scan} should be determined using the following equation (using a value recommended in Appendix A of U.S. Nuclear Regulatory Commission, NUREG-1757, Vol. 2, Rev. 1, "Consolidated NMSS Decommissioning Guidance," for the index sensitivity *d'* of 1.38, which is for 95 percent detection of a concentration equal to MDC_{scan} with a 60 percent false-positive). The background collection times shall be at least 1 minute, to ensure consistent data collection.

1. Calculate the MDC_{scan} in dpm/100cm^2:

$$MDC_{scan}(surfaces) = \frac{1.38\sqrt{\overline{C_{bscan}}}}{(\sqrt{p})(\varepsilon)(t_{scan})(A/100\,cm^2)}$$

Where:

1.38 = Index of sensitivity *d'*

$\overline{C_{bscan}}$ = Average background counts in time interval t_{scan}

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

p	=	Surveyor efficiency (0.5)
ε	=	Instrument 4 pi efficiency for the emitted radiation
t_{scan}	=	Sample count time, time interval of the observation while the probe passes over the source **in minutes**.
A	=	Active area of probe in cm^2

2. Record the calculated MDC_{scan} on the Scaler Instrumentation Check Sheet.
3. For static measurements of surface concentrations by either direct measurement or by a smear sample, the MDC_{static} should be determined using the equation from NUREG-1507. The sample collection times should be the same as the selected background times in Section 6.3.2, step 2, if practical. The Project RSO shall consult with the License RSO for all other conditions.
4. Calculate the MDC_{static} in dpm/100cm^2:

$$MDC_{static} = \frac{3 + 4.65\sqrt{\overline{C_{bstatic}}}}{(K)(t_{static})} = \frac{3 + 4.65\sqrt{\overline{C_{bstatic}}}}{(\varepsilon)(A/100cm^2)(t_{static})}$$

Where:

$\overline{C_{bstatic}}$	=	Average background counts during time interval t_{static}
t_{static}	=	Sample counting time, time interval in min. the probe is in direct contact with the surface or smear
K	=	ε*(A/100cm^2) A calibration constant (best estimate) to convert counts/min to dpm/100 cm^2.
A	=	Probe's active area, in cm^2
ε	=	Instrument 4 pi efficiency for the emitted radiation

5. Record the calculated MDC_{static} on the Scaler Instrumentation Check Sheet.

The calculated MDC_{static} should be less than 50 percent of the appropriate project release criterion or remediation goal, and while there is no specific recommendation of MDC_{scan}, it should be no more than 50 percent of the appropriate project release criterion or remediation goal if possible. If the desired MDC cannot be attained, then inspect the instrument for equipment problems (contaminated detector or sample holder, loose cables/connectors, etc.) and notify the Project RSO. If no equipment problems are found, parameters such as sample quantity, count time, or background radiation levels may have to be adjusted appropriately to obtain an acceptable MDC. On a case by case basis an MDC that is greater than 50 percent but less than 90 percent of the project release criteria or remediation goals may be used with the concurrence of the License RSO. If reasonable adjustment of these parameters (as directed by the Project RSO) does not result in an acceptable MDC, a more suitable instrument/detector shall be used

Static counts are reported in dpm/100 cm^2; 2.22 dpm = 1 picocurie.

Spreadsheet software is used to calculate instrument parameters (average background, efficiency, and MDC) and to track daily instrument performance checks. The PRSO or RCS will provide the instrument parameters to the RCTs via a printout or a label affixed to the meter.

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

6.3.6 Count Detection Probability for Alpha Scans (≤ 126 cm^2 Probe)

Scanning for alpha emitters differs significantly from scanning for beta and gamma emitters in that the expected background response of most alpha detectors is very close to zero. The following sections cover scanning for alpha emitters.

Because the amount of time that a contaminated area is under the probe varies and the background count rate of some alpha instruments is less than 1 cpm, it is not reasonable to determine a fixed MDC for scanning. Instead, it is more practical to determine the probability of detecting an area of contamination at a predetermined project release criterion or remediation goal for given scan rates.

For alpha survey instrumentation with backgrounds ranging from less than 1 to 3 cpm, a single count provides a surveyor sufficient cause to stop and investigate further. Assuming this to be true, the probability of detecting given levels of alpha surface contamination can be calculated by use of Poisson summation statistics.

Given a known scan rate and a surface contamination release limit, the probability of detecting a single count while passing over the contaminated area is given by the following equation:

$$P(n \geq 1) = 1 - e^{\frac{-(G)(\varepsilon_i)(d)}{(60)(v)}}$$

Where:

$P(n \geq 1)$	=	probability of observing a single count
G	=	surface contamination release limit (dpm)
ε	=	detector efficiency (4π)
d	=	width of detector in direction of scan (cm)
v	=	scan speed (centimeters per second)

Once a count is recorded and the guideline level of contamination is present, the surveyor should stop and wait until the probability of getting another count is at least 80 percent. This time interval can be calculated by the following equation:

$$t = \frac{13,800}{CAE}$$

Where:

t	=	time period for static count(s)
C	=	surface contamination release limit (dpm/100 cm^2)
A	=	physical probe area (cm^2)
E	=	detector 4 pi efficiency

A scan rate of 1.25 cm/second will be employed for alpha scans with Ludlum 43-68 or Ludlum 43-93 detectors. The PRSO or RCS will determine the time period required for 80 percent probability time interval, and document it on a printout or a label applied to the meter.

Using the probability of detecting an alpha count, a MDC for alpha scans ($MDC_{\alpha scan}$) can be determined with the following equation:

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

$$MDC_{\alpha scan} = \frac{\left[-ln\left(1 - P(n \geq 1)\right)\right] \times 60}{(\varepsilon)(t)}$$

Where:

$P(n \geq 1)$	=	the probability of detecting 1 count
ε	=	instrument 4 pi efficiency
t	=	residence time of the detector over activity (in seconds). This is the width of the detector (cm) in the direction of scanning divided by the scan speed (cm/s).

The PRSO or RCS will determine the $MDC_{\alpha scan}$, and document it on a printout or a label applied to the meter.

6.3.7 Count Detection Probability for Alpha Scans (584 cm^2 Probe)

The larger (584 cm^2) gas-proportional detectors have alpha background count rates on the order of 5 to 10 cpm, and a single count will not cause a surveyor to investigate further. A counting period long enough to establish that a single count indicates an elevated contamination level would be prohibitively inefficient. For these types of instruments, the surveyor usually will need to get at least two counts while passing over the source area before stopping for further investigation.

Assuming this assumption is valid; the probability of getting two or more counts can be calculated by equation:

$$P(n \geq 2) = 1 - \left[1 + \frac{(GE + B)t}{60}\right]\left[e^{\frac{-(GE+B)t}{60}}\right]$$

Where:

$P(n \geq 2)$	=	probability of getting two or more counts during the time interval t
t	=	time interval of detector over source (seconds)
G	=	surface contamination release limit (dpm)
E	=	detector efficiency (4π)
B	=	background count rate (cpm)

A scan rate that satisfies specific instrument MDC requirements will be employed for alpha scans with the Ludlum 43-37 detector. The PRSO or RCS will determine the probability of getting two or more counts in the time interval, and document it on a printout or a label applied to the meter.

6.4 GAMMA SURVEY INSTRUMENTS

Ludlum Model 2221 or equivalent meters with either Ludlum 44-10 or Ludlum 44-20 detectors are only used to identify potential elevated concentrations of ^{226}Ra contamination. Count rate measurements acquired using the 44-10 and 44-20 are never used in making the following decisions:

- Does the concentration of ^{226}Ra in the soil exceed the free release criterion?
- May personnel, material, or equipment be released from a controlled area?
- What is the classification of low level radioactive, sanitary, or solid waste?
- Does the external exposure or dose rate exceed any Treasure Island limit?

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

- What is the ^{226}Ra concentration or activity on or in soil, surface, material, or equipment?

Comparison of the Ludlum 44-10 2-inch by 2-inch Sodium Iodide Detector and the Ludlum Model 44-20 3-inch by 3-inch Detector's Response to Cesium-137/Barium-137m, Radium-226, and Treasure Island Background Soil, (Adams, June 22, 2011) documents the correlation between the response of these detectors to cesium-137 (^{137}Cs) and ^{226}Ra. Further when the detectors are maintained within 10 cm (4-in) above the surface of interest and scans are completed on a maximum transect width of 30 cm (1-foot), the MDC is less than the project release criteria for ^{226}Ra in soil.

Ludlum Model 2221 or equivalent meters with either Ludlum 44-10 or Ludlum 44-20 detectors will be prepared for use in accordance with the following steps.

6.4.1 Background Determination

1. Set the counting time to one minute.
2. Perform the background measurement for the selected time period (t_b) and record the total counts measured.
3. Repeat the background measurement ten times. Record the total counts observed for each measurement.
4. Calculate the average background counts ($\overline{C_b}$)

$$\overline{C_b} = \frac{\sum_{i=1}^{N} C_{b_i}}{N}$$

Where:

$\sum_{i=1}^{N}$	=	Summation of item 1,2,3…N
$\overline{C_b}$	=	Average number of background counts
N	=	Number of measurements
C_{b_i}	=	Background counts 1, 2, 3 … N

5. Divide $\overline{C_b}$ by t_b to determine the average background count rate in cpm ($\dot{C}_b$), and record the result.

<u>Daily</u>: perform a single background count (C_b) prior to instrument use. Analyze this value using the following formula:

$$C_b = \overline{C_b} \pm 20\%$$

Where:

$\overline{C_b}$	=	Average background counts.

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

If the background measurement is satisfactory, continue. If the background measurement does not meet this criterion, immediately notify the PRSO. Record the background measurement.

6.4.2 Source Response

1. Set the counting time to one minute.
2. Place the ^{137}Cs check source under the source check jig and the detector into the jig, ensuring the source to detector distance is 10 cm (4 in).
3. Perform the source measurement for the selected time period (t_b) and record the total counts measured.
4. Repeat the source measurement ten times. Record the total counts observed for each measurement.
5. Calculate the average source counts ($\overline{C_s}$)

$$\overline{C_s} = \frac{\sum_{i=1}^{N} C_{s_i}}{N}$$

Where:

$\sum_{i=1}^{N}$	=	Summation of item 1,2,3…N
$\overline{C_s}$	=	Average number of source counts
N	=	Number of measurements
C_{s_i}	=	Source counts 1, 2, 3 … N

6. Divide $\overline{C_s}$ by *t* to determine the average source count rate in cpm ($\dot{C}_s$), and record the result.

Daily: prior to instrument use, perform a single source count (C_s) in the same geometry employed for determining the initial source response. Analyze this value to the using the following formula:

$$C_s = \overline{C_s} \pm 20\%$$

Where:

$\overline{C_s}$	=	Average source counts.

Record the source measurement. If the source measurement is satisfactory, continue. If the source measurement does not meet this criterion, immediately notify the PRSO.

6.4.3 Reference Area Background Determination

Initially, for each gamma survey instrument designated for soil investigation use, perform a survey of the designated reference area (approximately 1,000 square meters) identified by the PRSO in

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

consultation with the client in accordance with TIWI-07 Gamma Walkover Survey Data Collection With GPS System.

Data collection will include scan data for the entire reference area and a minimum of 20 1-minute static counts collected within the reference area at a probe height of 10 cm. The location of the static counts will be determined by applying a systematic grid over the reference area using a random starting coordinate.

The scan data and the static measurements will be compiled and a mean count rate for static counts will be determined using spreadsheet and scan counts will be determined using the GIS software, and the standard deviation for each will be calculated.

Investigation levels for scans (mean of the scan data set plus 3 standard deviations) and investigation levels for static measurements (mean of the static data set plus 3 standard deviations) will be calculated for each gamma survey instrument in use. The PRSO or RCS will provide the RCTs with the instrument parameters and investigation levels on a spreadsheet printout or a label affixed to the meter.

6.4.4 Performance Of Gamma Surveys

Surveys with the Ludlum 44-10 or Ludlum 44-20 detectors are strictly used to identify areas of elevated gamma counts that may be the result of ^{226}Ra contamination. Locations identified during scanning that exceed the instrument-specific investigation level require further investigation. Initial investigation will consist of reacquiring the elevated location and conducting a 1 minute static count. Also the RCT will rescan the nearby vicinity to assess if the elevated reading is the result of a point source or distributed radioactive material. If the static count is less than the static investigation level and there is no evidence of a point source, further investigation is not required. If the static investigation level is exceeded or there is evidence of distributed contamination at or above either investigation level the area will be flagged for further intrusive investigation.

The surveys documented over land areas, building materials, or excavated soil with the gamma survey instruments are only intended to assess for the potential presence of radioactive commodities or ^{226}Ra contamination above the investigation levels and are not suitable to make unconditional release determinations or waste determinations for land areas, building materials, or excavated soil.

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

7. REVISION HISTORY AND APPROVAL

Rev Level	Rev Date	Rev Description	Approver
0	09/09/2011	Initial Issue	
1	10/29/2012	Revision of whole document	Mark Somerville, License Radiation Safety Officer Christine Donahue, Project Radiation Safety Officer William Bishop, Radiological Control Supervisor

Shaw Proprietary and Confidential-Copyright © 2011 by Shaw. All Rights Reserved.

Appendix B
In-Process Analytical and Survey Data

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica St. Louis
13715 Rider Trail North
Earth City, MO 63045
Tel: (314)298-8566

TestAmerica Job ID: 160-15772-2
Client Project/Site: Treasure Island - 500475

For:
CB&I Environmental & Infrastructure, Inc
4005 Port Chicago Hwy
Concord, California 94520

Attn: Patricia Flynn

Authorized for release by:
2/29/2016 12:30:58 PM

Erika Gish, Project Manager II
(314)298-8566
erika.gish@testamericainc.com

LINKS

Review your project results through TotalAccess

Have a Question? Ask The Expert

Visit us at:
www.testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

Table of Contents

Cover Page 1
Table of Contents 2
Case Narrative 3
Chain of Custody 5
Receipt Checklists 6
Definitions/Glossary 7
Method Summary 8
Sample Summary 9
Client Sample Results 10
QC Sample Results 11
QC Association Summary 13

Job ID: 160-15772-2

Laboratory: TestAmerica St. Louis

Narrative

CASE NARRATIVE

Client: CB&I Environmental & Infrastructure, Inc

Project: Treasure Island - 500475

Report Number: 160-15772-2

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In some cases, due to interference or analytes present at high concentrations, samples were diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

TestAmerica St. Louis attests to the validity of the laboratory data generated by TestAmerica facilities reported herein. All analyses performed by TestAmerica facilities were done using established laboratory SOPs that incorporate QA/QC procedures described in the application methods. TestAmerica's operations groups have reviewed the data for compliance with the laboratory QA/QC plan, and data have been found to be compliant with laboratory protocols unless otherwise noted below.

The test results in this report meet all NELAP requirements for parameters for which accreditation is required or available. Any exceptions to NELAP requirements are noted in this report. Pursuant to NELAP, this report may not be reproduced, except in full, without the written approval of the laboratory.

Calculations are performed before rounding to avoid round-off errors in calculated results.

All holding times were met and proper preservation noted for the methods performed on these samples, unless otherwise detailed in the individual sections below.

All solid sample results for Chemistry analyses are reported on an "as received" basis unless otherwise indicated by the presence of a % solids value in the method header. All soil/sediment sample results for radiochemistry analyses are based upon sample as dried and disaggregated with the exception of tritium, carbon-14, and iodine-129 by gamma spectroscopy unless requested as wet weight by the client."

Reference the chain of custody and condition upon receipt report for any variations on receipt conditions and temperature of samples on receipt
Manual Integrations were performed only when necessary and are in compliance with the laboratory's standard operating procedure. Detailed information can be found in the raw data section of the level IV report.

The following clean-up methods for Organic analyses may have been used on the samples in this data set. Specific methods employed are documented on the batch extraction logs:

Method 3600C: Cleanup
Method 3620C: Florisil Cleanup
Method 3630C: Silica Gel Cleanup
Method 3640A: Gel-Permeation Cleanup
Method 3650B: Acid-Base Partition Cleanup
Method 3660B: Sulfur Cleanup
Method 3665A: Sulfuric Acid/Permanganate Cleanup

This laboratory report is confidential and is intended for the sole use of TestAmerica and its client.

Job ID: 160-15772-2 (Continued)

Laboratory: TestAmerica St. Louis (Continued)

RECEIPT

The samples were received on 1/19/2016 8:35 AM; the samples arrived in good condition, properly preserved. The temperature of the cooler at receipt was 18.9º C.

RADIUM 226 (21 DAY INGROWTH)

Samples TITO12-WSTAVE-CH-S001 (160-15772-1) and TITO12-WSTAVE-WOOD (160-15772-2) were analyzed for Radium 226 (21 day ingrowth) in accordance with DOE GA-01-R. The samples were prepared on 01/21/2016 and analyzed on 02/18/2016 and 02/28/2016.

Sample was prepped as received rather than the project specified dry/grind. TITO12-WSTAVE-WOOD (160-15772-2)

The detection goal for radium-226 was not met for the following sample due to insufficient sample available for analysis: TITO12-WSTAVE-WOOD (160-15772-2). The sample is a low-density wood splinters. Analytical results are reported with the detection limit achieved.

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

CHAIN OF CUSTODY

Ref. Document # TI_WOOD STAVE_001

Page 1 of 1

Shaw Environmental and Infrastructure Inc. (a CB&I company)
Federal Services Division
4005 Port Chicago Hwy
Concord, CA 94520

Project Number: 500475
Project Name / Location: TI WOOD STAVE
Purchase Order #: 202220

Project Manager: John Hackett (Name & phone #)

Shipment Date: 1/18/2016
Waybill Number: 1Z 89Y462 01 9140 4851
Lab Destination: TestAmerica St Loius
Lab Contact Name / ph. #: Erika Gish

Send Report To: Patricia Flynn
Phone/Fax Number: 925-288-2037
Address: 4005 Port Chicago Hwy
City: Concord, CA, 94520

Sampler's Name(s):

Sample ID Number	Sample Description	Collection Information: Date	Time	Method	Matrix	# of containers	Preservative (water) / Preservative (soil) / Container Type	Analyses Requested: Gamma Scan							Dose Rate µR/Hr		
							Preservative (soil)	N/A									
TITO12-WSTAVE-CH-S001	Soil sample from section 1 within 1 foot of the wooden stave pipe	1/18/16	0835	G	SO	1	16 oz Plastic	X							5		
TITO12-WSTAVE-WOOD	Wood from the pipe itself	1/18/16	0844	G	CP	1	Plastic Ziploc bag	X							4		

Special Instructions: 7 days ingrown draft and follow with 21 days final

☐ 24-hr X 48-hr
Standard TAT ☐ ☐ 3-day ☐ 7-day

Level Of QC Required: I II III Project Specific:

Relinquished By: Date: 1/18/16 Time: 1200
Received By: Date: 1.19.16 Time: 0835
Relinquished By: Date: Time:
Received By: Date:

Method Codes
C = Composite G = Grab

Matrix Codes
DW = Drinking Water SO = Soil
GW = Ground Water SL = Sludge
WW = Waste Water CP = Chip Samples
A = Air ABS=Asbestos, PO=Pipe Openning

160-15772 Chain of Custody

Login Sample Receipt Checklist

Client: CB&I Environmental & Infrastructure, Inc

Job Number: 160-15772-2

Login Number: 15772
List Number: 1
Creator: Clarke, Jill C

List Source: TestAmerica St. Louis

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	N/A	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Definitions/Glossary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15772-2

Qualifiers

Rad

Qualifier	Qualifier Description
U	Undetected at the Limit of Detection.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains no Free Liquid
DER	Duplicate error ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision level concentration
MDA	Minimum detectable activity
EDL	Estimated Detection Limit
MDC	Minimum detectable concentration
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative error ratio
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Method Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15772-2

Method	Method Description	Protocol	Laboratory
GA-01-R	Radium-226 & Other Gamma Emitters (GS)	DOE	TAL SL

Protocol References:

DOE = U.S. Department of Energy

Laboratory References:

TAL SL = TestAmerica St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Sample Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15772-2

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
160-15772-1	TITO12-WSTAVE-CH-S001	Solid	01/18/16 08:35	01/19/16 08:35
160-15772-2	TITO12-WSTAVE-WOOD	Solid	01/18/16 08:44	01/19/16 08:35

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15772-2

Client Sample ID: TITO12-WSTAVE-CH-S001

Lab Sample ID: 160-15772-1
Date Collected: 01/18/16 08:35
Matrix: Solid
Date Received: 01/19/16 08:35

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium-227	0.370	U	0.450	0.451		0.739	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Actinium 228	**0.346**		0.150	0.154		0.286	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Bismuth-212	0.512	U	0.510	0.513		0.808	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Bismuth-214	**0.430**		0.120	0.128		0.119	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Lead-210	1.34	U	1.49	1.50		2.00	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Lead-212	**0.424**		0.0970	0.111		0.106	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Lead-214	**0.431**		0.0961	0.106		0.110	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Potassium-40	**9.88**		1.38	1.71		0.934	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Protactinium-231	0.0610	U	0.109	0.109		1.58	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Radium-226	**0.430**		0.120	0.128	0.500	0.119	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Radium-228	**0.346**		0.150	0.154		0.286	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Thorium-232	**0.346**		0.150	0.154		0.286	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Thorium-234	0.439	U	0.534	0.536		1.68	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Thallium-208	**0.146**		0.0437	0.0463		0.0461	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Uranium-235	0.00953	U	0.122	0.122		0.437	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Uranium-238	0.439	U	0.534	0.536		1.68	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Cesium-137	0.00247	U	0.0419	0.0419		0.0767	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Thorium-228	**0.424**		0.0970	0.111		0.106	pCi/g	01/21/16 12:37	02/18/16 21:09	1

Client Sample ID: TITO12-WSTAVE-WOOD

Lab Sample ID: 160-15772-2
Date Collected: 01/18/16 08:44
Matrix: Solid
Date Received: 01/19/16 08:35

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium-227	-0.0875	U	0.222	0.222		2.56	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Actinium 228	0.140	U	0.409	0.409		0.757	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Bismuth-212	0.000	U	1.34	1.34		4.59	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Bismuth-214	-0.0765	U	0.610	0.610		0.668	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Lead-210	1.23	U	2.84	2.85		4.94	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Lead-212	-0.00177	U	0.227	0.227		0.408	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Lead-214	-0.0237	U	0.189	0.189		0.555	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Potassium-40	-0.0893	U	1.79	1.79		4.01	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Protactinium-231	-0.0815	U	3.01	3.01		5.61	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Radium-226	-0.0765	U	0.610	0.610	0.500	0.668	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Radium-228	0.140	U	0.409	0.409		0.757	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Thorium-232	0.140	U	0.409	0.409		0.757	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Thorium-234	0.936	U	2.09	2.09		3.62	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Thallium-208	0.0882	U	0.181	0.181		0.209	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Uranium-235	-0.0463	U	0.219	0.219		0.954	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Uranium-238	0.936	U	2.09	2.09		3.62	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Cesium-137	-0.0299	U	0.150	0.150		0.277	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Thorium-228	-0.00177	U	0.227	0.227		0.408	pCi/g	01/21/16 12:37	02/28/16 04:01	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15772-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Lab Sample ID: MB 160-233550/1-A
Matrix: Solid
Analysis Batch: 238093

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 233550

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium-227	0.2140	U	0.296	0.297		0.492	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Actinium 228	0.08161	U	0.0942	0.0945		0.185	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Bismuth-212	-0.1458	U	0.511	0.511		0.940	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Bismuth-214	0.05397	U	0.0795	0.0797		0.151	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Lead-210	-0.1488	U	1.07	1.07		1.77	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Lead-212	0.01173	U	0.0575	0.0575		0.110	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Lead-214	-0.01941	U	0.153	0.153		0.150	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Potassium-40	-0.3547	U	14.2	14.2		1.69	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Protactinium-231	-0.1487	U	0.862	0.862		1.58	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Radium-226	0.05397	U	0.0795	0.0797	0.500	0.151	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Radium-228	0.08161	U	0.0942	0.0945		0.185	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Thorium-232	0.08161	U	0.0942	0.0945		0.185	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Thorium-234	-0.3077	U	1.94	1.94		1.30	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Thallium-208	-0.002645	U	0.0587	0.0587		0.0850	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Uranium-235	-0.005476	U	0.165	0.165		0.301	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Uranium-238	-0.3077	U	1.94	1.94		1.30	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Cesium-137	0.01676	U	0.0345	0.0346		0.0615	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Thorium-228	0.01173	U	0.0575	0.0575		0.110	pCi/g	01/21/16 12:37	02/18/16 18:13	1

Lab Sample ID: LCS 160-233550/2-A
Matrix: Solid
Analysis Batch: 238094

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 233550

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	%Rec	%Rec. Limits
Americium-241	97.2	95.35		10.0		1.16	pCi/g	98	87 - 116
Cesium-137	29.9	29.45		3.13		0.191	pCi/g	99	87 - 120
Cobalt-60	17.8	17.01		1.76		0.128	pCi/g	95	87 - 115

Lab Sample ID: 160-15771-A-1-E DU
Matrix: Solid
Analysis Batch: 238093

Client Sample ID: Duplicate
Prep Type: Total/NA
Prep Batch: 233550

Analyte	Sample Result	Sample Qual	DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	RER	RER Limit
Actinium-227	-0.110	U	0.06451	U	0.146		0.693	pCi/g	0.26	1
Actinium 228	0.675		0.3869		0.152		0.268	pCi/g	0.87	1
Bismuth-212	0.230	U	0.2241	U	0.489		0.853	pCi/g	0.01	1
Bismuth-214	0.468		0.4797		0.145		0.129	pCi/g	0.04	1
Lead-210	1.10	U	0.8127	U	1.15		1.69	pCi/g	0.11	1
Lead-212	0.449		0.4812		0.115		0.0927	pCi/g	0.13	1
Lead-214	0.540		0.5374		0.129		0.147	pCi/g	0.01	1
Potassium-40	9.15		9.808		1.78		0.711	pCi/g	0.19	1
Protactinium-231	0.0548	U	0.3242	U	0.931		1.62	pCi/g	0.19	1
Radium-226	0.468		0.4797		0.145	0.500	0.129	pCi/g	0.04	1
Radium-228	0.675		0.3869		0.152		0.268	pCi/g	0.87	1
Thorium-232	0.675		0.3869		0.152		0.268	pCi/g	0.87	1

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS) (Continued)

Lab Sample ID: 160-15771-A-1-E DU
Matrix: Solid
Analysis Batch: 238093

Client Sample ID: Duplicate
Prep Type: Total/NA
Prep Batch: 233550

Analyte	Sample Result	Sample Qual		DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit			RER	RER Limit
Thorium-234	0.317	U		0.1237	U	0.204		1.74	pCi/g			0.35	1
Thallium-208	0.145			0.1917		0.0621		0.0501	pCi/g			0.40	1
Uranium-235	0.105	U		0.08810	U	0.133		0.354	pCi/g			0.06	1
Uranium-238	0.317	U		0.1237	U	0.204		1.74	pCi/g			0.35	1
Cesium-137	-0.0119	U		0.008316	U	0.0358		0.0657	pCi/g			0.25	1
Thorium-228	0.449			0.4812		0.115		0.0927	pCi/g			0.13	1

QC Association Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15772-2

Rad

Leach Batch: 233142

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-15771-A-1-E DU	Duplicate	Total/NA	Solid	Dry and Grind	

Prep Batch: 233550

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-15771-A-1-E DU	Duplicate	Total/NA	Solid	Fill_Geo-21	233142
160-15772-1	TITO12-WSTAVE-CH-S001	Total/NA	Solid	Fill_Geo-21	
160-15772-2	TITO12-WSTAVE-WOOD	Total/NA	Solid	Fill_Geo-21	
LCS 160-233550/2-A	Lab Control Sample	Total/NA	Solid	Fill_Geo-21	
MB 160-233550/1-A	Method Blank	Total/NA	Solid	Fill_Geo-21	

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica St. Louis
13715 Rider Trail North
Earth City, MO 63045
Tel: (314)298-8566

TestAmerica Job ID: 160-15883-2
Client Project/Site: Treasure Island - 500475

For:
CB&I Environmental & Infrastructure, Inc
4005 Port Chicago Hwy
Concord, California 94520

Attn: Patricia Flynn

Authorized for release by:
3/1/2016 2:16:13 PM

Erika Gish, Project Manager II
(314)298-8566
erika.gish@testamericainc.com

LINKS

Review your project results through TotalAccess

Have a Question? Ask The Expert

Visit us at:
www.testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

Table of Contents

Cover Page 1
Table of Contents 2
Case Narrative 3
Chain of Custody 5
Receipt Checklists 6
Definitions/Glossary 7
Method Summary 8
Sample Summary 9
Client Sample Results 10
QC Sample Results 12
QC Association Summary 14

Job ID: 160-15883-2

Laboratory: TestAmerica St. Louis

Narrative

CASE NARRATIVE

Client: CB&I Environmental & Infrastructure, Inc

Project: Treasure Island - 500475

Report Number: 160-15883-2

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In some cases, due to interference or analytes present at high concentrations, samples were diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

TestAmerica St. Louis attests to the validity of the laboratory data generated by TestAmerica facilities reported herein. All analyses performed by TestAmerica facilities were done using established laboratory SOPs that incorporate QA/QC procedures described in the application methods. TestAmerica's operations groups have reviewed the data for compliance with the laboratory QA/QC plan, and data have been found to be compliant with laboratory protocols unless otherwise noted below.

The test results in this report meet all NELAP requirements for parameters for which accreditation is required or available. Any exceptions to NELAP requirements are noted in this report. Pursuant to NELAP, this report may not be reproduced, except in full, without the written approval of the laboratory.

Calculations are performed before rounding to avoid round-off errors in calculated results.

All holding times were met and proper preservation noted for the methods performed on these samples, unless otherwise detailed in the individual sections below.

All solid sample results for Chemistry analyses are reported on an "as received" basis unless otherwise indicated by the presence of a % solids value in the method header. All soil/sediment sample results for radiochemistry analyses are based upon sample as dried and disaggregated with the exception of tritium, carbon-14, and iodine-129 by gamma spectroscopy unless requested as wet weight by the client."

Reference the chain of custody and condition upon receipt report for any variations on receipt conditions and temperature of samples on receipt
Manual Integrations were performed only when necessary and are in compliance with the laboratory's standard operating procedure. Detailed information can be found in the raw data section of the level IV report.

The following clean-up methods for Organic analyses may have been used on the samples in this data set. Specific methods employed are documented on the batch extraction logs:

Method 3600C: Cleanup
Method 3620C: Florisil Cleanup
Method 3630C: Silica Gel Cleanup
Method 3640A: Gel-Permeation Cleanup
Method 3650B: Acid-Base Partition Cleanup
Method 3660B: Sulfur Cleanup
Method 3665A: Sulfuric Acid/Permanganate Cleanup

This laboratory report is confidential and is intended for the sole use of TestAmerica and its client.

Job ID: 160-15883-2 (Continued)

Laboratory: TestAmerica St. Louis (Continued)

RECEIPT
The samples were received on 1/27/2016 8:30 AM; the samples arrived in good condition, properly preserved. The temperature of the cooler at receipt was 18.1º C.

RADIUM-226 BY GAMMA SPEC (21 DAY INGROWTH)
Samples TITO12-WSTAVE-CH-SED001 (160-15883-2) and TITO12-WSTAVE-CH-SED002 (160-15883-3) were analyzed for Radium-226 by gamma spec (21 day ingrowth) in accordance with EPA GA_01_R. The samples were dried on 01/27/2016, prepared on 01/29/2016 and analyzed on 02/19/2016 and 02/27/2016.

No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

RADIUM 226 (21 DAY INGROWTH)
Sample TITO12-WSTAVE-WOOD012516 (160-15883-1) was analyzed for Radium 226 (21 day ingrowth) in accordance with DOE GA-01-R. The samples were prepared on 01/29/2016 and analyzed on 02/19/2016.

Prep Batch: 160-235061
Sample was prepped as received rather than the project specified dry/grind. TITO12-WSTAVE-WOOD012516 (160-15883-1)

The radium-226 detection goal was not met for the following sample due to the low density of the sample:
TITO12-WSTAVE-WOOD012516 (160-15883-1). Analytical results are reported with the detection limit achieved.

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

CHAIN OF CUSTODY

Ref. Document # TI_WOOD STAVE_002

Page 1 of 1

Shaw Environmental and Infrastructure Inc. (a CB&I company)
Federal Services Division

4005 Port Chicago Hwy
Concord, CA 94520

Project Number: 500475
Project Name / Location: TI WOOD STAVE
Purchase Order #: 202220

Project Manager: John Hackett (Name & phone #)

Shipment Date: 1/26/16
Waybill Number: 1Z89V4620197290786
Lab Destination: TestAmerica St Loius
Lab Contact Name / ph. #: Erika Gish

Send Report To: Patricia Flynn
Phone/Fax Number: 925-288-2037
Address: 4005 Port Chicago Hwy
City: Concord, CA, 94520

Sampler's Name(s): BC

Sample ID Number	Sample Description	Collection Information: Date	Time	Method	Matrix	# of containers	Container Type	Preservative (water)	Preservative (soil)	Analyses Requested: Gamma Scan							Dose Rate µR/Hr		
										N/A									
TITO12-WSTAVE-WOOD012516	Wood from bottom of wood stave	1/25/16	0905	G	CP	1	Plastic Ziploc bag			X							5		
TITO12-WSTAVE-CH-SED001	Sediment inside bottom of wood stave	1/25/16	0850	G	SL	1	16 oz Plastic			X							5		
TITO12-WSTAVE-CH-SED002	Sediment inside bottom of wood stave	1/25/16	0856	G	SL	1	16 oz Plastic			X							5		

Special Instructions: 7 days ingrown draft and follow with 21 days final

☐ 24-hr ☐ 48-hr

Standard TAT ☐ ☐ 3-day ☐ 7-day

Level Of QC Required: I II III Project Specific:

Relinquished By:	Date: 1-26-16 Time: 1200	Received By:	Date: 1-27-16 Time: 0830
Relinquished By:	Date: Time:	Received By:	Date: Time:

Method Codes

C = Composite G = Grab

Matrix Codes

DW = Drinking Water SO =Soil
GW = Ground Water SL = Sludge
WW = Waste Water CP = Chip Samples
A = Air ABS=Asbestos, PO=Pipe Openning

160-15883 Chain of Custody

Login Sample Receipt Checklist

Client: CB&I Environmental & Infrastructure, Inc

Job Number: 160-15883-2

Login Number: 15883
List Number: 1
Creator: Clarke, Jill C

List Source: TestAmerica St. Louis

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	N/A	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Definitions/Glossary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Qualifiers

Rad

Qualifier	Qualifier Description
U	Undetected at the Limit of Detection.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains no Free Liquid
DER	Duplicate error ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision level concentration
MDA	Minimum detectable activity
EDL	Estimated Detection Limit
MDC	Minimum detectable concentration
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative error ratio
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Method Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Method	Method Description	Protocol	Laboratory
GA-01-R	Radium-226 & Other Gamma Emitters (GS)	DOE	TAL SL

Protocol References:

DOE = U.S. Department of Energy

Laboratory References:

TAL SL = TestAmerica St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Sample Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
160-15883-1	TITO12-WSTAVE-WOOD012516	Solid	01/25/16 09:05	01/27/16 08:30
160-15883-2	TITO12-WSTAVE-CH-SED001	Solid	01/25/16 08:50	01/27/16 08:30
160-15883-3	TITO12-WSTAVE-CH-SED002	Solid	01/25/16 08:56	01/27/16 08:30

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Client Sample ID: TITO12-WSTAVE-WOOD012516

Lab Sample ID: 160-15883-1
Date Collected: 01/25/16 09:05
Matrix: Solid
Date Received: 01/27/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium-227	-0.161	U	1.24	1.24		2.22	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Actinium 228	0.0576	U	0.124	0.124		0.952	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Bismuth-212	0.000	U	0.432	0.432		1.13	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Bismuth-214	-0.0127	U	0.0823	0.0823		0.604	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Lead-210	3.86	U	4.62	4.65		6.97	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Lead-212	0.107	U	0.229	0.229		0.421	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Lead-214	0.0823	U	0.0978	0.0982		0.577	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Potassium-40	1.56	U	1.96	1.96		3.82	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Protactinium-231	0.000	U	0.846	0.846		5.91	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Radium-226	-0.0127	U	0.0823	0.0823	0.500	0.604	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Radium-228	0.0576	U	0.124	0.124		0.952	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Thorium-232	0.0576	U	0.124	0.124		0.952	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Thorium-234	1.64	U	1.49	1.50		4.16	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Thallium-208	0.0259	U	0.0494	0.0495		0.278	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Uranium-235	0.0865	U	0.271	0.271		0.929	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Uranium-238	1.64	U	1.49	1.50		4.16	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Cesium-137	0.000	U	0.0619	0.0619		0.304	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Thorium-228	0.107	U	0.229	0.229		0.421	pCi/g	01/29/16 09:35	02/19/16 08:22	1

Client Sample ID: TITO12-WSTAVE-CH-SED001

Lab Sample ID: 160-15883-2
Date Collected: 01/25/16 08:50
Matrix: Solid
Date Received: 01/27/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.486**		0.171	0.178		0.228	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Actinium-227	0.329	U	0.401	0.403		0.657	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Bismuth-212	0.0769	U	0.456	0.456		0.900	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Bismuth-214	**0.472**		0.145	0.153		0.146	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Cesium-137	**0.225**		0.0650	0.0691		0.0425	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Lead-210	0.792	U	1.16	1.17		1.85	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Lead-212	**0.400**		0.104	0.116		0.115	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Lead-214	**0.562**		0.116	0.130		0.102	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Potassium-40	**10.0**		1.52	1.83		0.981	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Protactinium-231	-0.0307	U	0.107	0.107		1.87	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Radium-226	**0.472**		0.145	0.153	0.500	0.146	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Radium-228	**0.486**		0.171	0.178		0.228	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Thallium-208	**0.164**		0.0474	0.0503		0.0252	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Thorium-228	**0.400**		0.104	0.116		0.115	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Thorium-232	**0.486**		0.171	0.178		0.228	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Thorium-234	0.669	U	0.434	0.440		1.64	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Uranium-235	0.184	U	0.138	0.139		0.524	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Uranium-238	0.669	U	0.434	0.440		1.64	pCi/g	01/29/16 09:35	02/27/16 08:52	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Client Sample ID: TITO12-WSTAVE-CH-SED002

Lab Sample ID: 160-15883-3

Date Collected: 01/25/16 08:56

Matrix: Solid

Date Received: 01/27/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.520**		0.159	0.167		0.146	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Actinium-227	0.0223	U	0.595	0.595		1.03	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Bismuth-212	0.337	U	0.468	0.469		0.777	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Bismuth-214	**0.412**		0.117	0.125		0.110	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Cesium-137	0.0491	U	0.0388	0.0391		0.0578	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Lead-210	0.590	U	1.20	1.20		1.96	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Lead-212	**0.265**		0.0931	0.0992		0.111	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Lead-214	**0.515**		0.128	0.139		0.115	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Potassium-40	**8.31**		1.24	1.51		0.602	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Protactinium-231	0.000	U	0.330	0.330		1.72	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Radium-226	**0.412**		0.117	0.125	0.500	0.110	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Radium-228	**0.520**		0.159	0.167		0.146	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Thallium-208	**0.165**		0.0538	0.0565		0.0428	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Thorium-228	**0.265**		0.0931	0.0992		0.111	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Thorium-232	**0.520**		0.159	0.167		0.146	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Thorium-234	1.04	U	0.813	0.820		1.40	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Uranium-235	0.112	U	0.171	0.171		0.292	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Uranium-238	1.04	U	0.813	0.820		1.40	pCi/g	01/29/16 09:35	02/19/16 09:00	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Lab Sample ID: MB 160-235061/1-A
Matrix: Solid
Analysis Batch: 238201

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 235061

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.0000	U	0.0313	0.0313		0.115	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Actinium-227	0.1240	U	0.290	0.291		0.512	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Bismuth-212	-0.1090	U	0.629	0.629		1.14	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Bismuth-214	-0.04373	U	1.20	1.20		0.174	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Lead-210	-0.2306	U	1.29	1.29		2.18	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Lead-212	0.03418	U	0.0624	0.0625		0.114	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Lead-214	0.01511	U	0.0627	0.0627		0.124	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Potassium-40	0.08161	U	0.436	0.436		0.986	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Protactinium-231	0.1993	U	0.773	0.773		1.40	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Radium-226	-0.04373	U	1.20	1.20	0.500	0.174	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Radium-228	0.0000	U	0.0313	0.0313		0.115	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Thallium-208	0.01480	U	0.0397	0.0398		0.0710	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Thorium-232	0.0000	U	0.0313	0.0313		0.115	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Cesium-137	0.007907	U	0.0288	0.0288		0.0548	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Thorium-234	0.3964	U	0.479	0.481		1.44	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Uranium-235	0.0000	U	0.170	0.170		0.331	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Thorium-228	0.03418	U	0.0624	0.0625		0.114	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Uranium-238	0.3964	U	0.479	0.481		1.44	pCi/g	01/29/16 09:35	02/19/16 01:54	1

Lab Sample ID: LCS 160-235061/2-A
Matrix: Solid
Analysis Batch: 238199

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 235061

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	%Rec	%Rec. Limits
Americium-241	97.2	96.29		10.1		1.05	pCi/g	99	87 - 116
Cesium-137	29.9	29.59		3.16		0.248	pCi/g	99	87 - 120
Cobalt-60	17.8	17.32		1.80		0.0807	pCi/g	97	87 - 115

Lab Sample ID: 160-15883-2 DU
Matrix: Solid
Analysis Batch: 238200

Client Sample ID: TITO12-WSTAVE-CH-SED001
Prep Type: Total/NA
Prep Batch: 235061

Analyte	Sample Result	Sample Qual	DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	RER	RER Limit
Actinium 228	0.486		0.1457	U	0.161		0.356	pCi/g	1.00	1
Actinium-227	0.329	U	-0.02715	U	0.0496		0.939	pCi/g	0.79	1
Bismuth-212	0.0769	U	0.3120	U	0.474		0.796	pCi/g	0.25	1
Bismuth-214	0.472		0.4987		0.130		0.112	pCi/g	0.1	1
Lead-210	0.792	U	-0.3113	U	1.77		2.48	pCi/g	0.38	1
Lead-212	0.400		0.4429		0.159		0.148	pCi/g	0.16	1
Lead-214	0.562		0.4548		0.123		0.151	pCi/g	0.42	1
Potassium-40	10.0		9.883		1.80		0.938	pCi/g	0.04	1
Protactinium-231	-0.0307	U	-0.1449	U	0.989		1.77	pCi/g	0.10	1
Radium-226	0.472		0.4987		0.130	0.500	0.112	pCi/g	0.1	1
Radium-228	0.486		0.1457	U	0.161		0.356	pCi/g	1.00	1
Thallium-208	0.164		0.1617		0.0744		0.0765	pCi/g	0.02	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS) (Continued)

Lab Sample ID: 160-15883-2 DU
Matrix: Solid
Analysis Batch: 238200

Client Sample ID: TITO12-WSTAVE-CH-SED001
Prep Type: Total/NA
Prep Batch: 235061

Analyte	Sample Result	Sample Qual		DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit			RER	RER Limit
Thorium-232	0.486			0.1457	U	0.161		0.356	pCi/g			1.00	1
Cesium-137	0.225			0.2877		0.0713		0.0268	pCi/g			0.45	1
Thorium-234	0.669	U		1.312	U	1.14		1.93	pCi/g			0.41	1
Uranium-235	0.184	U		0.2166	U	0.257		0.378	pCi/g			0.08	1
Thorium-228	0.400			0.4429		0.159		0.148	pCi/g			0.16	1
Uranium-238	0.669	U		1.312	U	1.14		1.93	pCi/g			0.41	1

QC Association Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Rad

Leach Batch: 234629

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-15883-2	TITO12-WSTAVE-CH-SED001	Total/NA	Solid	Dry and Grind	
160-15883-2 DU	TITO12-WSTAVE-CH-SED001	Total/NA	Solid	Dry and Grind	
160-15883-3	TITO12-WSTAVE-CH-SED002	Total/NA	Solid	Dry and Grind	

Prep Batch: 235061

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-15883-1	TITO12-WSTAVE-WOOD012516	Total/NA	Solid	Fill_Geo-21	
160-15883-2	TITO12-WSTAVE-CH-SED001	Total/NA	Solid	Fill_Geo-21	234629
160-15883-2 DU	TITO12-WSTAVE-CH-SED001	Total/NA	Solid	Fill_Geo-21	234629
160-15883-3	TITO12-WSTAVE-CH-SED002	Total/NA	Solid	Fill_Geo-21	234629
LCS 160-235061/2-A	Lab Control Sample	Total/NA	Solid	Fill_Geo-21	
MB 160-235061/1-A	Method Blank	Total/NA	Solid	Fill_Geo-21	

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica St. Louis
13715 Rider Trail North
Earth City, MO 63045
Tel: (314)298-8566

TestAmerica Job ID: 160-15947-2
Client Project/Site: Treasure Island - 500475

For:
CB&I Environmental & Infrastructure, Inc
4005 Port Chicago Hwy
Concord, California 94520

Attn: Patricia Flynn

Authorized for release by:
2/29/2016 6:27:10 PM

Erika Gish, Project Manager II
(314)298-8566
erika.gish@testamericainc.com

LINKS

Review your project results through TotalAccess

Have a Question? Ask The Expert

Visit us at: www.testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

Table of Contents

Cover Page 1
Table of Contents 2
Case Narrative 3
Chain of Custody 5
Receipt Checklists 6
Definitions/Glossary 7
Method Summary 8
Sample Summary 9
Client Sample Results 10
QC Sample Results 11
QC Association Summary 13

Job ID: 160-15947-2

Laboratory: TestAmerica St. Louis

Narrative

CASE NARRATIVE

Client: CB&I Environmental & Infrastructure, Inc

Project: Treasure Island - 500475

Report Number: 160-15947-2

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In some cases, due to interference or analytes present at high concentrations, samples were diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

TestAmerica St. Louis attests to the validity of the laboratory data generated by TestAmerica facilities reported herein. All analyses performed by TestAmerica facilities were done using established laboratory SOPs that incorporate QA/QC procedures described in the application methods. TestAmerica's operations groups have reviewed the data for compliance with the laboratory QA/QC plan, and data have been found to be compliant with laboratory protocols unless otherwise noted below.

The test results in this report meet all NELAP requirements for parameters for which accreditation is required or available. Any exceptions to NELAP requirements are noted in this report. Pursuant to NELAP, this report may not be reproduced, except in full, without the written approval of the laboratory.

Calculations are performed before rounding to avoid round-off errors in calculated results.

All holding times were met and proper preservation noted for the methods performed on these samples, unless otherwise detailed in the individual sections below.

All solid sample results for Chemistry analyses are reported on an "as received" basis unless otherwise indicated by the presence of a % solids value in the method header. All soil/sediment sample results for radiochemistry analyses are based upon sample as dried and disaggregated with the exception of tritium, carbon-14, and iodine-129 by gamma spectroscopy unless requested as wet weight by the client."

Reference the chain of custody and condition upon receipt report for any variations on receipt conditions and temperature of samples on receipt
Manual Integrations were performed only when necessary and are in compliance with the laboratory's standard operating procedure. Detailed information can be found in the raw data section of the level IV report.

The following clean-up methods for Organic analyses may have been used on the samples in this data set. Specific methods employed are documented on the batch extraction logs:

Method 3600C: Cleanup
Method 3620C: Florisil Cleanup
Method 3630C: Silica Gel Cleanup
Method 3640A: Gel-Permeation Cleanup
Method 3650B: Acid-Base Partition Cleanup
Method 3660B: Sulfur Cleanup
Method 3665A: Sulfuric Acid/Permanganate Cleanup

This laboratory report is confidential and is intended for the sole use of TestAmerica and its client.

Job ID: 160-15947-2 (Continued)

Laboratory: TestAmerica St. Louis (Continued)

RECEIPT

The samples were received on 2/2/2016 8:40 AM; the samples arrived in good condition, properly preserved. The temperature of the cooler at receipt was 23.5º C.

RADIUM-226 BY GAMMA SPEC (21 DAY INGROWTH)

Samples TITO12-WSTAVE-CNCRT-001 (160-15947-1) and TITO12-WSTAVE-CNCRT-002 (160-15947-2) were analyzed for Radium-226 by gamma spec (21 day ingrowth) in accordance with EPA GA_01_R. The samples were dried on 02/02/2016, prepared on 02/04/2016 and analyzed on 02/25/2016.

No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

CHAIN OF CUSTODY

Ref. Document # TI_WOOD STAVE_003

Page 1 of 1

Shaw Environmental and Infrastructure Inc. (a CB&I company)
Federal Services Division
4005 Port Chicago Hwy
Concord, CA 94520

Project Number: 500475
Project Name / Location: TI WOOD STAVE
Purchase Order #: 202220

Project Manager: John Hackett (Name & phone #)

Send Report To: Patricia Flynn
Phone/Fax Number: 925-288-2037
Address: 4005 Port Chicago Hwy
City: Concord, CA, 94520

Shipment Date: 2/1/2016
Waybill Number: 1Z 89V 462 01 9713 0805
Lab Destination: TestAmerica St Loius
Lab Contact Name / ph. #: Erika Gish

Sampler's Name(s): A.N.

Sample ID Number	Sample Description	Collection Information: Date	Time	Method	Matrix	# of containers	Preservative (water) / Preservative (soil) / Container Type	Gamma Scan							Dose Rate µR/Hr		
							Preservative (water)										
							Preservative (soil)	N/A									
							Container Type										
TITO12-WSTAVE-CNCRT-001	Concrete slurry from section 1W	01/29/16	10:10	G	CP	1	16 oz Plastic	X							5		
TITO12-WSTAVE-CNCRT-002	Concrete slurry from section 4W	01/29/16	10:00	G	CP	1	16 oz Plastic	X							5		

Analyses Requested

Special Instructions: 7 days ingrown draft and follow with 21 days final

Standard TAT ☐ ☐ 24-hr ☐ 48-hr ☐ 3-day ☐ 7-day

Level Of QC Required: I II III Project Specific:

Relinquished By: Bryon Rogers Date: 2/1/2016 Time: 1200
Received By: Date: 2-2-16 Time: 0840
Relinquished By: Date: Time:
Received By: Date:

Method Codes
C = Composite
G = Grab

Matrix Codes
DW = Drinking Water
GW = Ground Water
WW = Waste Water
A = Air
SO =Soil
SL = Sludge
CP = Chip Samples
ABS=Asbestos, PO=Pipe Openning

160-15947 Chain of Custody

Login Sample Receipt Checklist

Client: CB&I Environmental & Infrastructure, Inc

Job Number: 160-15947-2

Login Number: 15947
List Number: 1
Creator: Clarke, Jill C

List Source: TestAmerica St. Louis

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	N/A	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Definitions/Glossary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15947-2

Qualifiers

Rad

Qualifier	Qualifier Description
U	Undetected at the Limit of Detection.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains no Free Liquid
DER	Duplicate error ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision level concentration
MDA	Minimum detectable activity
EDL	Estimated Detection Limit
MDC	Minimum detectable concentration
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative error ratio
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Method Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15947-2

Method	Method Description	Protocol	Laboratory
GA-01-R	Radium-226 & Other Gamma Emitters (GS)	DOE	TAL SL

Protocol References:

DOE = U.S. Department of Energy

Laboratory References:

TAL SL = TestAmerica St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Sample Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15947-2

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
160-15947-1	TITO12-WSTAVE-CNCRT-001	Solid	01/29/16 10:10	02/02/16 08:40
160-15947-2	TITO12-WSTAVE-CNCRT-002	Solid	01/29/16 10:00	02/02/16 08:40

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15947-2

Client Sample ID: TITO12-WSTAVE-CNCRT-001

Lab Sample ID: 160-15947-1
Date Collected: 01/29/16 10:10
Matrix: Solid
Date Received: 02/02/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.193	U	0.187	0.188		0.460	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Actinium-227	0.263	U	0.365	0.366		0.607	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Bismuth-212	0.000	U	0.226	0.226		2.24	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Bismuth-214	0.218	U	0.163	0.165		0.220	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Cesium-137	-0.0509	U	0.275	0.275		0.138	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Lead-210	1.31	U	1.16	1.17		1.99	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Lead-212	**0.301**		0.0959	0.104		0.0973	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Lead-214	**0.368**		0.124	0.129		0.105	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Potassium-40	**4.30**		1.50	1.57		1.60	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Protactinium-231	0.113	U	0.655	0.655		2.36	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Radium-226	0.218	U	0.163	0.165	0.500	0.220	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Radium-228	0.193	U	0.187	0.188		0.460	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Thallium-208	0.0285	U	0.0576	0.0577		0.101	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Thorium-228	**0.301**		0.0959	0.104		0.0973	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Thorium-232	0.193	U	0.187	0.188		0.460	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Thorium-234	0.533	U	0.448	0.452		1.64	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Uranium-235	0.0951	U	0.222	0.222		0.398	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Uranium-238	0.533	U	0.448	0.452		1.64	pCi/g	02/04/16 12:56	02/25/16 09:32	1

Client Sample ID: TITO12-WSTAVE-CNCRT-002

Lab Sample ID: 160-15947-2
Date Collected: 01/29/16 10:00
Matrix: Solid
Date Received: 02/02/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.248	U	0.160	0.162		0.302	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Actinium-227	0.0922	U	0.341	0.341		0.847	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Bismuth-212	-0.169	U	6.78	6.78		1.09	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Bismuth-214	**0.423**		0.151	0.157		0.161	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Cesium-137	0.0577	U	0.0529	0.0532		0.0822	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Lead-210	-0.322	U	1.92	1.92		2.10	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Lead-212	**0.357**		0.101	0.111		0.116	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Lead-214	**0.533**		0.142	0.152		0.132	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Potassium-40	**5.67**		1.21	1.34		1.04	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Protactinium-231	-0.423	U	1.03	1.03		1.79	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Radium-226	**0.423**		0.151	0.157	0.500	0.161	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Radium-228	0.248	U	0.160	0.162		0.302	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Thallium-208	**0.0933**		0.0571	0.0579		0.0817	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Thorium-228	**0.357**		0.101	0.111		0.116	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Thorium-232	0.248	U	0.160	0.162		0.302	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Thorium-234	0.265	U	0.226	0.227		2.04	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Uranium-235	0.0916	U	0.205	0.205		0.350	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Uranium-238	0.265	U	0.226	0.227		2.04	pCi/g	02/04/16 12:56	02/25/16 09:29	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15947-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Lab Sample ID: MB 160-236334/1-A
Matrix: Solid
Analysis Batch: 238294

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 236334

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.01682	U	0.137	0.137		0.271	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Actinium-227	-0.1469	U	0.435	0.435		0.761	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Bismuth-212	-0.2076	U	0.612	0.612		1.10	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Bismuth-214	-0.01220	U	0.147	0.147		0.152	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Cesium-137	-0.01753	U	0.103	0.103		0.0911	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Lead-210	-0.03956	U	0.719	0.719		1.34	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Lead-212	-0.01074	U	0.112	0.112		0.108	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Lead-214	0.03896	U	0.0559	0.0560		0.114	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Potassium-40	-0.2332	U	9.33	9.33		0.843	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Protactinium-231	0.03194	U	0.107	0.107		1.86	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Radium-226	-0.01220	U	0.147	0.147	0.500	0.152	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Radium-228	0.01682	U	0.137	0.137		0.271	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Thallium-208	0.005866	U	0.0155	0.0155		0.0752	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Thorium-228	-0.01074	U	0.112	0.112		0.108	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Thorium-232	0.01682	U	0.137	0.137		0.271	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Thorium-234	-0.009564	U	0.0242	0.0242		1.48	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Uranium-235	0.01178	U	0.152	0.152		0.303	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Uranium-238	-0.009564	U	0.0242	0.0242		1.48	pCi/g	02/04/16 12:56	02/25/16 09:30	1

Lab Sample ID: LCS 160-236334/2-A
Matrix: Solid
Analysis Batch: 238293

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 236334

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	%Rec	%Rec. Limits
Americium-241	97.2	95.58		10.0		1.00	pCi/g	98	87 - 116
Cesium-137	29.9	28.43		3.03		0.211	pCi/g	95	87 - 120
Cobalt-60	17.8	17.01		1.77		0.109	pCi/g	96	87 - 115

Lab Sample ID: 160-15947-1 DU
Matrix: Solid
Analysis Batch: 238294

Client Sample ID: TITO12-WSTAVE-CNCRT-001
Prep Type: Total/NA
Prep Batch: 236334

Analyte	Sample Result	Sample Qual	DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	RER	RER Limit
Actinium 228	0.193	U	0.1550	U	0.190		0.401	pCi/g	0.1	1
Actinium-227	0.263	U	-0.002258	U	0.472		0.859	pCi/g	0.32	1
Bismuth-212	0.000	U	0.4285	U	0.798		1.37	pCi/g	0.42	1
Bismuth-214	0.218	U	0.2472		0.134		0.186	pCi/g	0.1	1
Cesium-137	-0.0509	U	-0.01092	U	0.0862		0.109	pCi/g	0.11	1
Lead-210	1.31	U	-0.3999	U	1.24		2.14	pCi/g	0.71	1
Lead-212	0.301		0.2555		0.105		0.121	pCi/g	0.22	1
Lead-214	0.368		0.4293		0.137		0.0875	pCi/g	0.23	1
Potassium-40	4.30		5.129		1.44		0.903	pCi/g	0.27	1
Protactinium-231	0.113	U	0.07138	U	0.0945		2.27	pCi/g	0.06	1
Radium-226	0.218	U	0.2472		0.134	0.500	0.186	pCi/g	0.1	1
Radium-228	0.193	U	0.1550	U	0.190		0.401	pCi/g	0.1	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15947-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS) (Continued)

Lab Sample ID: 160-15947-1 DU
Matrix: Solid
Analysis Batch: 238294

Client Sample ID: TITO12-WSTAVE-CNCRT-001
Prep Type: Total/NA
Prep Batch: 236334

Analyte	Sample Result	Sample Qual		DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit			RER	RER Limit
Thallium-208	0.0285	U		0.1020		0.0585		0.0732	pCi/g			0.63	1
Thorium-228	0.301			0.2555		0.105		0.121	pCi/g			0.22	1
Thorium-232	0.193	U		0.1550	U	0.190		0.401	pCi/g			0.1	1
Thorium-234	0.533	U		1.067	U	0.628		1.80	pCi/g			0.49	1
Uranium-235	0.0951	U		0.1288	U	0.248		0.381	pCi/g			0.07	1
Uranium-238	0.533	U		1.067	U	0.628		1.80	pCi/g			0.49	1

QC Association Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15947-2

Rad

Leach Batch: 235441

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-15947-1	TITO12-WSTAVE-CNCRT-001	Total/NA	Solid	Dry and Grind	
160-15947-1 DU	TITO12-WSTAVE-CNCRT-001	Total/NA	Solid	Dry and Grind	
160-15947-2	TITO12-WSTAVE-CNCRT-002	Total/NA	Solid	Dry and Grind	

Prep Batch: 236334

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-15947-1	TITO12-WSTAVE-CNCRT-001	Total/NA	Solid	Fill_Geo-21	235441
160-15947-1 DU	TITO12-WSTAVE-CNCRT-001	Total/NA	Solid	Fill_Geo-21	235441
160-15947-2	TITO12-WSTAVE-CNCRT-002	Total/NA	Solid	Fill_Geo-21	235441
LCS 160-236334/2-A	Lab Control Sample	Total/NA	Solid	Fill_Geo-21	
MB 160-236334/1-A	Method Blank	Total/NA	Solid	Fill_Geo-21	

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica St. Louis
13715 Rider Trail North
Earth City, MO 63045
Tel: (314)298-8566

TestAmerica Job ID: 160-16018-2
Client Project/Site: Treasure Island - 500475

For:
CB&I Environmental & Infrastructure, Inc
4005 Port Chicago Hwy
Concord, California 94520

Attn: Patricia Flynn

Authorized for release by:
3/8/2016 4:53:44 PM

Erika Gish, Project Manager II
(314)298-8566
erika.gish@testamericainc.com

LINKS

Review your project results through TotalAccess

Have a Question? Ask The Expert

Visit us at:
www.testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

Table of Contents

Cover Page 1
Table of Contents 2
Case Narrative 3
Chain of Custody 5
Receipt Checklists 6
Definitions/Glossary 7
Method Summary 8
Sample Summary 9
Client Sample Results 10
QC Sample Results 13
QC Association Summary 15

Job ID: 160-16018-2

Laboratory: TestAmerica St. Louis

Narrative

CASE NARRATIVE

Client: CB&I Environmental & Infrastructure, Inc

Project: Treasure Island - 500475

Report Number: 160-16018-2

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In some cases, due to interference or analytes present at high concentrations, samples were diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

TestAmerica St. Louis attests to the validity of the laboratory data generated by TestAmerica facilities reported herein. All analyses performed by TestAmerica facilities were done using established laboratory SOPs that incorporate QA/QC procedures described in the application methods. TestAmerica's operations groups have reviewed the data for compliance with the laboratory QA/QC plan, and data have been found to be compliant with laboratory protocols unless otherwise noted below.

The test results in this report meet all NELAP requirements for parameters for which accreditation is required or available. Any exceptions to NELAP requirements are noted in this report. Pursuant to NELAP, this report may not be reproduced, except in full, without the written approval of the laboratory.

Calculations are performed before rounding to avoid round-off errors in calculated results.

All holding times were met and proper preservation noted for the methods performed on these samples, unless otherwise detailed in the individual sections below.

All solid sample results for Chemistry analyses are reported on an "as received" basis unless otherwise indicated by the presence of a % solids value in the method header. All soil/sediment sample results for radiochemistry analyses are based upon sample as dried and disaggregated with the exception of tritium, carbon-14, and iodine-129 by gamma spectroscopy unless requested as wet weight by the client."

Reference the chain of custody and condition upon receipt report for any variations on receipt conditions and temperature of samples on receipt
Manual Integrations were performed only when necessary and are in compliance with the laboratory's standard operating procedure. Detailed information can be found in the raw data section of the level IV report.

The following clean-up methods for Organic analyses may have been used on the samples in this data set. Specific methods employed are documented on the batch extraction logs:

Method 3600C: Cleanup
Method 3620C: Florisil Cleanup
Method 3630C: Silica Gel Cleanup
Method 3640A: Gel-Permeation Cleanup
Method 3650B: Acid-Base Partition Cleanup
Method 3660B: Sulfur Cleanup
Method 3665A: Sulfuric Acid/Permanganate Cleanup

This laboratory report is confidential and is intended for the sole use of TestAmerica and its client.

Job ID: 160-16018-2 (Continued)

Laboratory: TestAmerica St. Louis (Continued)

RECEIPT
The samples were received on 2/5/2016 8:30 AM; the samples arrived in good condition, properly preserved. The temperature of the cooler at receipt was 23.0º C.

RADIUM-226 BY GAMMA SPEC (21 DAY INGROWTH)
Samples TITO12-WSTAVE-CNCRTW8CH-001 (160-16018-1), TITO12-WSTAVE-W8CH-S002 (160-16018-2), TITO12-WSTAVE-CNCRTE1CH-004 (160-16018-4) and TITO12-WSTAVE-CH-SED005 (160-16018-5) were analyzed for Radium-226 by gamma spec (21 day ingrowth) in accordance with EPA GA_01_R. The samples were dried on 02/10/2016, prepared on 02/12/2016 and analyzed on 03/04/2016.

No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

RADIUM 226 (21 DAY INGROWTH)
Samples TITO12-WSTAVE-WOODW8CH-003 (160-16018-3) and TITO12-WSTAVE-WOODE1CH-006 (160-16018-6) were analyzed for Radium 226 (21 day ingrowth) in accordance with DOE GA-01-R. The samples were prepared on 02/12/2016 and analyzed on 03/04/2016.

Due to the matrix, the samples were not dried and ground as per the project requirements.

No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

CHAIN OF CUSTODY

Ref. Document # TI_WOOD STAVE_006

Page 1 of 1

Shaw Environmental and Infrastructure Inc. (a CB&I company)
Federal Services Division
4005 Port Chicago Hwy
Concord, CA 94520

Project Number: 500475
Project Name / Location: TI WOOD STAVE Backfill
Purchase Order #: 202220

Project Manager: John Hackett (Name & phone #)

Send Report To: Patricia Flynn
Phone/Fax Number: 925-288-2037
Address: 4005 Port Chicago Hwy
City: Concord, CA, 94520

Shipment Date: 2/4/2016
Waybill Number: 1Z 89V462019718 6827
Lab Destination: TestAmerica St Loius
Lab Contact Name / ph. #: Erika Gish

Sampler's Name(s): A. Neotti

Sample ID Number	Sample Description	Collection Information: Date	Time	Method	Matrix	# of containers	Container Type	Gamma Scan							Dose Rate µR/Hr		
							Preservative (water)										
							Preservative (soil)	N/A									
TITO12-WSTAVE-CNCRTW8CH-001	Concrete slurry chracterization section West 8 inside pipe	02/03/16	8:10	G	CP	1	16 oz Plastic	X							5		
TITO12-WSTAVE-W8CH-S002	Soil characterization section West 8 within 1 foot of the pipe	02/03/16	9:05	G	S	1	16 oz Plastic	X							5		
TITO12-WSTAVE-WOODW8CH-003	Wood characterization section West 8 bottom of pipe	02/03/16	8:25	G	CP	1	16 oz Plastic	X							5		
TITO12-WSTAVE-CNCRTE1CH-004	Concrete slurry chracterization section East 1 inside pipe	02/03/16	8:00	G	CP	1	16 oz Plastic	X							5		
TITO12-WSTAVE-CH-SED005	Sediment Section East 1 inside bottom of pipe	02/02/16	13:30	G	S	1	16 oz Plastic	X							5		
TITO12-WSTAVE-WOODE1CH-006	Wood characterization section East 1 bottom of pipe	02/03/16	8:17	G	CP	1	16 oz Plastic	X							5		

Analyses Requested

160-16018 Chain of Custody

Special Instructions: 7 days ingrown draft and follow with 21 days final

Standard TAT ☐ ☐ 24-hr ☐ 48-hr ☐ 3-day ☐ 7-day

Level Of QC Required: I II III Project Specific:

Relinquished By: Bryon Rogers Date: 2/4/2016 Time: 1200
Received By: C McB Date: 020516 Time: 0830
Relinquished By: Date: Time:
Received By: Date: Time:

Method Codes
C = Composite G = Grab

Matrix Codes
DW = Drinking Water SO =Soil
GW = Ground Water SL = Sludge
WW = Waste Water CP = Chip Samples
A = Air ABS=Asbestos, PO=Pipe Openning

Login Sample Receipt Checklist

Client: CB&I Environmental & Infrastructure, Inc

Job Number: 160-16018-2

Login Number: 16018
List Number: 1
Creator: Daniels, Brian J

List Source: TestAmerica St. Louis

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	N/A	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	N/A	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Definitions/Glossary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Qualifiers

Rad

Qualifier	Qualifier Description
U	Undetected at the Limit of Detection.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains no Free Liquid
DER	Duplicate error ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision level concentration
MDA	Minimum detectable activity
EDL	Estimated Detection Limit
MDC	Minimum detectable concentration
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative error ratio
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Method Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Method	Method Description	Protocol	Laboratory
GA-01-R	Radium-226 & Other Gamma Emitters (GS)	DOE	TAL SL

Protocol References:

DOE = U.S. Department of Energy

Laboratory References:

TAL SL = TestAmerica St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Sample Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
160-16018-1	TITO12-WSTAVE-CNCRTW8CH-001	Solid	02/03/16 08:10	02/05/16 08:30
160-16018-2	TITO12-WSTAVE-W8CH-S002	Solid	02/03/16 09:05	02/05/16 08:30
160-16018-3	TITO12-WSTAVE-WOODW8CH-003	Solid	02/03/16 08:25	02/05/16 08:30
160-16018-4	TITO12-WSTAVE-CNCRTE1CH-004	Solid	02/03/16 08:00	02/05/16 08:30
160-16018-5	TITO12-WSTAVE-CH-SED005	Solid	02/03/16 13:30	02/05/16 08:30
160-16018-6	TITO12-WSTAVE-WOODE1CH-006	Solid	02/03/16 08:17	02/05/16 08:30

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Client Sample ID: TITO12-WSTAVE-CNCRTW8CH-001

Lab Sample ID: 160-16018-1
Date Collected: 02/03/16 08:10
Matrix: Solid
Date Received: 02/05/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.249	U	0.108	0.111		0.251	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Actinium-227	0.0551	U	0.323	0.324		0.577	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Bismuth-212	0.288	U	0.479	0.479		0.815	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Bismuth-214	**0.375**		0.0960	0.104		0.0462	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Cesium-137	0.00527	U	0.0352	0.0352		0.0660	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Lead-210	0.0537	U	0.809	0.809		1.57	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Lead-212	**0.275**		0.0778	0.0856		0.0833	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Lead-214	**0.364**		0.0960	0.103		0.0912	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Potassium-40	**4.73**		1.10	1.20		0.612	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Protactinium-231	-0.224	U	0.838	0.838		1.48	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Radium-226	**0.375**		0.0960	0.104	0.500	0.0462	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Radium-228	0.249	U	0.108	0.111		0.251	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Thallium-208	**0.142**		0.0538	0.0558		0.0420	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Thorium-228	**0.275**		0.0778	0.0856		0.0833	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Thorium-232	0.249	U	0.108	0.111		0.251	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Thorium-234	0.358	U	0.310	0.313		1.15	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Uranium-235	0.125	U	0.146	0.147		0.179	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Uranium-238	0.358	U	0.310	0.313		1.15	pCi/g	02/12/16 08:34	03/04/16 06:02	1

Client Sample ID: TITO12-WSTAVE-W8CH-S002

Lab Sample ID: 160-16018-2
Date Collected: 02/03/16 09:05
Matrix: Solid
Date Received: 02/05/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.331**		0.136	0.140		0.186	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Actinium-227	0.0427	U	0.254	0.254		0.456	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Bismuth-212	0.295	U	0.407	0.408		0.676	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Bismuth-214	**0.371**		0.0930	0.101		0.0878	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Cesium-137	-0.00167	U	0.0346	0.0346		0.0637	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Lead-210	0.685	U	0.744	0.748		1.21	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Lead-212	**0.353**		0.0858	0.0972		0.0904	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Lead-214	**0.412**		0.104	0.112		0.101	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Potassium-40	**10.6**		1.31	1.70		0.633	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Protactinium-231	0.0602	U	0.134	0.134		1.63	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Radium-226	**0.371**		0.0930	0.101	0.500	0.0878	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Radium-228	**0.331**		0.136	0.140		0.186	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Thallium-208	**0.180**		0.0418	0.0458		0.0179	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Thorium-228	**0.353**		0.0858	0.0972		0.0904	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Thorium-232	**0.331**		0.136	0.140		0.186	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Thorium-234	0.608	U	0.901	0.903		1.50	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Uranium-235	0.119	U	0.157	0.157		0.295	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Uranium-238	0.608	U	0.901	0.903		1.50	pCi/g	02/12/16 08:34	03/04/16 05:58	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Client Sample ID: TITO12-WSTAVE-WOODW8CH-003

Lab Sample ID: 160-16018-3
Date Collected: 02/03/16 08:25
Matrix: Solid
Date Received: 02/05/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium-227	0.108	U	0.519	0.519		2.49	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Actinium 228	0.196	U	0.282	0.283		1.01	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Bismuth-212	0.245	U	2.10	2.10		3.85	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Bismuth-214	-0.0713	U	0.712	0.712		0.460	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Lead-210	1.85	U	3.87	3.87		6.97	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Lead-212	0.258	U	0.192	0.195		0.285	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Lead-214	0.0398	U	0.207	0.207		0.428	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Potassium-40	0.389	U	1.52	1.53		3.31	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Protactinium-231	-0.486	U	2.96	2.97		5.39	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Radium-226	-0.0713	U	0.712	0.712	0.500	0.460	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Radium-228	0.196	U	0.282	0.283		1.01	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Thorium-232	0.196	U	0.282	0.283		1.01	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Thorium-234	-1.74	U	6.59	6.59		5.84	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Thallium-208	-0.00281	U	0.112	0.112		0.229	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Uranium-235	0.322	U	0.544	0.545		0.922	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Uranium-238	-1.74	U	6.59	6.59		5.84	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Cesium-137	0.0313	U	0.127	0.127		0.235	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Thorium-228	0.258	U	0.192	0.195		0.285	pCi/g	02/12/16 12:18	03/04/16 05:58	1

Client Sample ID: TITO12-WSTAVE-CNCRTE1CH-004

Lab Sample ID: 160-16018-4
Date Collected: 02/03/16 08:00
Matrix: Solid
Date Received: 02/05/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.219	U	0.138	0.140		0.277	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Actinium-227	-0.0442	U	0.0888	0.0889		0.829	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Bismuth-212	0.393	U	0.408	0.410		0.624	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Bismuth-214	**0.280**		0.126	0.130		0.140	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Cesium-137	0.0179	U	0.0418	0.0418		0.0738	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Lead-210	-0.186	U	1.39	1.39		1.83	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Lead-212	**0.261**		0.0863	0.0927		0.0979	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Lead-214	**0.268**		0.0949	0.0989		0.137	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Potassium-40	**4.16**		1.12	1.20		1.07	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Protactinium-231	0.0456	U	0.375	0.375		1.49	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Radium-226	**0.280**		0.126	0.130	0.500	0.140	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Radium-228	0.219	U	0.138	0.140		0.277	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Thallium-208	0.0229	U	0.0480	0.0481		0.0762	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Thorium-228	**0.261**		0.0863	0.0927		0.0979	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Thorium-232	0.219	U	0.138	0.140		0.277	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Thorium-234	0.114	U	0.445	0.445		1.64	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Uranium-235	0.0515	U	0.114	0.115		0.349	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Uranium-238	0.114	U	0.445	0.445		1.64	pCi/g	02/12/16 08:34	03/04/16 05:55	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Client Sample ID: TITO12-WSTAVE-CH-SED005

Lab Sample ID: 160-16018-5
Date Collected: 02/03/16 13:30
Matrix: Solid
Date Received: 02/05/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.275**		0.146	0.149		0.204	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Actinium-227	0.0941	U	0.161	0.161		0.808	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Bismuth-212	0.352	U	0.510	0.511		0.851	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Bismuth-214	**0.365**		0.0998	0.107		0.103	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Cesium-137	-0.00756	U	0.0410	0.0410		0.0740	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Lead-210	-0.118	U	1.31	1.31		2.18	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Lead-212	**0.316**		0.113	0.120		0.132	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Lead-214	**0.517**		0.109	0.122		0.141	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Potassium-40	**7.53**		1.28	1.50		1.17	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Protactinium-231	0.326	U	0.916	0.917		1.59	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Radium-226	**0.365**		0.0998	0.107	0.500	0.103	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Radium-228	**0.275**		0.146	0.149		0.204	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Thallium-208	**0.181**		0.0639	0.0667		0.0642	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Thorium-228	**0.316**		0.113	0.120		0.132	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Thorium-232	**0.275**		0.146	0.149		0.204	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Thorium-234	0.802	U	0.443	0.451		1.45	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Uranium-235	0.0694	U	0.143	0.143		0.424	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Uranium-238	0.802	U	0.443	0.451		1.45	pCi/g	02/12/16 08:34	03/04/16 05:56	1

Client Sample ID: TITO12-WSTAVE-WOODE1CH-006

Lab Sample ID: 160-16018-6
Date Collected: 02/03/16 08:17
Matrix: Solid
Date Received: 02/05/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium-227	-0.00172	U	0.990	0.990		1.84	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Actinium 228	0.314	U	0.302	0.304		0.592	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Bismuth-212	0.388	U	1.40	1.40		2.62	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Bismuth-214	**0.484**		0.241	0.246		0.295	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Lead-210	0.164	U	2.24	2.24		4.67	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Lead-212	0.0217	U	0.146	0.146		0.287	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Lead-214	**0.391**		0.191	0.195		0.234	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Potassium-40	0.0849	U	1.54	1.54		3.45	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Protactinium-231	-0.586	U	2.49	2.49		4.54	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Radium-226	**0.484**		0.241	0.246	0.500	0.295	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Radium-228	0.314	U	0.302	0.304		0.592	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Thorium-232	0.314	U	0.302	0.304		0.592	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Thorium-234	-0.149	U	0.356	0.356		3.67	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Thallium-208	0.0378	U	0.115	0.115		0.201	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Uranium-235	0.0581	U	0.396	0.396		0.762	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Uranium-238	-0.149	U	0.356	0.356		3.67	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Cesium-137	-0.0158	U	0.172	0.172		0.253	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Thorium-228	0.0217	U	0.146	0.146		0.287	pCi/g	02/12/16 12:18	03/04/16 07:40	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Lab Sample ID: MB 160-236499/1-A
Matrix: Solid
Analysis Batch: 239242

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 236499

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	-0.06512	U	2.60	2.60		0.300	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Actinium-227	0.07114	U	0.120	0.120		0.878	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Bismuth-212	-0.09688	U	1.56	1.56		0.945	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Bismuth-214	-0.04155	U	0.317	0.317		0.178	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Lead-210	0.1172	U	0.784	0.784		1.65	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Lead-212	-0.03079	U	0.238	0.238		0.109	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Lead-214	-0.03970	U	1.59	1.59		0.183	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Potassium-40	-0.2212	U	1.05	1.05		1.27	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Protactinium-231	0.01604	U	0.704	0.704		1.34	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Radium-226	-0.04155	U	0.317	0.317	0.500	0.178	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Radium-228	-0.06512	U	2.60	2.60		0.300	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Thallium-208	0.006394	U	0.0368	0.0368		0.0610	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Thorium-232	-0.06512	U	2.60	2.60		0.300	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Cesium-137	0.01374	U	0.0355	0.0355		0.0640	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Thorium-234	-0.6046	U	2.21	2.22		1.46	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Uranium-235	0.05094	U	0.100	0.100		0.353	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Thorium-228	-0.03079	U	0.238	0.238		0.109	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Uranium-238	-0.6046	U	2.21	2.22		1.46	pCi/g	02/12/16 08:34	03/04/16 06:01	1

Lab Sample ID: LCS 160-236499/2-A
Matrix: Solid
Analysis Batch: 239244

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 236499

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	%Rec	%Rec. Limits
Americium-241	97.2	100.1		10.5		1.24	pCi/g	103	87 - 116
Cesium-137	29.8	30.05		3.24		0.321	pCi/g	101	87 - 120
Cobalt-60	17.7	17.84		1.87		0.117	pCi/g	101	87 - 115

Lab Sample ID: 160-16018-1 DU
Matrix: Solid
Analysis Batch: 239242

Client Sample ID: TITO12-WSTAVE-CNCRTW8CH-001
Prep Type: Total/NA
Prep Batch: 236499

Analyte	Sample Result	Sample Qual	DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	RER	RER Limit
Actinium 228	0.249	U	0.2635		0.140		0.226	pCi/g	0.06	1
Actinium-227	0.0551	U	0.1980	U	0.382		0.650	pCi/g	0.20	1
Bismuth-212	0.288	U	0.04349	U	0.556		1.06	pCi/g	0.24	1
Bismuth-214	0.375		0.4768		0.140		0.124	pCi/g	0.42	1
Lead-210	0.0537	U	0.3025	U	1.02		1.92	pCi/g	0.14	1
Lead-212	0.275		0.2789		0.106		0.116	pCi/g	0.02	1
Lead-214	0.364		0.4303		0.126		0.125	pCi/g	0.29	1
Potassium-40	4.73		6.044		1.34		0.954	pCi/g	0.52	1
Protactinium-231	-0.224	U	0.2411	U	0.568		1.44	pCi/g	0.33	1
Radium-226	0.375		0.4768		0.140	0.500	0.124	pCi/g	0.42	1
Radium-228	0.249	U	0.2635		0.140		0.226	pCi/g	0.06	1
Thallium-208	0.142		0.1613		0.0490		0.0245	pCi/g	0.19	1

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS) (Continued)

Lab Sample ID: 160-16018-1 DU
Matrix: Solid
Analysis Batch: 239242

Client Sample ID: TITO12-WSTAVE-CNCRTW8CH-001
Prep Type: Total/NA
Prep Batch: 236499

Analyte	Sample Result	Sample Qual		DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit			RER	RER Limit
Thorium-232	0.249	U		0.2635		0.140		0.226	pCi/g			0.06	1
Cesium-137	0.00527	U		0.003734	U	0.0350		0.0662	pCi/g			0.02	1
Thorium-234	0.358	U		0.2772	U	0.477		1.46	pCi/g			0.10	1
Uranium-235	0.125	U		0.03806	U	0.124		0.282	pCi/g			0.32	1
Thorium-228	0.275			0.2789		0.106		0.116	pCi/g			0.02	1
Uranium-238	0.358	U		0.2772	U	0.477		1.46	pCi/g			0.10	1

QC Association Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Rad

Leach Batch: 236344

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-16018-1	TITO12-WSTAVE-CNCRTW8CH-001	Total/NA	Solid	Dry and Grind	
160-16018-1 DU	TITO12-WSTAVE-CNCRTW8CH-001	Total/NA	Solid	Dry and Grind	
160-16018-2	TITO12-WSTAVE-W8CH-S002	Total/NA	Solid	Dry and Grind	
160-16018-4	TITO12-WSTAVE-CNCRTE1CH-004	Total/NA	Solid	Dry and Grind	
160-16018-5	TITO12-WSTAVE-CH-SED005	Total/NA	Solid	Dry and Grind	

Prep Batch: 236499

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-16018-1	TITO12-WSTAVE-CNCRTW8CH-001	Total/NA	Solid	Fill_Geo-21	236344
160-16018-1 DU	TITO12-WSTAVE-CNCRTW8CH-001	Total/NA	Solid	Fill_Geo-21	236344
160-16018-2	TITO12-WSTAVE-W8CH-S002	Total/NA	Solid	Fill_Geo-21	236344
160-16018-3	TITO12-WSTAVE-WOODW8CH-003	Total/NA	Solid	Fill_Geo-21	
160-16018-4	TITO12-WSTAVE-CNCRTE1CH-004	Total/NA	Solid	Fill_Geo-21	236344
160-16018-5	TITO12-WSTAVE-CH-SED005	Total/NA	Solid	Fill_Geo-21	236344
160-16018-6	TITO12-WSTAVE-WOODE1CH-006	Total/NA	Solid	Fill_Geo-21	
LCS 160-236499/2-A	Lab Control Sample	Total/NA	Solid	Fill_Geo-21	
MB 160-236499/1-A	Method Blank	Total/NA	Solid	Fill_Geo-21	

CB&I Federal Services, LLC

RADIOLOGICAL SURVEY FORM

Survey Number: **TIRS- 01152016 WSP SUR 011**

Survey Description: Wood stave - Contamination survey performed on five pieces of the wood stave from West.
Survey includes 100% scan on all accessible areas, a static at the highest scan location, and a smear at the static location.

All smear results were less than MDA.
All statics less than Release Limits.

RWP: 2016 WSP JS 01 0

Start Date: **01/15/2016** Time: **1430** End Date: **1/18/2016** Time: **1100**

Surveyor
(Name) Antonio Neotti
(Signature)
Date: 1/22/16

Smear Counter (Inst. #1)			α	β/γ
Model:	3030	4 π Efficiency:	32.5%	32.6%
Serial #:	224340	Bkgd (lab) CPM:	0.3	32.7
Probe #:	N/A	MDA (dpm/100cm²):	17	91
Cal. Due:	4/21/2016	Count Time(min):	1	

Survey Meter (Inst. #2)			α	β/γ
Model:	2360/43-93	2 π Efficiency:	42.60%	30.77%
Serial #:	268506	Bkgd (lab) CPM:	0.2	118.7
Probe / #:	PR286559	MDA (dpm/100cm²):	28	243
Cal. Due:	9/28/2016	Count Time(min):	2	
Probe Area(cm²):	100	Area Bkg (count):	1	203
Surface Efficiency:	α: 0.25 β: 0.50	Sat/Unsat:	sat	

Survey Meter (Inst. #3)		**Exposure Rate Meter (Inst. #4)**	
Model:		Model:	
Serial #:		Serial #:	
Cal. Due:		Cal. Due:	
Ref Area BKG(Scan):		Bkgd (lab):	
Ref Area IL(Scan):		Area Bkgd:	
Site:		Sat/Unsat:	

Survey Location	Removable Contamination Inst. #1				Total Contamination Inst. #2				Gamma Inst.# 3		Exposure Rate Inst. #4		Comments
	Count per smear		dpm/100 cm²		Counts		dpm/100 cm²		*Gross*	*< or ≥*	μR/hr		
	α	β/γ	α	β/γ	α	β/γ	α	β/γ	cpm	IL	Contact Gross	1 m Gross	
1	1	35	<MDA	<MDA	0	246	<MDA	<MDA					See map
2	0	27	<MDA	<MDA	2	215	<MDA	<MDA					See map
3	0	36	<MDA	<MDA	2	201	<MDA	<MDA					See map
4	0	32	<MDA	<MDA	1	261	<MDA	<MDA					See map
5	0	27	<MDA	<MDA	1	227	<MDA	<MDA					See map

Approved By: Takeshi Ibuki — *Print Name*
Signature
RE — *Title*
1/22/2016 — *Date*

FRM-TI-01-1

Surveyor

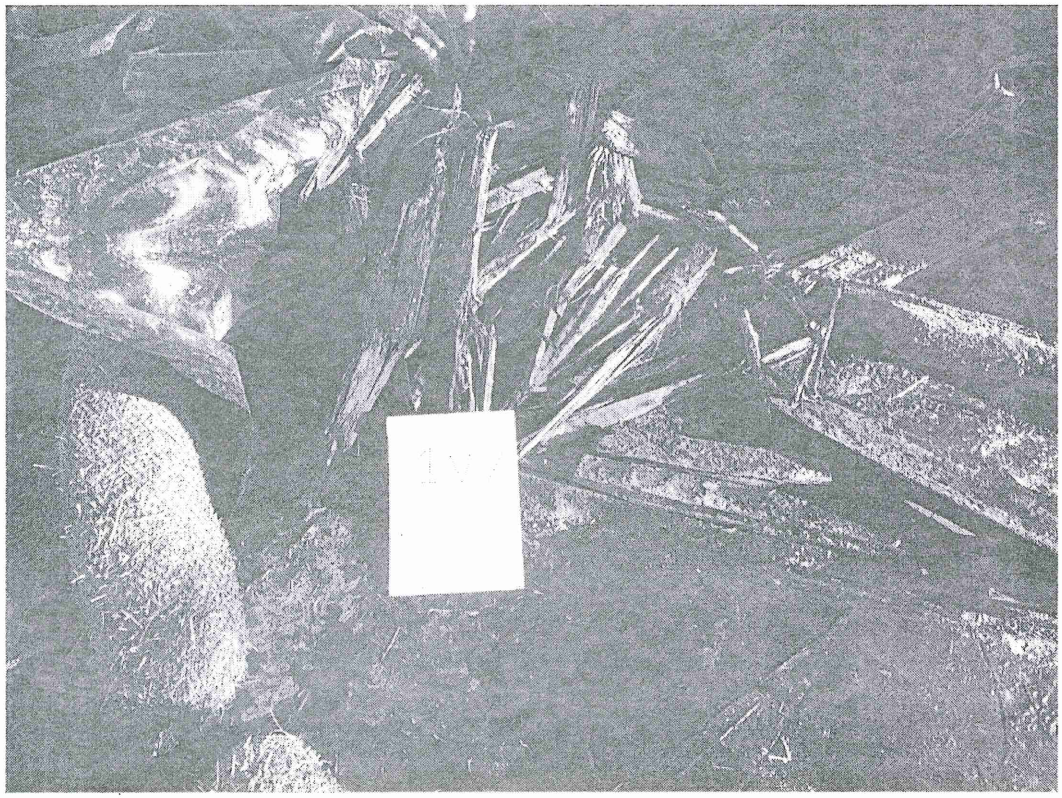
(Printed Name) Antonio Neotti

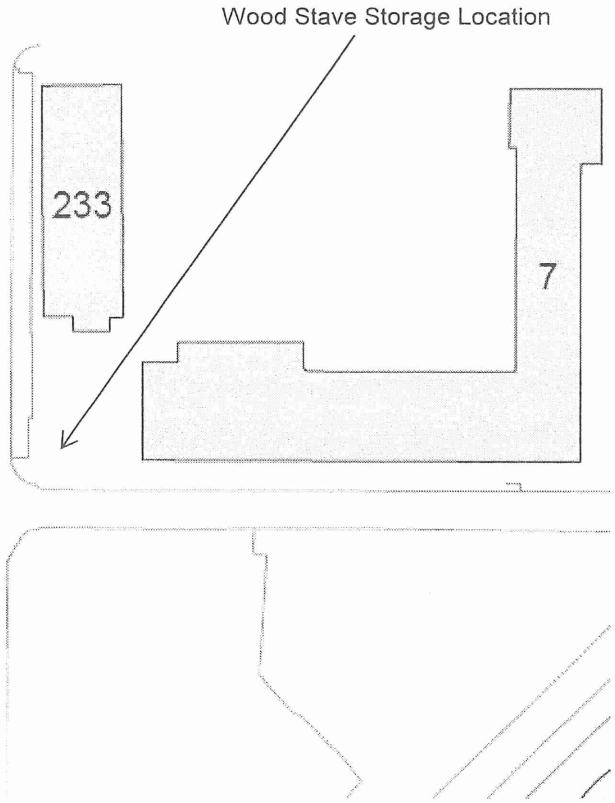
(Signature)

Date: 1/22/16

Survey Number:

TIRS- 01152016 WSP SUR 011





Legend

○ Smear Location	□ *Exposure Rate microR/hr
☆ Static Location	△ Soil Sample Location

Ludlum Measurements,Inc.
Model 3030 Sample Data

1/18/2016
10:30:45 AM

Header 1: 3030 S/N:224340
Header 2: Wood Stove Section 1
Header 3: RCT: A Neotti
Header 4: WSP-JSS-011
Calibration Due Date: 3/24/2016

Sample #	Date	Time	Alpha Count	Beta Count	Count Time	Type	Comment
1	1/18/2016	10:23:13	1	35	1	S	
2	1/18/2016	10:25:24	0	27	1	S	
3	1/18/2016	10:26:55	0	36	1	S	
4	1/18/2016	10:29:31	0	32	1	S	
5	1/18/2016	10:33:09	0	27	1	S	

Header 1: 2360 S/N 268506
Header 2: WSP-JSS-011
Header 3: RCT:A.Neotti

Sample #	Date	Time		Alpha	Beta	S/R	Count Time	Location
BKG	1/15/2016	2:38:07	PM	1	203	S	2	
1	1/15/2016	2:41:01	PM	0	246	S	2	
2	1/15/2016	2:43:22	PM	2	215	S	2	
3	1/15/2016	2:45:37	PM	2	201	S	2	
4	1/15/2016	2:47:52	PM	1	261	S	2	
5	1/15/2016	2:50:10	PM	1	227	S	2	

Surveyor
(Printed Name) Antonio Neotti

(Signature) Date: 1/22/16

Survey Number: **TIRS- 01152016 WSP SUR 011**

RADIOLOGICAL SURVEY FORM

Survey Number: **TIRS- 01202016 WSP SUR 020**

Survey Description: Wood stave project - Contamination survey performed on two pieces of the wood stave from Section West 2. Survey includes 100% scan on all accessible areas, a static at the highest scan location, and a smear at the static location.

All results were less than MDA.

RWP: 2016 WSP JS 01 0

Start Date: **1/20/2016** Time: **1440** End Date: **1/20/2016** Time: **1500**

Surveyor

(Name) Antonio Neotti

(Signature) [signature] Date: 1/29/16

Smear Counter (Inst. #1)			α	β/γ
Model:	3030	4 π Efficiency:	32.9%	30.5%
Serial #:	265985	Bkgd (lab) CPM:	0.2	31.2
Probe #:	N/A	MDA (dpm/100cm²):	15	95
Cal. Due:	3/24/2016	Count Time(min):	1	

Survey Meter (Inst. #2)			α	β/γ
Model:	2360/43-93	2 π Efficiency:	42.60%	30.77%
Serial #:	268506	Bkgd (lab) CPM:	0.2	118.7
Probe / #:	PR286559	MDA (dpm/100cm²):	28	243
Cal. Due:	9/28/2016	Count Time(min):	2	
Probe Area(cm²):	100	Area Bkg (count):	1	226
Surface Efficiency:	α: 0.25 β: 0.50	Sat/Unsat:	sat	

Survey Meter (Inst. #3)		**Exposure Rate Meter (Inst. #4)**	
Model:		Model:	
Serial #:		Serial #:	
Cal. Due:		Cal. Due:	
Ref Area BKG(Scan):		Bkgd (lab):	
Ref Area IL(Scan):		Area Bkgd:	
Site:		Sat/Unsat:	

Survey Location	Removable Contamination Inst. #1				Total Contamination Inst. #2				Gamma Inst.# 3		Exposure Rate Inst. #4		Comments
	Count per smear		dpm/100 cm²		Counts		dpm/100 cm²		*Gross*	*< or ≥*	μR/hr		
	α	β/γ	α	β/γ	α	β/γ	α	β/γ	cpm	IL	Contact Gross	1 m Gross	
1	0	31	<MDA	<MDA	2	298	<MDA	<MDA					See map
2	0	34	<MDA	<MDA	0	256	<MDA	<MDA					See map

Approved By: Takeshi Ibuki — *Print Name* [signature] — *Signature* RE — *Title* 1/29/2016 — *Date*

FRM-TI-01-1

Surveyor

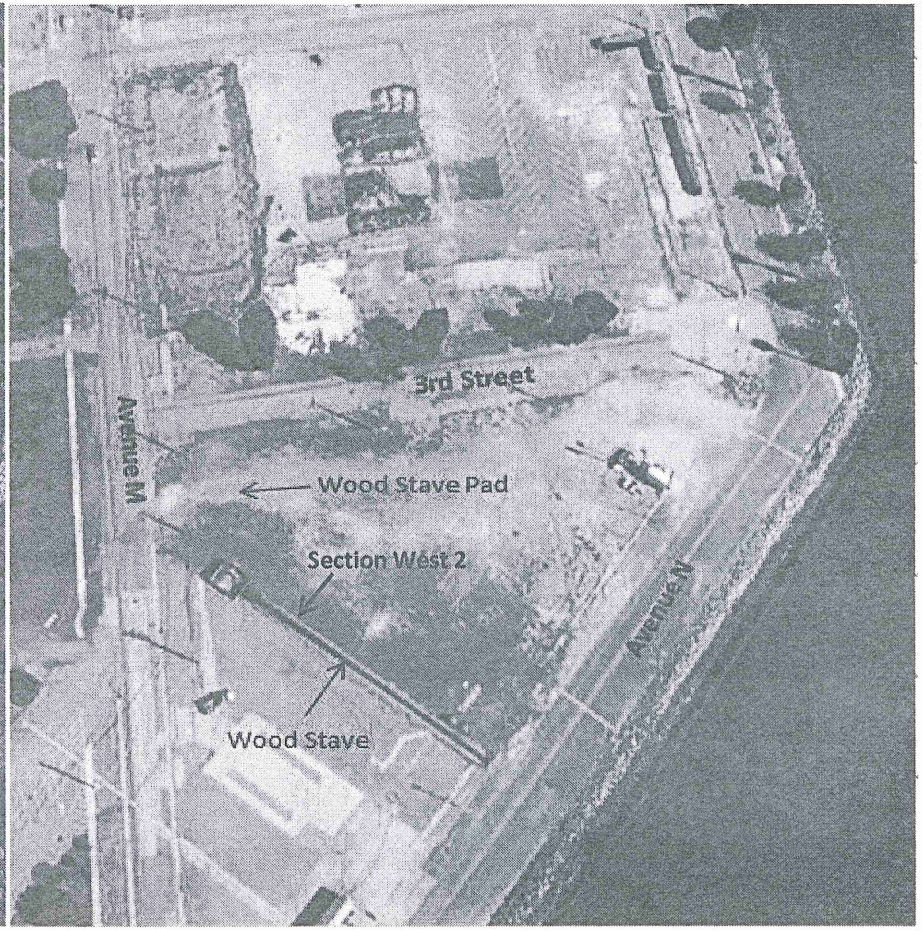
(Printed Name) Antonio Neotti

(Signature)

Survey Number:

TIRS- 01202016 WSP SUR 020

Date: 1/29/16



Legend

○ Smear Location	□ *Exposure Rate microR/hr
☆ Static Location	△ Soil Sample Location

Ludlum Measurements,Inc.
Model 3030 Sample Data

1/22/2016
2:39:23 PM

Header 1: 3030 S/N 265985
Header 2: WSP-SUR-020
Header 3: RCT:A.NEOTTI
Calibration Due Date: 3/24/2016

Sample #	Date	Time	Alpha Count	Beta Count	Count Time	Type	Comment
1	1/22/2016	14:41:01	0	31	1	S	
2	1/22/2016	14:42:10	0	34	1	S	

Header 1: 2360 S/N 268506
Header 2: WSP-SUR-020
Header 3: RCT:A.Neotti
S=Scaler, R=Ratemeter

Sample #	Date	Time		Alpha	Beta	S/R	Count Time	Location
BKG	1/20/2016	11:08:35	AM	1	226	S		2
1	1/20/2016	2:48:55	PM	2	298	S		2
2	1/20/2016	2:51:14	PM	0	256	S		2

Surveyor
(Printed Name) Antonio Neotti

(Signature) Date: 1/29/16

Survey Number: **TIRS- 01202016 WSP SUR 020**

CB&I Federal Services, LLC

RADIOLOGICAL SURVEY FORM

Survey Number: **TIRS- 01212016 WSP SUR 021**

Survey Description: Wood stave project - Contamination survey performed on five pieces of the wood stave from Section. West 3. Survey includes 100% scan on all accessible areas, a static at the highest scan location, and a smear at the static location.

Elevated total beta/gamma counts above MDA were identified; however, these activities are considerably below the Release Limit.

RWP: 2016 WSP JS 01 0

Start Date: **1/21/2016** Time: End Date: **1/22/2016** Time: **1300**

Surveyor

(Name) Antonio Neotti

(Signature)

Date: 1/29/16

Smear Counter (Inst. #1)			α	β/γ
Model:	3030	4 π Efficiency:	32.5%	32.6%
Serial #:	224340	Bkgd (lab) CPM:	0.3	32.7
Probe #:	N/A	MDA (dpm/100cm²):	17	91
Cal. Due:	4/21/2016	Count Time(min):	1	

Survey Meter (Inst. #2)			α	β/γ
Model:	2360/43-93	2 π Efficiency:	42.60%	30.77%
Serial #:	268506	Bkgd (lab) CPM:	0.2	118.7
Probe / #:	PR286559	MDA (dpm/100cm²):	28	243
Cal. Due:	9/28/2016	Count Time(min):	2	
Probe Area(cm²):	100	Area Bkg (count):	0	214
Surface Efficiency:	α: 0.25 β: 0.50	Sat/Unsat:	sat	

Survey Meter (Inst. #3)		**Exposure Rate Meter (Inst. #4)**	
Model:		Model:	
Serial #:		Serial #:	
Cal. Due:		Cal. Due:	
Ref Area BKG(Scan):		Bkgd (lab):	
Ref Area IL(Scan):		Area Bkgd:	
Site:		Sat/Unsat:	

Survey Location	Removable Contamination Inst. #1				Total Contamination Inst. #2				Gamma Inst.# 3		Exposure Rate Inst. #4		Comments
	Count per smear		dpm/100 cm²		Counts		dpm/100 cm²		*Gross*	*< or ≥*	μR/hr		
	α	β/γ	α	β/γ	α	β/γ	α	β/γ	cpm	IL	Contact Gross	1 m Gross	
1	0	33	<MDA	<MDA	4	301	<MDA	<MDA					See map
2	0	30	<MDA	<MDA	4	324	<MDA	281					See map
					4	299	<MDA	<MDA					Follow up
3	0	30	<MDA	<MDA	6	314	<MDA	249					See map
					1	300	<MDA	<MDA					Follow up
4	0	33	<MDA	<MDA	4	314	<MDA	249					See map
					6	315	<MDA	252					Follow up
5	0	30	<MDA	<MDA	4	272	<MDA	<MDA					See map

Approved By: Takeshi Ibuki — *Print Name*

Signature

RE — *Title*

1/29/2016 — *Date*

FRM-TI-01-1

Surveyor

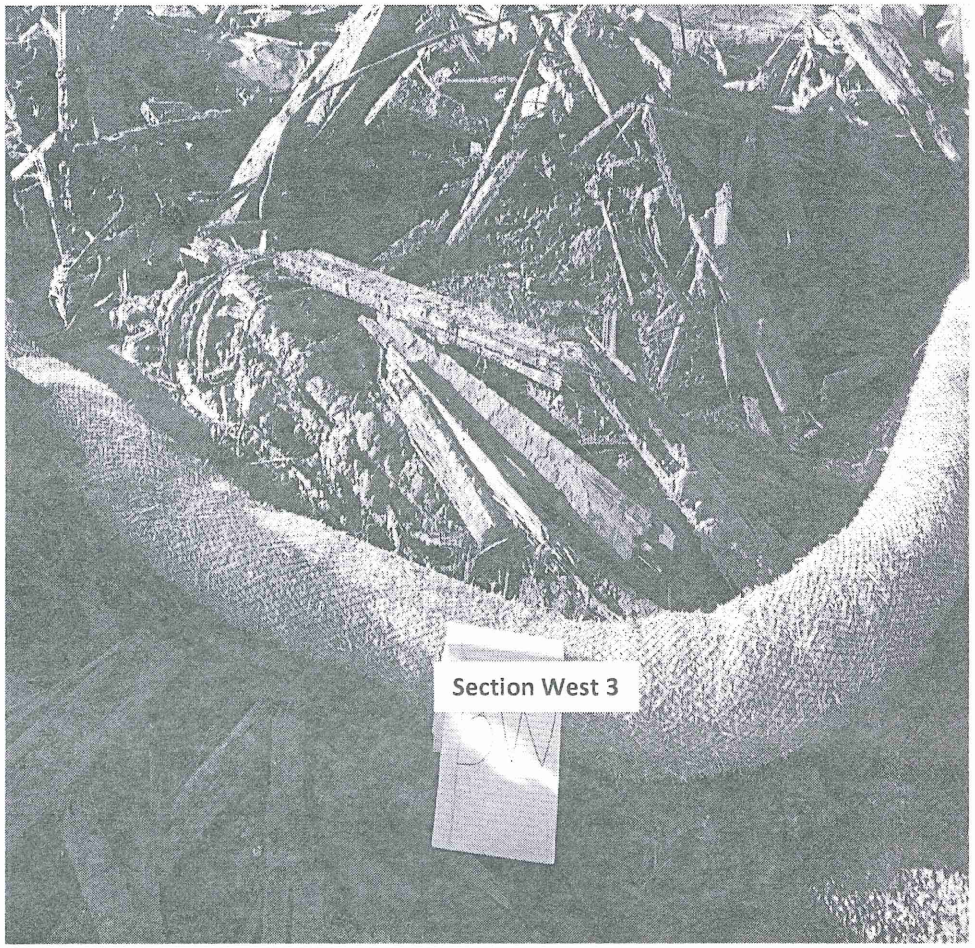
(Printed Name) Antonio Neotti

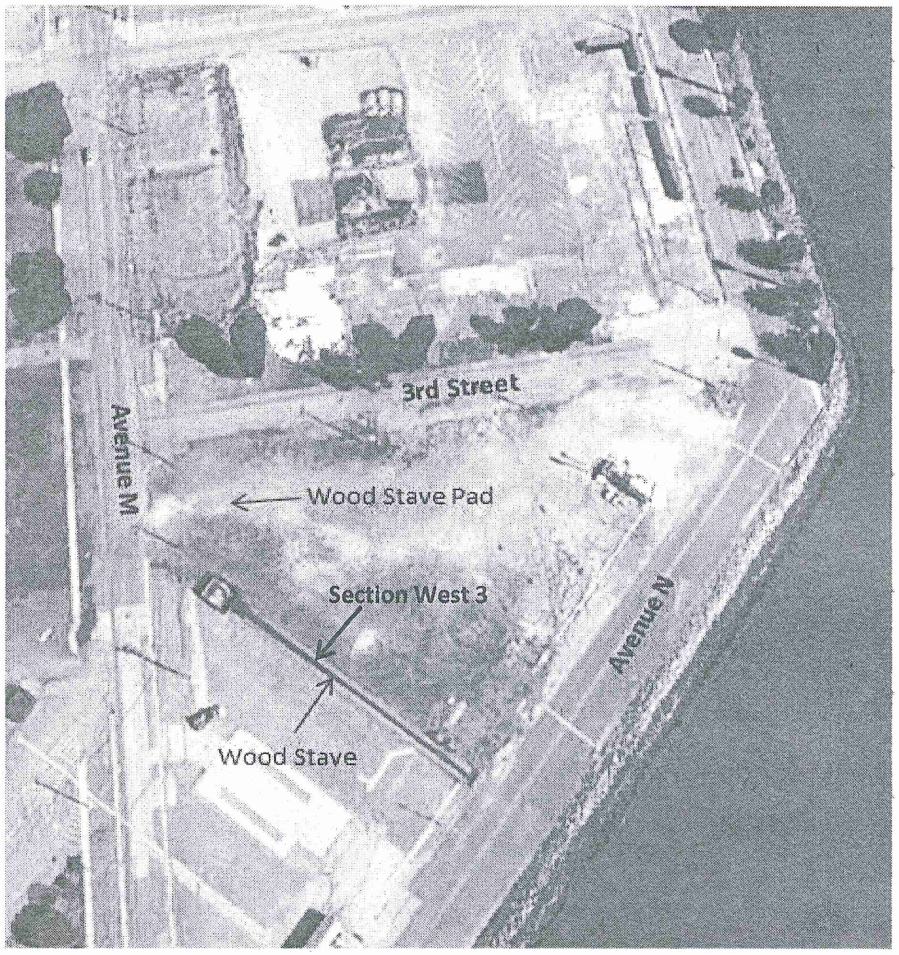
(Signature)

Date: 1/29/16

Survey Number:

TIRS- 01212016 WSP SUR 021





Legend

○ Smear Location	□ *Exposure Rate microR/hr
☆ Static Location	△ Soil Sample Location

Ludlum Measurements,Inc.
Model 3030 Sample Data

1/22/2016
12:45:44 PM

Header 1: 3030 S/N:224340
Header 2: WSP-SUR-021
Header 3: RCT:A.Neotti
Calibration Due Date: 3/24/2016

Sample #	Date	Time	Alpha Count	Beta Count	Count Time	Type	Comment
1	1/22/2016	12:48:03	0	33	1	S	
2	1/22/2016	12:49:18	0	30	1	S	
3	1/22/2016	12:50:30	0	30	1	S	
4	1/22/2016	12:51:40	0	33	1	S	
5	1/22/2016	12:53:05	0	30	1	S	

Header 1: 2360 S/N 268506
Header 2: WSP-SUR-020
Header 3: RCT:A.Neotti
S=Scaler, R=Ratemeter

Sample #	Date	Time		Alpha	Beta	S/R	Count Time	Location
BKG	1/21/2016	11:05:17	AM	0	214	S	2	
1	1/21/2016	2:30:26	PM	4	301	S	2	
2	1/21/2016	2:32:44	PM	4	324	S	2	
Follow up	1/21/2016	2:35:02	PM	4	299	S	2	
3	1/21/2016	2:37:22	PM	6	314	S	2	
Follow up	1/21/2016	2:39:40	PM	1	300	S	2	
4	1/21/2016	2:42:01	PM	4	314	S	2	
Follow up	1/21/2016	2:44:12	PM	6	315	S	2	
5	1/21/2016	2:46:28	PM	4	272	S	2	

Surveyor
(Printed Name) Antonio Neotti

(Signature)

Date: 1/29/16

Survey Number: **TIRS- 01212016 WSP SUR 021**

CB&I Federal Services, LLC

RADIOLOGICAL SURVEY FORM

Survey Number: **TIRS- 01252016 WSP SUR 028**

Survey Description: Wood stave project - Contamination survey performed on five pieces of the wood stave from Section West 4. Survey includes 100% scan on all accessible areas, a static at the highest scan location, and a smear at the static location.

Elevated total beta/gamma counts above MDA were identified; however, these activities are considerably below the Release Limit.

RWP: 2016 WSP JS 01 0

Start Date: **1/25/2016** Time: **1410** End Date: **1/27/2016** Time: **1100**

Surveyor

(Name) Antonio Neotti

(Signature)

Date: 2/2/2016

Smear Counter (Inst. #1)

			α	β/γ
Model:	3030	4 π Efficiency:	32.9%	30.5%
Serial #:	265985	Bkgd (lab) CPM:	0.2	31.2
Probe #:	N/A	MDA (dpm/100cm²):	15	95
Cal. Due:	3/24/2016	Count Time(min):	1	

Survey Meter (Inst. #2)

			α	β/γ
Model:	2360/43-93	2 π Efficiency:	42.60%	30.77%
Serial #:	268506	Bkgd (lab) CPM:	0.2	118.7
Probe / #:	PR286559	MDA (dpm/100cm²):	28	243
Cal. Due:	9/28/2016	Count Time(min):	2	
Probe Area(cm²):	100	Area Bkg (count):	1	209
Surface Efficiency:	α: 0.25 β: 0.50	Sat/Unsat:	sat	

Survey Meter (Inst. #3)

Model:
Serial #:
Cal. Due:
Ref Area BKG(Scan):
Ref Area IL(Scan):
Site:

Exposure Rate Meter (Inst. #4)

Model:
Serial #:
Cal. Due:
Bkgd (lab):
Area Bkgd:
Sat/Unsat:

Survey Location	Removable Contamination Inst. #1				Total Contamination Inst. #2				Gamma Inst.# 3		Exposure Rate Inst. #4		Comments
	Count per smear		dpm/100 cm²		Counts		dpm/100 cm²		Gross	< or ≥	μR/hr		
	α	β/γ	α	β/γ	α	β/γ	α	β/γ	cpm	IL	Contact Gross	1 m Gross	
1	0	27	<MDA	<MDA	1	374	<MDA	444					See Map
					2	339	<MDA	330					Follow up
2	0	36	<MDA	<MDA	2	285	<MDA	<MDA					See Map
3	0	34	<MDA	<MDA	2	360	<MDA	398					See Map
					0	340	<MDA	333					Follow up
4	0	29	<MDA	<MDA	3	336	<MDA	320					See Map
					4	348	<MDA	359					Follow up
5	0	37	<MDA	<MDA	0	352	<MDA	372					See Map
					0	380	<MDA	463					Follow up

Approved By: Takeshi Ibuki — *Print Name*

Signature

RE — *Title*

2/2/2016 — *Date*

FRM-TI-01-1

Surveyor

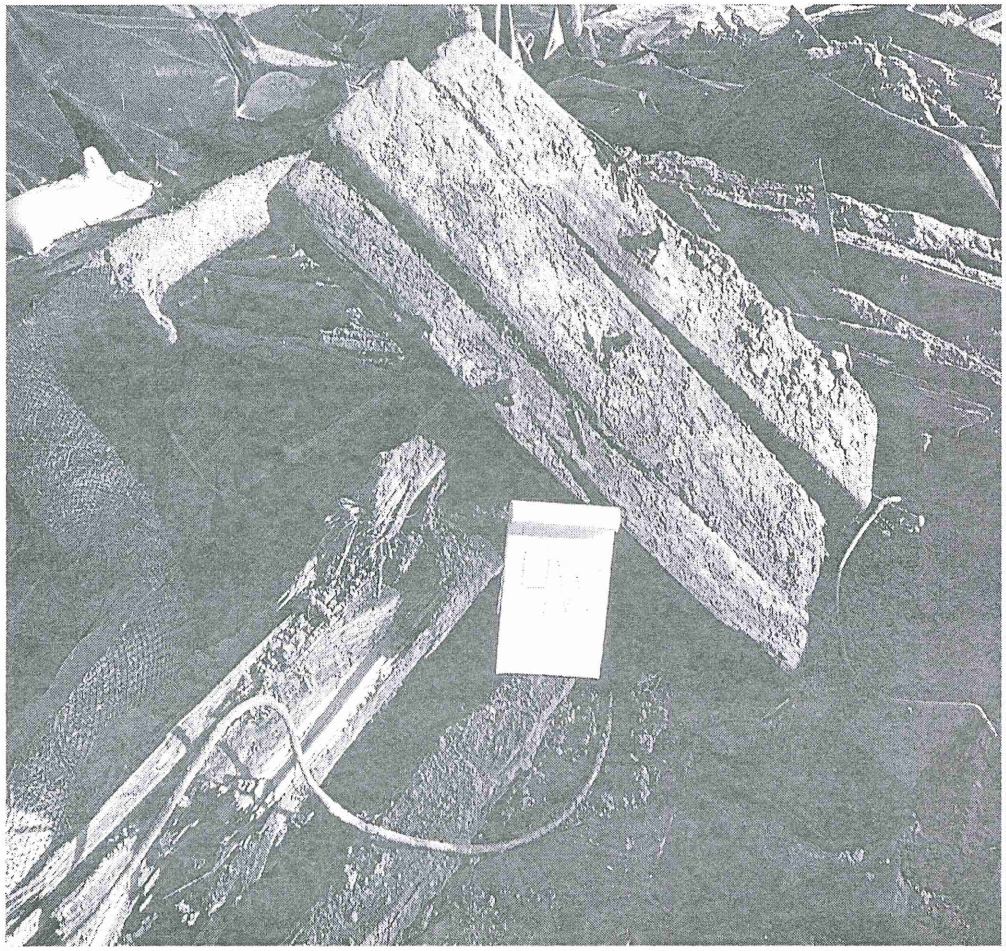
(Printed Name) Antonio Neotti

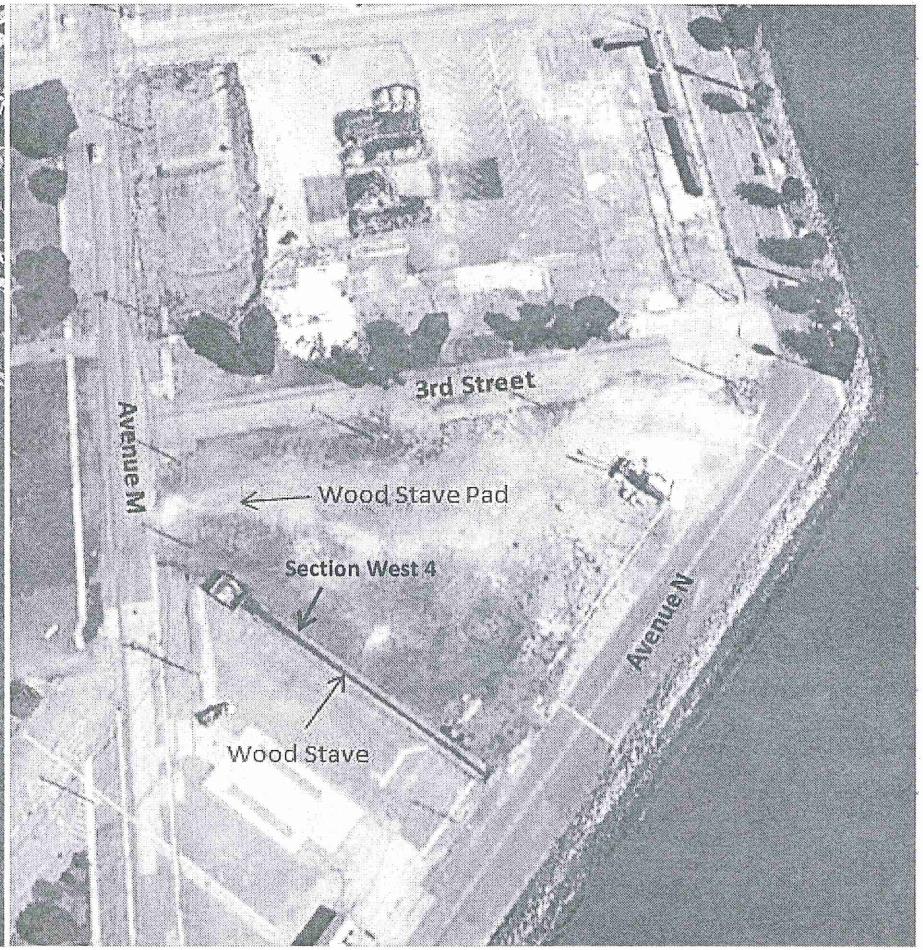
(Signature)

Survey Number:

TIRS- 01252016 WSP SUR 028

Date: 2/2/2016





Legend

Smear Location

*Exposure Rate microR/hr

Static Location

Soil Sample Location

Header 1: 3030 S/N 265985
Header 2: WSP-SUR-028
Header 3: RCT:A.NEOTTI
Calibration Due Date: 3/24/2016

Sample #	Date	Time	Alpha Count	Beta Count	Count Time	Type	Comment
1	1/27/2018	10:28:31	0	27	1	S	
2	1/27/2018	10:31:24	0	36	1	S	
3	1/27/2018	10:32:40	0	34	1	S	
4	1/27/2018	10:34:02	0	29	1	S	
5	1/27/2018	10:35:22	0	37	1	S	

Header 1: 2360 S/N 268506
Header 2: WSP-SUR-028
Header 3: RCT:A.NEOTTI
S=Scaler, R=Ratemeter

Sample #	Date	Time		Alpha	Beta	S/R	Count Time	Location
BKG	1/25/2016	10:19:33	AM	1	209	S	2	
1	1/25/2016	2:19:35	PM	1	374	S	2	
	1/25/2016	2:21:52	PM	2	339	S	2	
2	1/25/2016	2:24:18	PM	2	285	S	2	
3	1/25/2016	2:26:29	PM	2	360	S	2	
	1/25/2016	2:28:37	PM	0	340	S	2	
4	1/25/2016	2:30:56	PM	3	336	S	2	
	1/25/2016	2:33:18	PM	4	348	S	2	
5	1/25/2016	2:35:30	PM	0	352	S	2	
	1/25/2016	2:38:50	PM	0	360	S	2	

Surveyor
(Printed Name) Antonio Neotti

(Signature)

Date: 2/2/2016

Survey Number: **TIRS- 01252016 WSP SUR 028**

RADIOLOGICAL SURVEY FORM

Survey Number: **TIRS- 01252016 WSP SUR 029**

Survey Description: Wood stave project - Contamination survey performed on five pieces of the wood stave from Section West 5. Survey includes 100% scan on all accessible areas, a static at the highest scan location, and a smear at the static location.

Elevated total beta/gamma counts above MDA were identified; however, these activities are considerably below the Release Limit.

Smear Counter (Inst. #1)			α	β/γ
Model:	3030	4 π Efficiency:	32.5%	32.6%
Serial #:	224340	Bkgd (lab) CPM:	0.3	32.7
Probe #:	N/A	MDA (dpm/100cm²):	17	91
Cal. Due:	4/21/2016	Count Time(min):	1	

Survey Meter (Inst. #2)			α	β/γ
Model:	2360/43-93	2 π Efficiency:	42.60%	30.77%
Serial #:	268506	Bkgd (lab) CPM:	0.2	118.7
Probe / #:	PR286559	MDA (dpm/100cm²):	28	243
Cal. Due:	9/28/2016	Count Time(min):	2	
Probe Area(cm²):	100	Area Bkg (count):	1	209
Surface Efficiency:	α: 0.25 β: 0.50	Sat/Unsat:	sat	

Survey Meter (Inst. #3)		**Exposure Rate Meter (Inst. #4)**	
Model:		Model:	
Serial #:		Serial #:	
Cal. Due:		Cal. Due:	
Ref Area BKG(Scan):		Bkgd (lab):	
Ref Area IL(Scan):		Area Bkgd:	
Site:		Sat/Unsat:	

RWP: 2016 WSP JS 01 0

Start Date: **1/25/2016** Time: **1410** End Date: **1/27/2016** Time: **1100**

Surveyor

(Name) Antonio Neotti

(Signature)

Date: 2/2/2016

Survey Location	Removable Contamination Inst. #1				Total Contamination Inst. #2				Gamma Inst.# 3		Exposure Rate Inst. #4		Comments
	Count per smear		dpm/100 cm²		Counts		dpm/100 cm²		*Gross*	*< or ≥*	μR/hr		
	α	β/γ	α	β/γ	α	β/γ	α	β/γ	cpm	IL	Contact Gross	1 m Gross	
1	0	36	<MDA	<MDA	3	289	<MDA	<MDA					See Map
2	1	37	<MDA	<MDA	4	366	<MDA	418					See Map
					4	359	<MDA	395					Follo up
3	0	45	<MDA	<MDA	1	352	<MDA	372					See Map
					2	344	<MDA	346					Follo up
4	0	43	<MDA	<MDA	2	332	<MDA	307					See Map
					0	349	<MDA	363					Follo up
5	0	39	<MDA	<MDA	3	302	<MDA	<MDA					See Map

Approved By: Takeshi Ibuki — *Print Name*

Signature

RE — *Title*

2/2/2016 — *Date*

FRM-TI-01-1

Surveyor

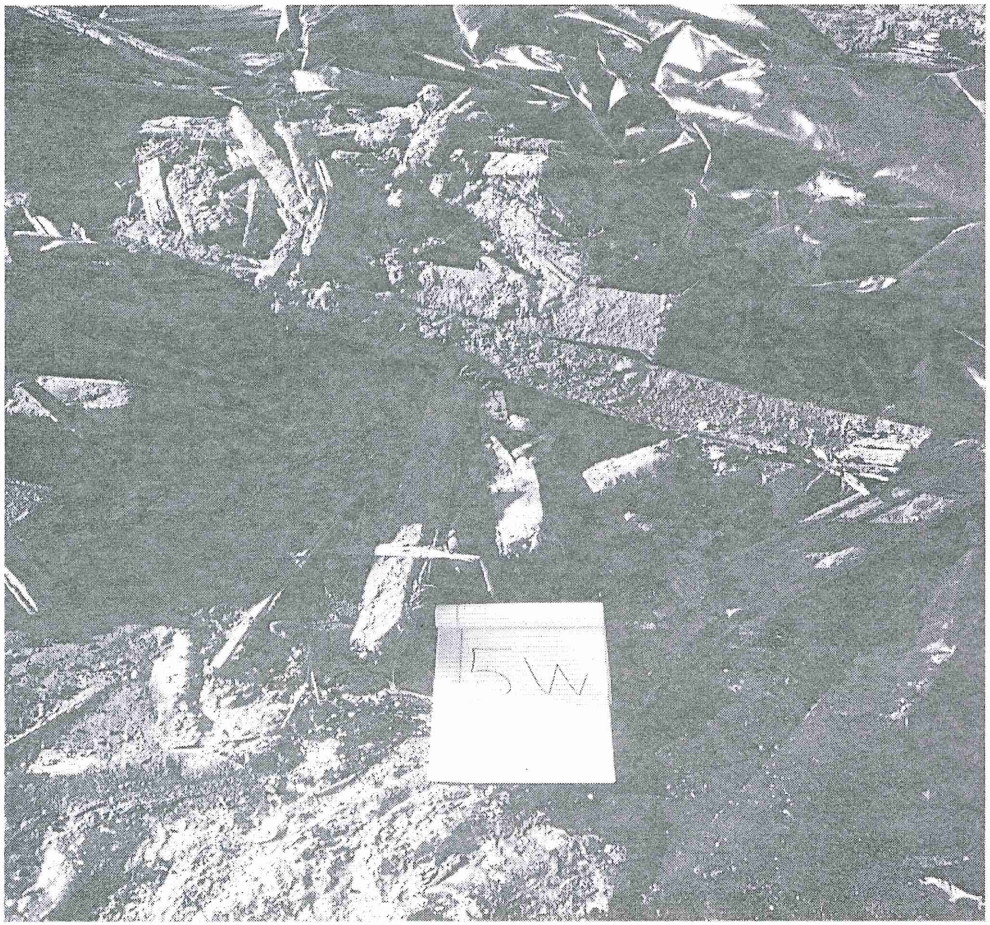
(Printed Name) Antonio Neotti

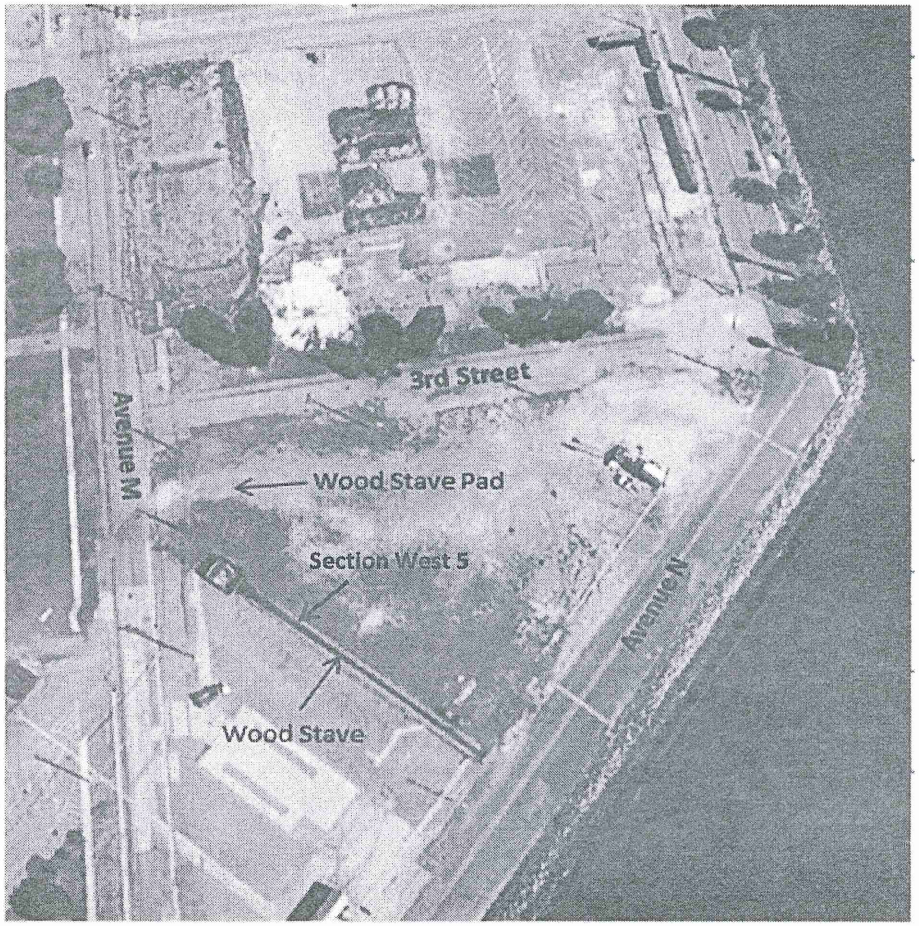
(Signature)

Date: 2/2/16

Survey Number:

TIRS- 01252016 WSP SUR 029





Legend

○ Smear Location	□ *Exposure Rate microR/hr
☆ Static Location	△ Soil Sample Location

Header 1: 3030 S/N:224340
Header 2: WSP-SUR-029
Header 3: RCT.A.NEOTTI
Calibration Due Date: 4/21/2016

Sample #	Date	Time	Alpha Count	Beta Count	Count Time	Type	Comment
1	1/27/2016	10:33:31	0	36	1	S	
2	1/27/2016	10:34:43	1	37	1	S	
3	1/27/2016	10:36:07	0	45	1	S	
4	1/27/2016	10:38:19	0	43	1	S	
5	1/27/2016	10:39:34	0	39	1	S	

Header 1: 2360 S/N 268506
Header 2: WSP-SUR-029
Header 3: RCT.A.NEOTTI
S=Scaler, R=Ratemeter

Sample #	Date	Time	Alpha	Beta	S/R	Count Time
BKG	1/25/2016	10:19:33 AM	1	209	S	2
1	1/25/2016	2:41:34 PM	3	289	S	2
2	1/25/2016	2:43:48 PM	4	366	S	2
Follow Up	1/25/2016	2:46:09 PM	4	359	S	2
3	1/25/2016	2:48:21 PM	1	352	S	2
Follow Up	1/25/2016	2:50:40 PM	2	344	S	2
4	1/25/2016	2:52:57 PM	2	332	S	2
Follow Up	1/25/2016	2:55:09 PM	0	349	S	2
5	1/25/2016	2:57:46 PM	3	302	S	2

Surveyor
(Printed Name) Antonio Neotti

(Signature)

Date: 2/2/2016

Survey Number: **TIRS- 01252016 WSP SUR 029**

CB&I Federal Services, LLC

RADIOLOGICAL SURVEY FORM

Survey Number: **TIRS- 01262016 WSP SUR 030**

Survey Description: Wood stave project - Contamination survey performed on five pieces of the wood stave from West 6. Survey includes 100% scan on all accessible areas, a static at the highest scan location, and a smear at the static location.

Elevated total beta/gamma count above MDA was identified at location 1; however, the activity is considerably below the Release Limit.

RWP: 2016 WSP JS 01 0

Start Date: **1/26/2016** Time: **1200** End Date: **1/26/2016** Time: **1750**

Surveyor

(Name) Antonio Neotti

(Signature)

Date: 2/2/16

Smear Counter (Inst. #1)

			α	β/γ
Model:	3030	4 π Efficiency:	32.5%	32.6%
Serial #:	224340	Bkgd (lab) CPM:	0.3	32.7
Probe #:	N/A	MDA (dpm/100cm²):	17	91
Cal. Due:	4/21/2016	Count Time(min):	1	

Survey Meter (Inst. #2)

			α	β/γ
Model:	2360/43-93	2 π Efficiency:	42.60%	30.77%
Serial #:	268506	Bkgd (lab) CPM:	0.2	118.7
Probe / #:	PR286559	MDA (dpm/100cm²):	28	243
Cal. Due:	9/28/2016	Count Time(min):	2	
Probe Area(cm²):	100	Area Bkg (count):	0	289
Surface Efficiency:	α: 0.25 β: 0.50	Sat/Unsat:	sat	

Survey Meter (Inst. #3)

Model:	
Serial #:	
Cal. Due:	
Ref Area BKG(Scan):	
Ref Area IL(Scan):	
Site:	

Exposure Rate Meter (Inst. #4)

Model:	
Serial #:	
Cal. Due:	
Bkgd (lab):	
Area Bkgd:	
Sat/Unsat:	

Survey Location	Removable Contamination Inst. #1				Total Contamination Inst. #2				Gamma Inst.# 3		Exposure Rate Inst. #4		Comments
	Count per smear		dpm/100 cm²		Counts		dpm/100 cm²		Gross	< or ≥	μR/hr		
	α	β/γ	α	β/γ	α	β/γ	α	β/γ	cpm	IL	Contact Gross	1 m Gross	
1	0	39	<MDA	<MDA	2	375	<MDA	447					See Map
					2	379	<MDA	460					Follow up
2	0	45	<MDA	<MDA	2	307	<MDA	<MDA					See Map
3	0	28	<MDA	<MDA	0	261	<MDA	<MDA					See Map
4	0	34	<MDA	<MDA	1	325	<MDA	285					See Map
					1	311	<MDA	<MDA					Follow up
5	0	34	<MDA	<MDA	2	282	<MDA	<MDA					See Map

Approved By: Takeshi Ibuki — *Print Name*

Signature

RE — *Title*

2/2/2016 — *Date*

FRM-TI-01-1

Surveyor

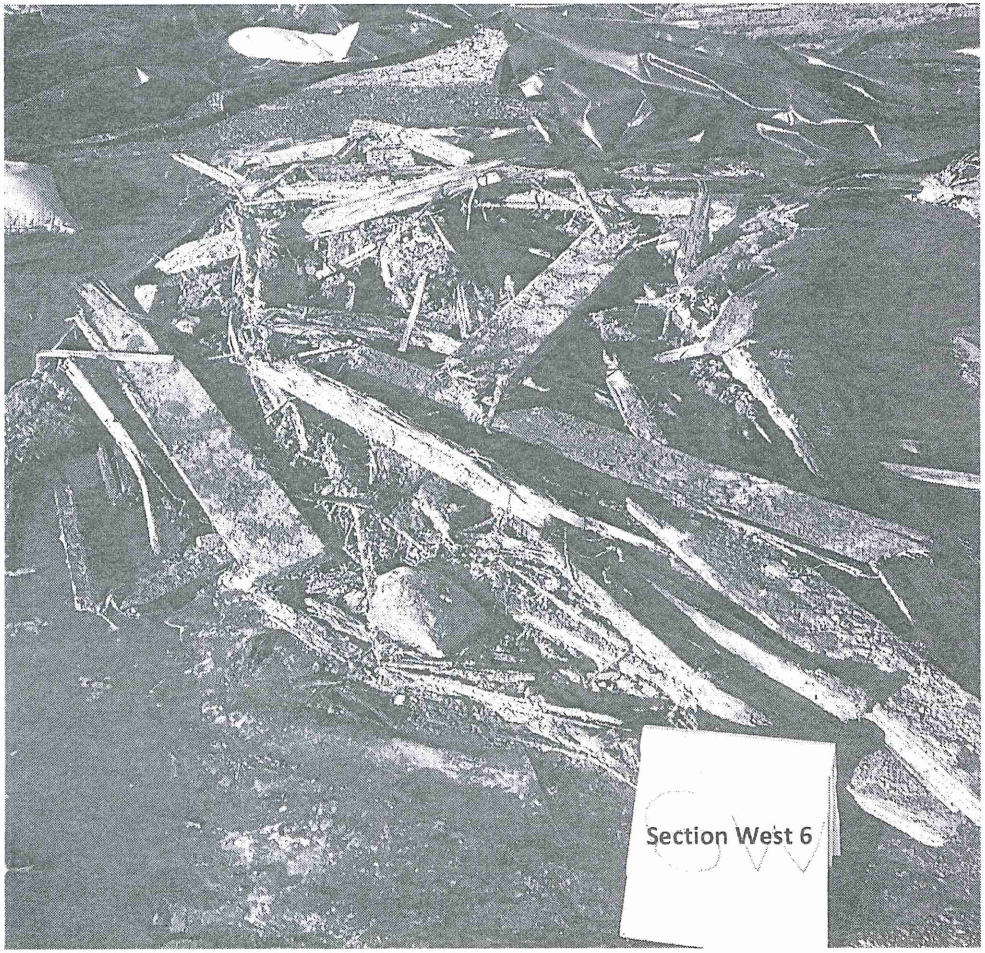
(Printed Name) Antonio Neotti

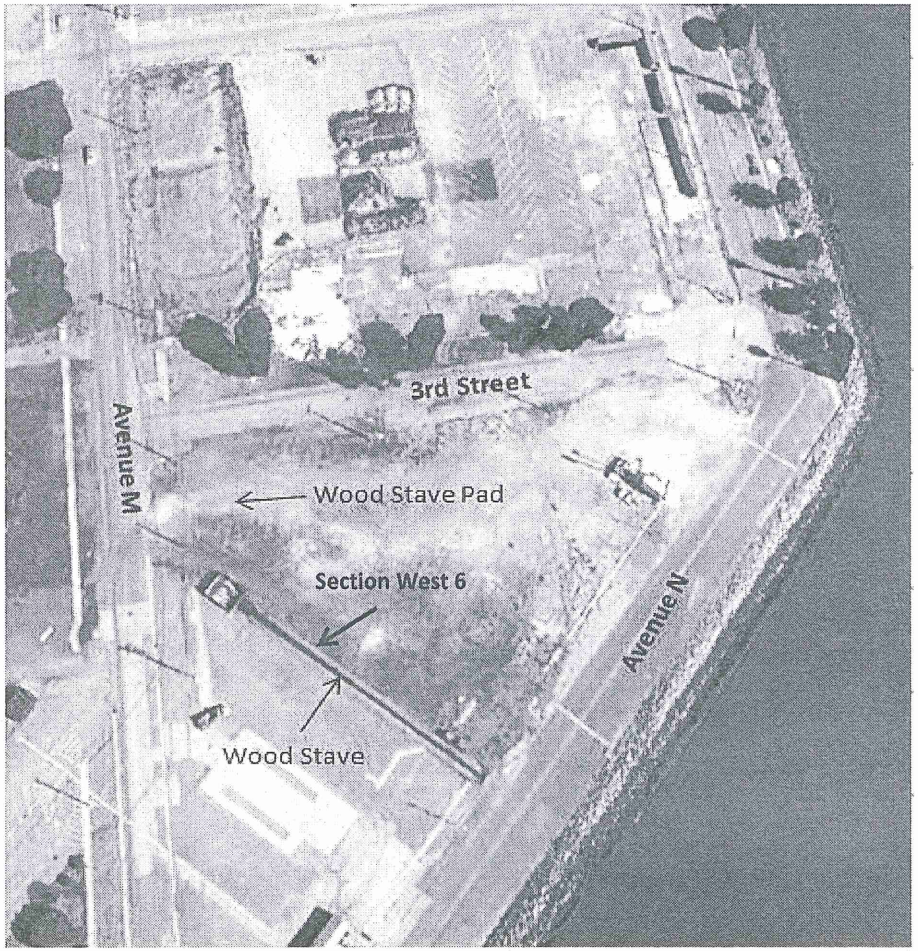
(Signature)

Date: 2/2/16

Survey Number:

TIRS- 01262016 WSP SUR 030





Legend

○ Smear Location	□ *Exposure Rate microR/hr
☆ Static Location	△ Soil Sample Location

Ludlum Measurements,Inc.
Model 3030 Sample Data

1/26/2016
5:32:11 PM

Header 1: 3030 S/N:224340
Header 2: WSP-SUR-030
Header 3: RCT.A.NEOTTI
Calibration Due Date: 4/21/2016

Sample #	Date	Time	Alpha Count	Beta Count	Count Time	Type
1	1/26/2016	17:32:09	0	39	1	S
2	1/26/2016	17:34:11	0	45	1	S
3	1/26/2016	17:36:38	0	28	1	S
4	1/26/2016	17:38:02	0	34	1	S
5	1/26/2016	17:39:35	0	34	1	S

Header 1: 2360 S/N 268506
Header 2: WSP-SUR-030
Header 3: RCT:A.NEOTTI
S=Scaler, R=Ratemeter

Sample #	Date	Time		Alpha	Beta	S/R	Count Time
BKG	1/26/2016	8:21:26	AM	0	289	S	2
1	1/26/2016	12:30:07	PM	2	375	S	2
Follow up	1/26/2016	12:32:19	PM	2	379	S	2
2	1/26/2016	12:34:42	PM	2	307	S	2
3	1/26/2016	12:37:26	PM	0	261	S	2
4	1/26/2016	12:39:46	PM	1	325	S	2
Follow up	1/26/2016	12:41:55	PM	1	311	S	2
5	1/26/2016	12:44:15	PM	2	282	S	2

Surveyor
(Printed Name) Antonio Neotti

(Signature)

Date: 2/2/16

Survey Number: **TIRS- 01262016 WSP SUR 030**

RADIOLOGICAL SURVEY FORM

Survey Number: **TIRS- 01272016 WSP SUR 031**

Survey Description: Wood stave project - Contamination survey performed on five pieces of the wood stave from Section. West 7. Survey includes 100% scan on all accessible areas, a static at the highest scan location, and a smear at the static location.

Elevated beta/gamma counts above MDA were identified; however, these activities are considerably below the Release Limit.

RWP: 2016 WSP JS 01 0

Start Date: **1/27/2016** Time: **1350** End Date: **1/28/2016** Time: **0900**

Surveyor

(Name) Antonio Neotti

(Signature) [signature] Date: 2/2/16

Smear Counter (Inst. #1)			α	β/γ
Model:	3030	4 π Efficiency:	32.5%	32.6%
Serial #:	224340	Bkgd (lab) CPM:	0.3	32.7
Probe #:	N/A	MDA (dpm/100cm²):	17	91
Cal. Due:	4/21/2016	Count Time(min):	1	

Survey Meter (Inst. #2)			α	β/γ
Model:	2360/43-93	2 π Efficiency:	42.60%	30.77%
Serial #:	268506	Bkgd (lab) CPM:	0.2	118.7
Probe / #:	PR286559	MDA (dpm/100cm²):	28	243
Cal. Due:	9/28/2016	Count Time(min):	2	
Probe Area(cm²):	100	Area Bkg (count):	1	305
Surface Efficiency:	α: 0.25 β: 0.50	Sat/Unsat:	sat	

Survey Meter (Inst. #3)		**Exposure Rate Meter (Inst. #4)**	
Model:		Model:	
Serial #:		Serial #:	
Cal. Due:		Cal. Due:	
Ref Area BKG(Scan):		Bkgd (lab):	
Ref Area IL(Scan):		Area Bkgd:	
Site:		Sat/Unsat:	

Survey Location	Removable Contamination Inst. #1				Total Contamination Inst. #2				Gamma Inst.# 3		Exposure Rate Inst. #4		Comments
	Count per smear		dpm/100 cm²		Counts		dpm/100 cm²		Gross	< or ≥	μR/hr		
	α	β/γ	α	β/γ	α	β/γ	α	β/γ	cpm	IL	Contact Gross	1 m Gross	
1	0	40	<MDA	<MDA	1	325	<MDA	285					See Map
					3	327	<MDA	291					Follow Up
2	0	27	<MDA	<MDA	1	331	<MDA	304					See Map
					4	335	<MDA	317					Follow Up
3	0	47	<MDA	<MDA	3	251	<MDA	<MDA					See Map
4	0	29	<MDA	<MDA	1	276	<MDA	<MDA					See Map
5	0	30	<MDA	<MDA	3	310	<MDA	<MDA					See Map

Approved By: Takeshi Ibuki — *Print Name*; [signature] — *Signature*; RE — *Title*; 2/2/2016 — *Date*

FRM-TI-01-1

Surveyor

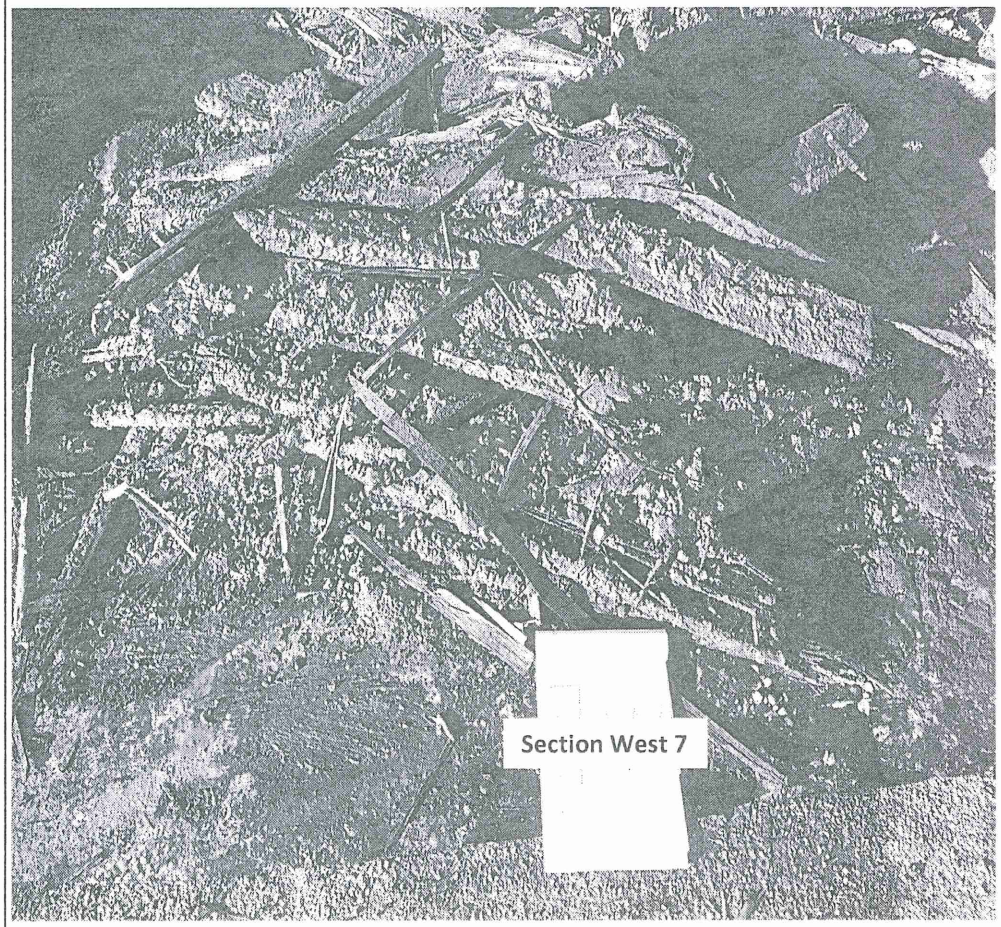
(Printed Name) Antonio Neotti

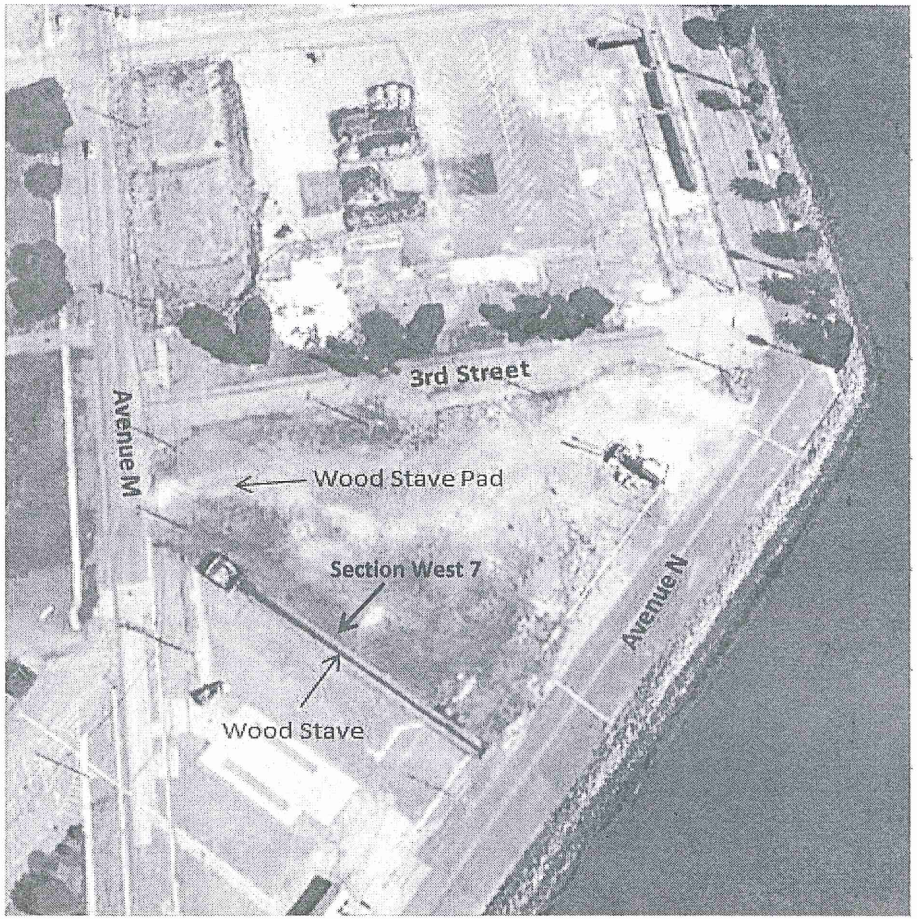
(Signature)

Survey Number:

TIRS- 01272016 WSP SUR 031

Date: 2/2/16





Legend

○ Smear Location	□ *Exposure Rate microR/hr
☆ Static Location	△ Soil Sample Location

Ludlum Measurements,Inc.
Model 3030 Sample Data

1/28/2016
8:18:30 AM

Header 1: 3030 S/N:224340
Header 2: WSP-SUR-031
Header 3: RCT.A.NEOTTI

Calibration Due Date: 4/21/2016

Sample #	Date	Time	Alpha Count	Beta Coun	Count Time	Type	Comment
1	1/28/2016	08:19:12	0	40	1	S	
2	1/28/2016	08:20:26	0	27	1	S	
3	1/28/2016	08:23:44	0	47	1	S	
4	1/28/2016	08:24:55	0	29	1	S	
5	1/28/2016	08:27:18	0	30	1	S	

Header 1: 2360 S/N 268506
Header 2: WSP-SUR-031
Header 3: RCT:A.NEOTTI
S=Scaler, R=Ratemeter

Sample #	Date	Time	Alpha	Beta	S/R	Count Time	Location
BKG	1/27/2016	12:30:44 PM	1	305	S	2	
1	1/27/2016	2:05:19 PM	1	325	S	2	
2	1/27/2016	2:07:45 PM	3	327	S	2	
Folow Up	1/27/2016	2:10:49 PM	1	331	S	2	
3	1/27/2016	2:12:57 PM	4	335	S	2	
Folow Up	1/27/2016	2:15:13 PM	3	251	S	2	
4	1/27/2016	2:17:38 PM	1	276	S	2	
5	1/27/2016	2:20:29 PM	3	310	S	2	

Surveyor
(Printed Name) Antonio Neotti

(Signature)

Date: 2/2/16

Survey Number: **TIRS- 01272016 WSP SUR 031**

RADIOLOGICAL SURVEY FORM

Survey Number: **TIRS- 02042016 WSP SUR 045**

Survey Description: Wood stave project - Contamination survey performed on five pieces of the wood stave from Section West 8. Survey includes 100% scan on all accessible areas, a static at the highest scan location, and a smear at the static location.

No elevated activity noted.

Smear Counter (Inst. #1)			α	β/γ
Model:	3030	4 π Efficiency:	32.5%	32.6%
Serial #:	224340	Bkgd (lab) CPM:	0.3	32.7
Probe #:	N/A	MDA (dpm/100cm²):	17	91
Cal. Due:	4/21/2016	Count Time(min):	1	

Survey Meter (Inst. #2)			α	β/γ
Model:	2360/43-93	2 π Efficiency:	42.60%	30.77%
Serial #:	268506	Bkgd (lab) CPM:	0.2	118.7
Probe / #:	PR286559	MDA (dpm/100cm²):	28	243
Cal. Due:	9/28/2016	Count Time(min):	2	
Probe Area(cm²):	100	Area Bkg (count):	0	272
Surface Efficiency:	α: 0.25 β: 0.50	Sat/Unsat:	sat	

Survey Meter (Inst. #3)		**Exposure Rate Meter (Inst. #4)**	
Model:		Model:	
Serial #:		Serial #:	
Cal. Due:		Cal. Due:	
Ref Area BKG(Scan):		Bkgd (lab):	
Ref Area IL(Scan):		Area Bkgd:	
Site:		Sat/Unsat:	

RWP: 2016 WSP JS 01 0

Start Date: **2/4/2016** Time: **1040** End Date: **2/5/2016** Time: **0830**

Surveyor

(Name) Antonio Neotti

(Signature) [signature] Date: 2/10/16

Survey Location	Removable Contamination Inst. #1				Total Contamination Inst. #2				Gamma Inst.# 3		Exposure Rate Inst. #4		Comments
	Count per smear		dpm/100 cm²		Counts		dpm/100 cm²		*Gross*	*< or ≥*	μR/hr		
	α	β/γ	α	β/γ	α	β/γ	α	β/γ	cpm	IL	Contact Gross	1 m Gross	
1	0	29	<MDA	<MDA	1	313	<MDA	246					See Map
					0	309	<MDA	<MDA					Follow Up
2	0	25	<MDA	<MDA	5	326	<MDA	288					See Map
					2	278	<MDA	<MDA					Follow Up
3	0	31	<MDA	<MDA	1	288	<MDA	<MDA					See Map
4	0	29	<MDA	<MDA	3	259	<MDA	<MDA					See Map
5	0	33	<MDA	<MDA	2	299	<MDA	<MDA					See Map

Approved By: Takeshi Ibuki — *Print Name*

[signature] — *Signature*

RE — *Title*

2/10/2016 — *Date*

FRM-TI-01-1

Surveyor

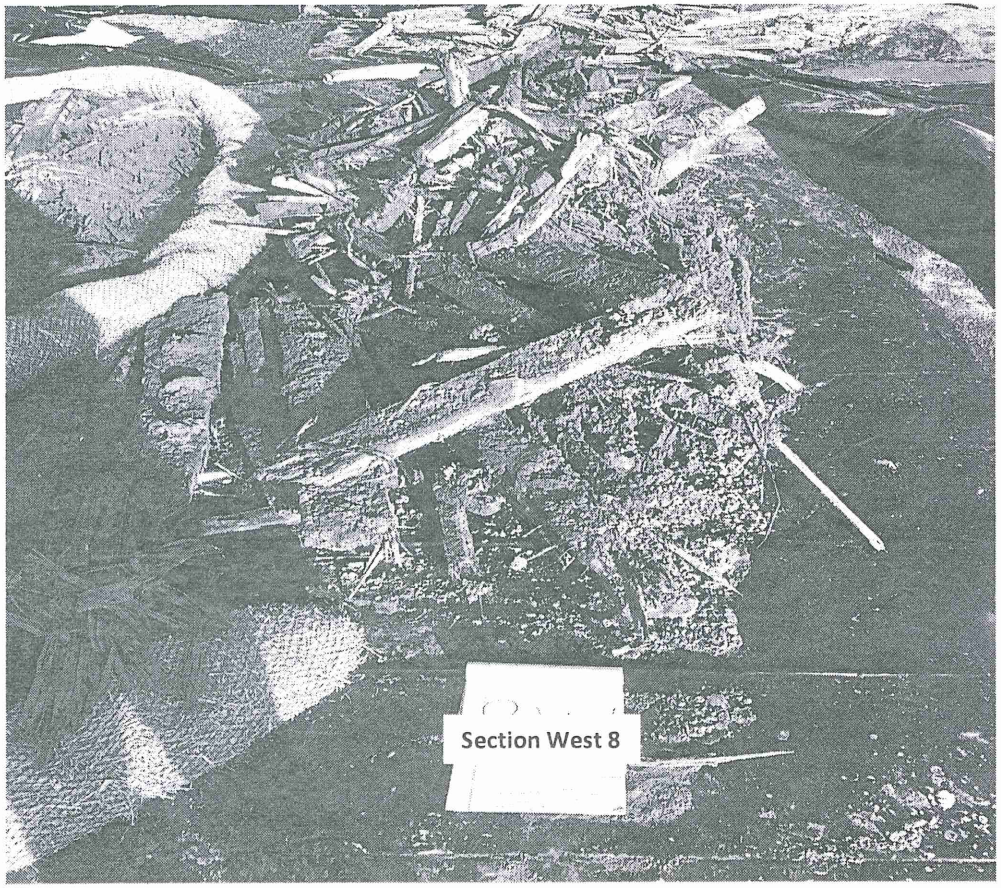
(Printed Name) Antonio Neotti

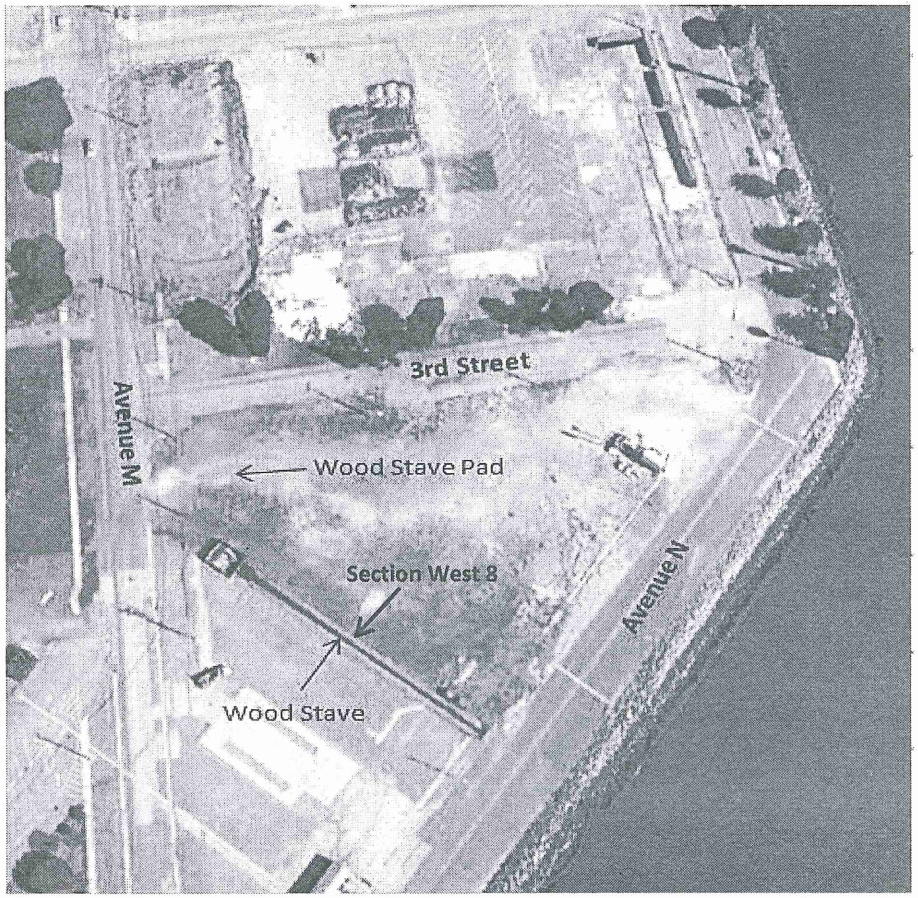
(Signature)

Date: 2/10/16

Survey Number:

TIRS- 02042016 WSP SUR 045





Legend

Smear Location

*Exposure Rate microR/hr

Static Location

Soil Sample Location

Header 1: 3030 S/N:224340
Header 2: WSP-SUR-045
Header 3: RCT:A.N

Calibration Due Date: 4/21/2017

Sample #	Date	Time	Alpha Count	Beta Count	Count Time	Type	Comment
1	2/5/2016	07:55:51	0	29	1	S	
2	2/5/2016	07:57:20	0	25	1	S	
3	2/5/2016	07:58:36	0	31	1	S	
4	2/5/2016	07:59:50	0	29	1	S	
5	2/5/2016	08:01:07	0	33	1	S	

Header 1: 2360 S/N 268506
Header 2: WSP-SUR-045
Header 3: RCT:A.Neotti

Sample #	Date	Time		Alpha	Beta	S/R	Count Time	Location
BKG	2/4/2016	8:27:00	AM	0	272	S	2	
1	2/4/2016	10:59:14	AM	1	313	S	2	
Follow Up	2/4/2016	11:01:58	AM	0	309	S	2	
2	2/4/2016	11:04:28	AM	5	326	S	2	
Follow Up	2/4/2016	11:06:54	AM	2	278	S	2	
3	2/4/2016	11:11:34	AM	1	288	S	2	
4	2/4/2016	11:14:19	AM	3	259	S	2	
5	2/4/2016	11:16:40	AM	2	299	S	2	

Surveyor

(Printed Name) Antonio Neotti

(Signature)

Date: 2/10/16

Survey Number: **TIRS- 02042016 WSP SUR 045**

RADIOLOGICAL SURVEY FORM

Survey Number: **TIRS- 02042016 WSP SUR 046**

Survey Description: Wood stave project - Contamination survey performed on five pieces of the wood stave from Section East 1. Survey includes 100% scan on all accessible areas, a static at the highest scan location, and a smear at the static location.

Elevated total beta/gamma counts above MDA were identified; however, these activities are considerably below the Release Limit.

RWP: 2016 WSP JS 01 0

Start Date: **2/4/2016** Time: **1200** End Date: **2/5/2016** Time: **0830**

Surveyor

(Name) Antonio Neotti

(Signature)

Date: 2/10/16

Smear Counter (Inst. #1)			α	β/γ
Model:	3030	4 π Efficiency:	32.5%	32.6%
Serial #:	224340	Bkgd (lab) CPM:	0.3	32.7
Probe #:	N/A	MDA (dpm/100cm²):	17	91
Cal. Due:	4/21/2016	Count Time(min):	1	

Survey Meter (Inst. #2)			α	β/γ
Model:	2360/43-93	2 π Efficiency:	42.60%	30.77%
Serial #:	268506	Bkgd (lab) CPM:	0.2	118.7
Probe / #:	PR286559	MDA (dpm/100cm²):	28	243
Cal. Due:	9/28/2016	Count Time(min):	2	
Probe Area(cm²):	100	Area Bkg (count):	0	272
Surface Efficiency:	α: 0.25 β: 0.50	Sat/Unsat:	sat	

Survey Meter (Inst. #3)		**Exposure Rate Meter (Inst. #4)**	
Model:		Model:	
Serial #:		Serial #:	
Cal. Due:		Cal. Due:	
Ref Area BKG(Scan):		Bkgd (lab):	
Ref Area IL(Scan):		Area Bkgd:	
Site:		Sat/Unsat:	

Survey Location	Removable Contamination Inst. #1				Total Contamination Inst. #2				Gamma Inst.# 3		Exposure Rate Inst. #4		Comments
	Count per smear		dpm/100 cm²		Counts		dpm/100 cm²		Gross	< or ≥	μR/hr		
	α	β/γ	α	β/γ	α	β/γ	α	β/γ	cpm	IL	Contact Gross	1 m Gross	
1	1	35	<MDA	<MDA	5	337	<MDA	324					See Map
					3	310	<MDA	<MDA					Follow Up
2	0	41	<MDA	<MDA	3	358	<MDA	392					See Map
					2	351	<MDA	369					Follow Up
3	0	38	<MDA	<MDA	1	271	<MDA	<MDA					See Map
4	1	29	<MDA	<MDA	6	342	<MDA	340					See Map
					2	375	<MDA	447					Follow Up
5	0	31	<MDA	<MDA	4	354	<MDA	379					See Map
					3	357	<MDA	389					Follow Up

Approved By: Takeshi Ibuki — *Print Name*

Signature

RE — *Title*

2/10/2016 — *Date*

FRM-TI-01-1

Surveyor

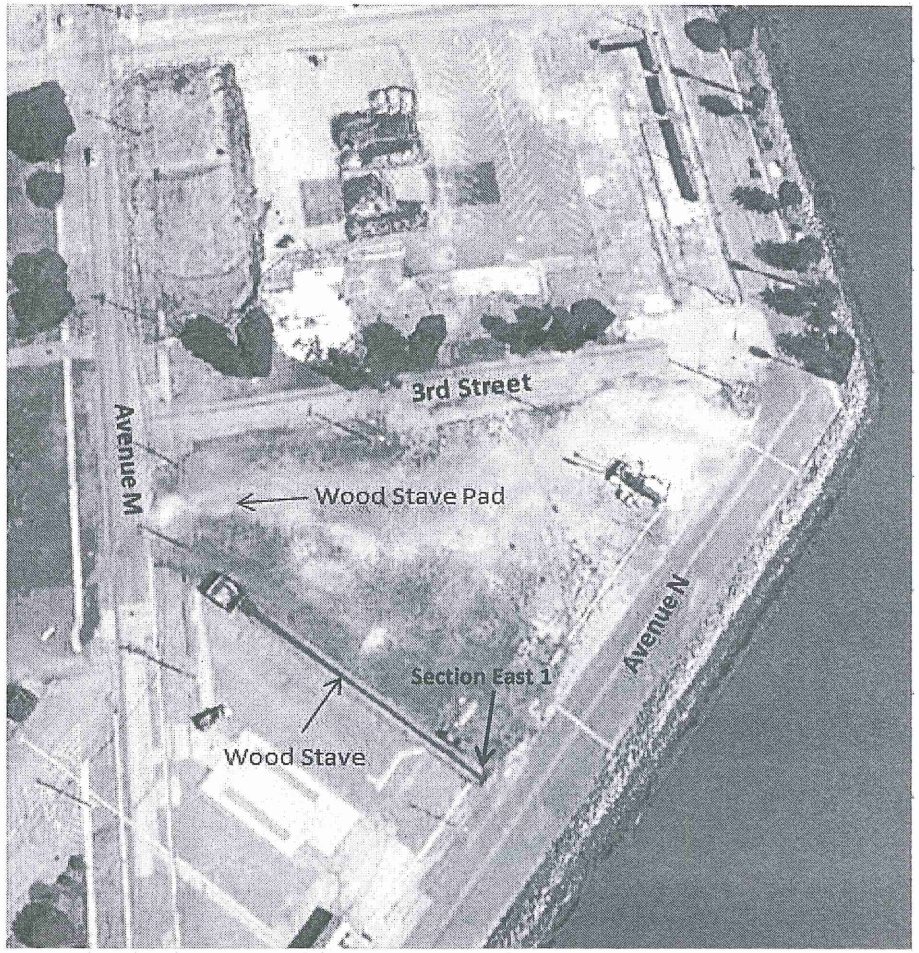
(Printed Name) Antonio Neotti

(Signature)

Survey Number:

TIRS- 02042016 WSP SUR 046

Date: 2/10/16



Legend

Smear Location

*Exposure Rate microR/hr

Static Location

Soil Sample Location

Header 1: 3030 S/N:224340
Header 2: WSP-SUR-046
Header 3: RCT:A.N

Calibration Due Date: 4/21/2017

Sample #	Date	Time	Alpha Count	Beta Count	Count Time	Type	Comment
1	2/5/2016	08:06:52	1	35	1	S	
2	2/5/2016	08:08:04	0	41	1	S	
3	2/5/2016	08:09:14	0	38	1	S	
4	2/5/2016	08:10:26	1	29	1	S	
5	2/5/2016	08:11:39	0	31	1	S	

Header 1: 2360 S/N 268506
Header 2: WSP-SUP-046
Header 3: RCT:A.Neotti

S=Scaler, R=Ratemeter

Sample #	Date	Time	Alpha	Beta	S/R	Count Time	Location
BKG	2/4/2016	8:27:00 AM	0	272	S	2	
1	2/4/2016	11:20:03 AM	5	337	S	2	
Follow Up	2/4/2016	11:22:14 AM	3	310	S	2	
2	2/4/2016	11:24:53 AM	3	358	S	2	
Follow Up	2/4/2016	11:27:34 AM	2	351	S	2	
3	2/4/2016	11:30:00 AM	1	271	S	2	
4	2/4/2016	11:33:07 AM	6	342	S	2	
Follow Up	2/4/2016	11:35:16 AM	2	375	S	2	
5	2/4/2016	11:37:33 AM	4	354	S	2	
Follow Up	2/4/2016	11:39:41 AM	3	357	S	2	

Surveyor
(Printed Name) Antonio Neotti

(Signature)

Date: 2/10/16

Survey Number: **TIRS- 02042016 WSP SUR 046**

CB&I Federal Services, LLC

RADIOLOGICAL SURVEY FORM

Survey Number: **TIRS- 01272016 WSP SUR 032**

Survey Description: Wood stave project - Contamination survey performed on concrete from all sections of Wood Stave. Survey includes 100% scan on all accessible areas, a static at the highest scan location, and a smear at the static location.

Elevated total alpha and beta/gamma counts above MDA were identified; however, these activities were considerably below the Release Limits.

RWP: 2016 WSP JS 01 0

Start Date: **1/27/2016** Time: **1200** End Date: **2/22/2016** Time: **1430**

Surveyor

(Name) Antonio Neotti

(Signature)

Date: 3/1/16

Smear Counter (Inst. #1)			α	β/γ
Model:	3030	4 π Efficiency:	32.5%	32.6%
Serial #:	224340	Bkgd (lab) CPM:	0.3	32.7
Probe #:	N/A	MDA (dpm/100cm²):	17	91
Cal. Due:	4/21/2016	Count Time(min):	1	

Survey Meter (Inst. #2)			α	β/γ
Model:	2360/43-93	2 π Efficiency:	42.60%	30.77%
Serial #:	268506	Bkgd (lab) CPM:	0.2	118.7
Probe / #:	PR286559	MDA (dpm/100cm²):	28	243
Cal. Due:	9/28/2016	Count Time(min):	2	
Probe Area(cm²):	100	Area Bkg (count):	1	305
Surface Efficiency:	α: 0.25 β: 0.50	Sat/Unsat:	sat	

Survey Meter (Inst. #3)		**Exposure Rate Meter (Inst. #4)**	
Model:		Model:	
Serial #:		Serial #:	
Cal. Due:		Cal. Due:	
Ref Area BKG(Scan):		Bkgd (lab):	
Ref Area IL(Scan):		Area Bkgd:	
Site:		Sat/Unsat:	

Survey Location	Removable Contamination Inst. #1				Total Contamination Inst. #2				Gamma Inst.# 3		Exposure Rate Inst. #4		Comments
	Count per smear		dpm/100 cm²		Counts		dpm/100 cm²		Gross	< or ≥	μR/hr		
	α	β/γ	α	β/γ	α	β/γ	α	β/γ	cpm	IL	Contact Gross	1 m Gross	
1	0	35	<MDA	<MDA	2	322	<MDA	275					See Map
					4	327	<MDA	291					Follow Up
2	0	35	<MDA	<MDA	3	311	<MDA	<MDA					See Map
3	0	31	<MDA	<MDA	1	346	<MDA	353					See Map
					4	354	<MDA	379					Follow Up
4	0	25	<MDA	<MDA	1	341	<MDA	337					See Map
					2	364	<MDA	411					Follow Up
5	0	27	<MDA	<MDA	6	324	<MDA	281					See Map
					5	324	<MDA	281					Follow Up
6	0	36	<MDA	<MDA	4	348	<MDA	359					See Map
					5	344	<MDA	346					Follow Up
7	0	38	<MDA	<MDA	6	360	<MDA	398					See Map
					3	356	<MDA	385					Follow Up
8	0	31	<MDA	<MDA	6	357	<MDA	389					See Map
					8	387	36	486					Follow Up
9	0	35	<MDA	<MDA	3	356	<MDA	385					See Map
					1	358	<MDA	392					Follow Up
10	0	36	<MDA	<MDA	7	362	31	405					See Map
					3	346	<MDA	353					Follow Up
11	0	34	<MDA	<MDA	0	319	<MDA	265					See Map

Approved By: Takeshi Ibuki — *Print Name*

Signature

RE — *Title*

3/2/2016 — *Date*

FRM-TI-01-1

Surveyor (Printed Name) Antonio Neotti

Survey Number: TIRS- 01272016 WSP SUR 032

(Signature)

Date: 3/1/16

Survey Location	Removable Contamination Inst. #1				Total Contamination Inst. #2				Gamma Inst. #3		Exposure Rate Inst. #4		Comments
	Count per smear		dpm/100 cm²		Counts		dpm/100 cm²		Gross	< or ≥	μR/hr		
	α	β/γ	α	β/γ	α	β/γ	α	β/γ	cpm	IL	Contact Gross	1 m Gross	
					6	341	<MDA	337					Follow Up
12	1	27	<MDA	<MDA	2	277	<MDA	<MDA					See Map
13	2	31	<MDA	<MDA	1	340	<MDA	333					See Map
					0	336	<MDA	320					Follow Up
14	1	33	<MDA	<MDA	0	367	<MDA	421					See Map
					2	401	<MDA	532					Follow Up
15	0	29	<MDA	<MDA	5	353	<MDA	376					See Map
					3	342	<MDA	340					Follow Up
16	1	31	<MDA	<MDA	5	328	<MDA	294					See Map
					1	339	<MDA	330					Follow Up
17	0	26	<MDA	<MDA	5	341	<MDA	337					See Map
					2	353	<MDA	376					Follow Up
18	0	37	<MDA	<MDA	1	372	<MDA	437					See Map
					1	369	<MDA	428					Follow Up
19	0	38	<MDA	<MDA	2	314	<MDA	249					See Map
					3	297	<MDA	<MDA					Follow Up
20	1	25	<MDA	<MDA	3	309	<MDA	<MDA					See Map
21	1	34	<MDA	<MDA	9	358	40	392					See Map
					11	310	50	<MDA					Follow Up
22	0	43	<MDA	<MDA	4	372	<MDA	437					See Map
					6	380	<MDA	463					Follow Up
23	0	34	<MDA	<MDA	6	387	<MDA	486					See Map
					6	368	<MDA	424					Follow Up
24	0	41	<MDA	<MDA	8	362	36	405					See Map
					14	317	64	259					Follow Up
25	0	34	<MDA	<MDA	8	333	36	311					See Map
					5	360	<MDA	398					Follow Up
26	0	41	<MDA	<MDA	10	379	45	460					See Map
					5	328	<MDA	294					Follow Up
27	0	37	<MDA	<MDA	6	359	<MDA	395					See Map
					6	344	<MDA	346					Follow Up
28	0	21	<MDA	<MDA	11	336	50	320					See Map
					8	343	36	343					Follow Up
29	0	27	<MDA	<MDA	9	360	40	398					See Map
					4	358	<MDA	392					Follow Up
30	0	39	<MDA	<MDA	4	318	<MDA	262					See Map
					4	309	<MDA	<MDA					Follow Up

Surveyor (Printed Name) Antonio Neotti

Survey Number: TIRS- 01272016 WSP SUR 032

(Signature)

Date: 3/1/16

Survey Location	Removable Contamination Inst. #1				Total Contamination Inst. #2				Gamma Inst. #3		Exposure Rate Inst. #4		Comments
	Count per smear		dpm/100 cm²		Counts		dpm/100 cm²		Gross	< or ≥	μR/hr		
	α	β/γ	α	β/γ	α	β/γ	α	β/γ	cpm	IL	Contact Gross	1 m Gross	
31	0	36	<MDA	<MDA	3	369	<MDA	428					See Map
					10	415	45	577					Follow Up
32	0	34	<MDA	<MDA	8	348	36	359					See Map
					2	347	<MDA	356					Follow Up
33	0	43	<MDA	<MDA	10	377	45	454					See Map
					11	354	50	379					Follow Up
34	0	33	<MDA	<MDA	6	340	<MDA	333					See Map
					4	359	<MDA	395					Follow Up
35	1	27	<MDA	<MDA	2	414	<MDA	574					See Map
					0	397	<MDA	519					Follow Up
36	0	50	<MDA	<MDA	0	370	<MDA	431					See Map
					2	367	<MDA	421					Follow Up
37	0	30	<MDA	<MDA	1	400	<MDA	528					See Map
38	1	25	<MDA	<MDA	2	430	<MDA	626					See Map
39	0	25	<MDA	<MDA	0	397	<MDA	519					See Map
					2	395	<MDA	512					Follow Up
40	0	26	<MDA	<MDA	0	334	<MDA	314					See Map
					0	377	<MDA	454					Follow Up
41	1	33	<MDA	<MDA	1	367	<MDA	421					See Map
					1	401	<MDA	532					Follow Up
42	0	31	<MDA	<MDA	3	369	<MDA	428					See Map
					3	385	<MDA	480					Follow Up
43	0	33	<MDA	<MDA	4	372	<MDA	437					See Map
					5	327	<MDA	291					Follow Up
44	0	43	<MDA	<MDA	4	403	<MDA	538					See Map
					1	387	<MDA	486					Follow Up
45	0	20	<MDA	<MDA	1	366	<MDA	418					See Map
					2	300	<MDA	<MDA					Follow Up
46	1	32	<MDA	<MDA	2	332	<MDA	307					See Map
					3	320	<MDA	268					Follow Up
47	0	48	<MDA	<MDA	0	297	<MDA	<MDA					See Map
48	0	32	<MDA	<MDA	4	331	<MDA	304					See Map
					4	350	<MDA	366					Follow Up
49	0	23	<MDA	<MDA	2	322	<MDA	275					See Map
					0	315	<MDA	252					Follow Up
50	1	28	<MDA	<MDA	0	314	<MDA	249					See Map
					0	312	<MDA	<MDA					Follow Up

Surveyor

(Printed Name) Antonio Neotti

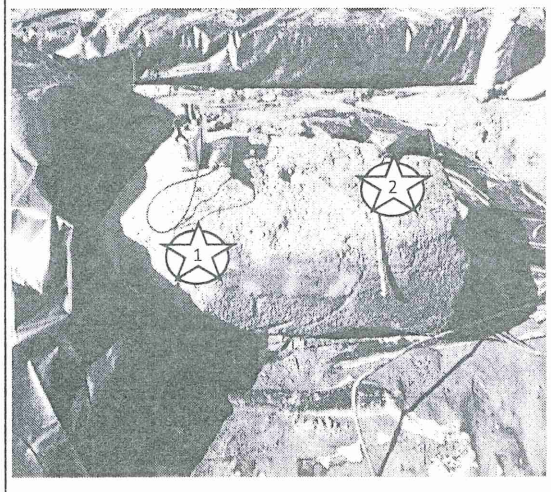
(Signature)

Date: 3/1/16

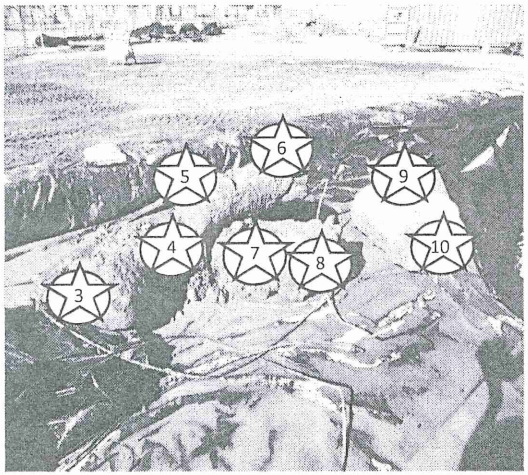
Survey Number:

TIRS- 01272016 WSP SUR 032

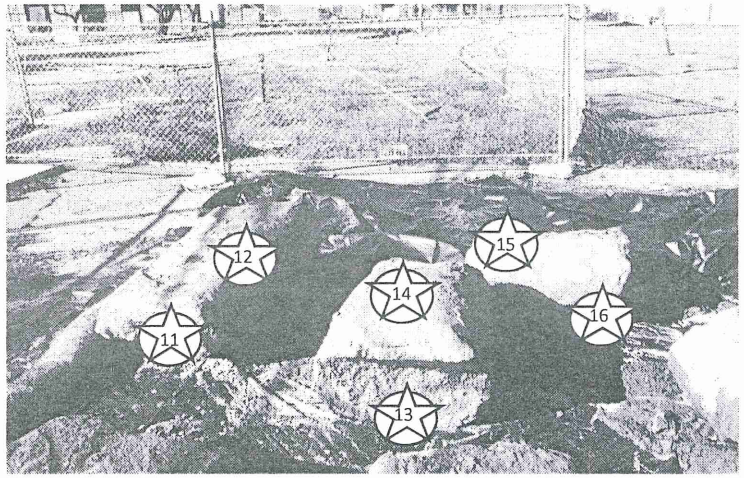
West 1



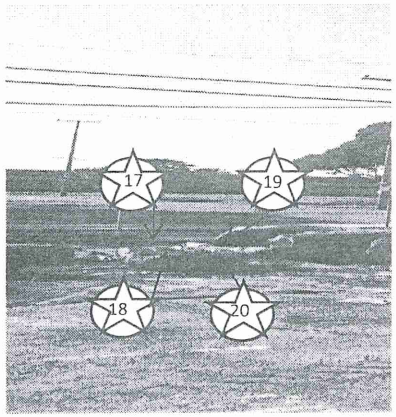
West 2



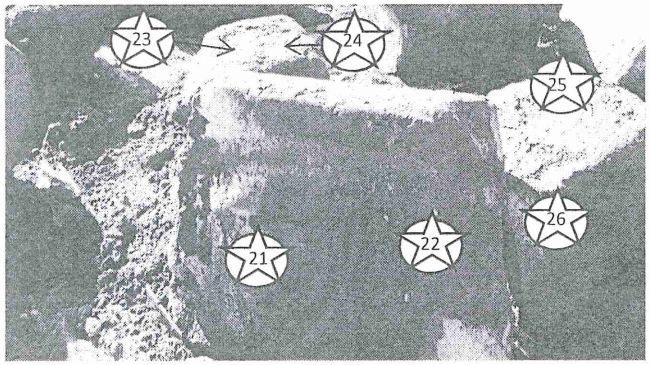
West 3



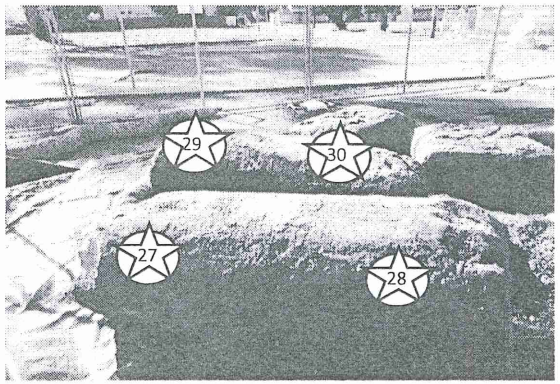
West 4



West 5



West 6



Legend

○ Smear Location	□ *Exposure Rate microR/hr
☆ Static Location	△ Soil Sample Location

Surveyor

(Printed Name) Antonio Neotti

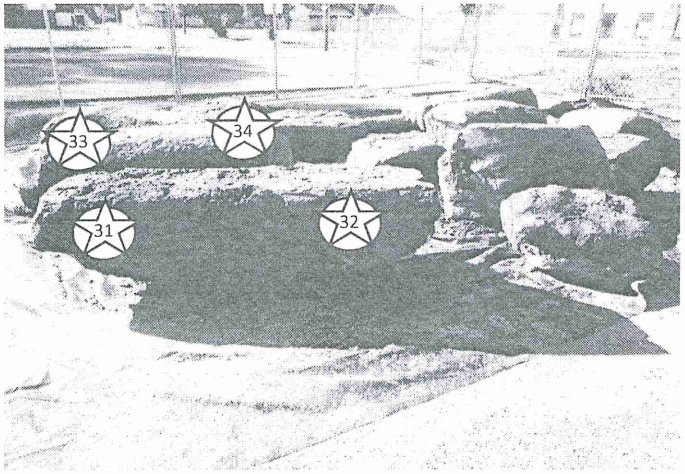
(Signature)

Survey Number:

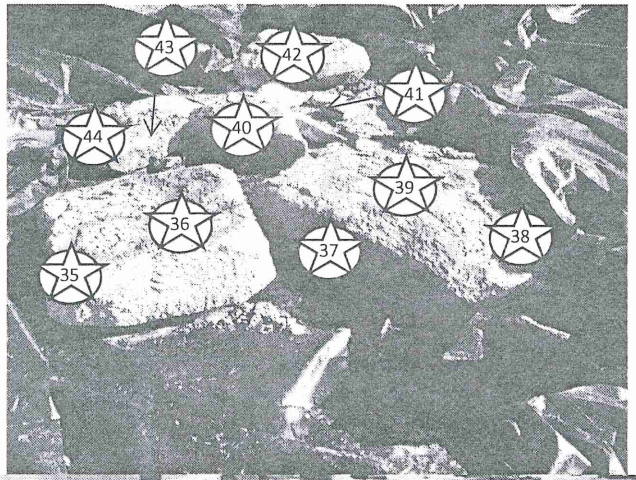
TIRS- 01272016 WSP SUR 032

Date: 3/1/16

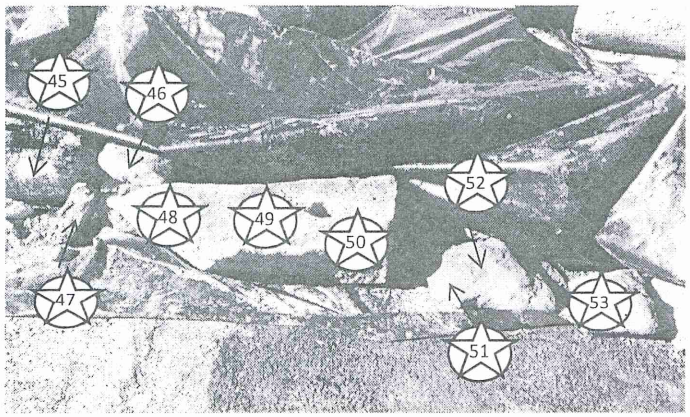
West 7

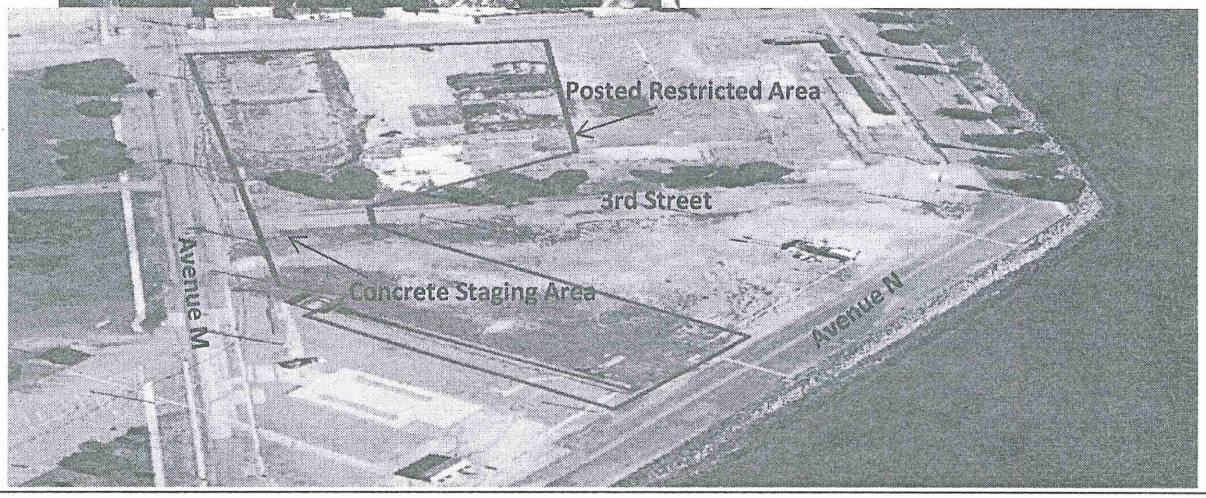


West 8



East 1





Legend

Smear Location

*Exposure Rate microR/hr

Static Location

Soil Sample Location

Header 1: 2360 S/N 268506
Header 2: WSP-SUR-032
Header 3: RCT:A.NEOTTI

Sample #	Date	Time	Alpha	Beta	S/R	Count Time	Location
BKG	1/27/2016	12:30:44 PM	1	305	S	2	
1	1/27/2016	12:33:13 PM	2	322	S	2	
Follow Up	1/27/2016	12:35:51 PM	4	327	S	2	
2	1/27/2016	12:39:18 PM	3	311	S	2	
3	1/27/2016	12:42:51 PM	1	346	S	2	
Follow Up	1/27/2016	12:45:29 PM	4	354	S	2	
4	1/27/2016	12:48:24 PM	1	341	S	2	
Follow Up	1/27/2016	12:50:42 PM	2	364	S	2	
5	1/27/2016	12:53:32 PM	6	324	S	2	
Follow Up	1/27/2016	12:55:58 PM	5	324	S	2	
6	1/27/2016	12:58:14 PM	4	348	S	2	
Follow Up	1/27/2016	1:08:54 PM	5	344	S	2	
7	1/27/2016	1:40:53 PM	6	360	S	2	
Follow Up	1/27/2016	1:44:35 PM	3	356	S	2	
8	1/27/2016	1:47:22 PM	6	357	S	2	
Follow Up	1/27/2016	1:49:29 PM	8	387	S	2	
9	1/27/2016	1:51:59 PM	3	356	S	2	
Follow Up	1/27/2016	1:54:26 PM	1	358	S	2	
10	1/27/2016	1:56:51 PM	7	362	S	2	
Follow Up	1/27/2016	1:59:00 PM	3	346	S	2	

Header 1: 2360 S/N 268506
Header 2: WSP-SUR-032
Header 3: RCT:A.Neotti

Sample #	Date	Time	Alpha	Beta	S/R	Count Time	Location
11	1/28/2016	10:10:24 AM	0	319	S	2	
Follow Up	1/28/2016	10:13:31 AM	6	341	S	2	
12	1/28/2016	10:16:01 AM	2	277	S	2	
13	1/28/2016	10:19:45 AM	1	340	S	2	
Follow Up	1/28/2016	10:22:14 AM	0	336	S	2	
14	1/28/2016	10:24:59 AM	0	367	S	2	
Follow Up	1/28/2016	10:27:20 AM	2	401	S	2	
15	1/28/2016	10:30:04 AM	5	353	S	2	
Follow Up	1/28/2016	10:32:33 AM	3	342	S	2	
16	1/28/2016	10:37:13 AM	5	328	S	2	
Follow Up	1/28/2016	10:39:32 AM	1	339	S	2	
17	1/28/2016	10:55:20 AM	5	341	S	2	
Follow Up	1/28/2016	10:57:30 AM	2	353	S	2	
18	1/28/2016	11:00:00 AM	1	372	S	2	
Follow Up	1/28/2016	11:04:14 AM	1	369	S	2	
19	1/28/2016	11:07:55 AM	2	314	S	2	
Follow Up	1/28/2016	11:11:47 AM	3	297	S	2	
20	1/28/2016	11:14:15 AM	3	309	S	2	

Surveyor
(Printed Name) Antonio Neotti

(Signature) Date: 3/1/16

Survey Number: **TIRS- 01272016 WSP SUR 032**

Header 1: 2360 S/N 268506
Header 2: WSP-SUR-032
Header 3: RCT:A.NEOTTI

Sample #	Date	Time	Alpha	Beta	S/R	Count Time	Location
21	2/1/2016	12:44:36 PM	9	358	S	2	
Follow Up	2/1/2016	12:48:41 PM	11	310	S	2	
22	2/1/2016	12:51:29 PM	4	372	S	2	
Follow Up	2/1/2016	12:57:01 PM	6	380	S	2	
23	2/1/2016	1:00:11 PM	6	387	S	2	
Follow Up	2/1/2016	1:05:19 PM	6	368	S	2	
24	2/1/2016	1:08:22 PM	8	362	S	2	
Follow Up	2/1/2016	1:12:14 PM	14	317	S	2	
25	2/1/2016	1:15:21 PM	8	333	S	2	
Follow Up	2/1/2016	1:18:10 PM	5	360	S	2	
26	2/1/2016	1:20:23 PM	10	379	S	2	
Follow Up	2/1/2016	1:23:04 PM	5	328	S	2	
27	2/1/2016	1:26:12 PM	6	359	S	2	
Follow Up	2/1/2016	1:28:47 PM	6	344	S	2	
28	2/1/2016	1:31:28 PM	11	336	S	2	
Follow Up	2/1/2016	1:33:57 PM	8	343	S	2	
29	2/1/2016	1:36:56 PM	9	360	S	2	
Follow Up	2/1/2016	1:39:27 PM	4	358	S	2	
30	2/1/2016	1:42:09 PM	4	318	S	2	
Follow Up	2/1/2016	1:46:29 PM	4	309	S	2	
31	2/1/2016	1:56:11 PM	3	369	S	2	
Follow Up	2/1/2016	1:58:32 PM	10	415	S	2	
32	2/1/2016	2:01:30 PM	8	348	S	2	
Follow Up	2/1/2016	2:04:04 PM	2	347	S	2	
33	2/1/2016	2:06:57 PM	10	377	S	2	
Follow Up	2/1/2016	2:09:25 PM	11	354	S	2	
34	2/1/2016	2:12:53 PM	6	340	S	2	
Follow Up	2/1/2016	2:15:06 PM	4	359	S	2	

Header 1: 2360 S/N 268506
Header 2: WSP-SUR-032
Header 3: RCT:A.Neotti

Sample #	Date	Time	Alpha	Beta	S/R	Count Time	Location
BKG	2/3/2016	10:20:14 AM	0	249	S	2	
35	2/3/2016	10:32:26 AM	2	414	S	2	
Follow Up	2/3/2016	10:34:36 AM	0	397	S	2	
36	2/3/2016	10:36:58 AM	0	370	S	2	
Follow Up	2/3/2016	10:39:17 AM	2	367	S	2	
37	2/3/2016	10:41:53 AM	1	400	S	2	
38	2/3/2016	10:51:34 AM	2	430	S	2	
39	2/3/2016	10:54:02 AM	0	397	S	2	
Follow Up	2/3/2016	10:56:19 AM	2	395	S	2	
40	2/3/2016	10:58:52 AM	0	334	S	2	
Follow Up	2/3/2016	11:01:20 AM	0	377	S	2	
41	2/3/2016	11:03:57 AM	1	367	S	2	
Follow Up	2/3/2016	11:06:16 AM	1	401	S	2	
42	2/3/2016	11:08:39 AM	3	369	S	2	
Follow Up	2/3/2016	11:11:09 AM	3	385	S	2	
43	2/3/2016	11:13:42 AM	4	372	S	2	
Follow Up	2/3/2016	11:15:55 AM	5	327	S	2	
44	2/3/2016	11:23:44 AM	4	403	S	2	
Follow Up	2/3/2016	11:26:28 AM	1	387	S	2	

Surveyor
(Printed Name) Antonio Neotti
(Signature)
Date: 3/1/16

Survey Number: **TIRS- 01272016 WSP SUR 032**

Header 1: 2360 S/N 268506
Header 2: WSP-SUR-032
Header 3: RCT:A.Neotti

Sample #	Date	Time		Alpha	Beta	S/R	Count Time	Location
BKG	2/4/2016	8:27:00	AM	0	272	S	2	
45	2/4/2016	8:31:34	AM	1	366	S	2	
Follow Up	2/4/2016	8:49:33	AM	2	300	S	2	
46	2/4/2016	8:52:04	AM	2	332	S	2	
Follow Up	2/4/2016	8:55:34	AM	3	320	S	2	
47	2/4/2016	8:58:07	AM	0	297	S	2	
48	2/4/2016	9:00:47	AM	4	331	S	2	
Follow Up	2/4/2016	9:03:11	AM	4	350	S	2	
49	2/4/2016	9:07:29	AM	2	322	S	2	
Follow Up	2/4/2016	9:09:52	AM	0	315	S	2	
50	2/4/2016	9:13:30	AM	0	314	S	2	
Follow Up	2/4/2016	9:15:52	AM	0	312	S	2	
51	2/4/2016	9:18:27	AM	0	305	S	2	
52	2/4/2016	9:21:07	AM	3	334	S	2	
Follow Up	2/4/2016	9:23:14	AM	4	332	S	2	
53	2/4/2016	9:25:41	AM	1	335	S	2	
Follow Up	2/4/2016	9:27:48	AM	1	324	S	2	

Ludlum Measurements,Inc.
Model 3030 Sample Data

1/28/2016
8:00:56 AM

Header 1: 3030 S/N:224340
Header 2: WSP-SUR-032
Header 3: RCT.A.NEOTTI
Calibration Due Date: 4/21/2016

Sample #	Date	Time	Alpha Count	Beta Count	Count Time	Type	Comment
1	1/28/2016	07:57:21	0	35	1	S	
2	1/28/2016	07:58:37	0	35	1	S	
3	1/28/2016	08:00:08	0	31	1	S	
4	1/28/2016	08:01:30	0	25	1	S	
5	1/28/2016	08:03:05	0	27	1	S	
6	1/28/2016	08:04:19	0	36	1	S	
7	1/28/2016	08:05:42	0	38	1	S	
8	1/28/2016	08:07:16	0	31	1	S	
9	1/28/2016	08:08:31	0	35	1	S	
10	1/28/2016	08:10:59	0	36	1	S	

Surveyor
(Printed Name) Antonio Neotti

(Signature)

Date: 3/1/16

Survey Number: **TIRS- 01272016 WSP SUR 032**

Ludlum Measurements,Inc.
Model 3030 Sample Data

2/4/2016
4:11:46 PM

Header 1: 3030 S/N:224340
Header 2: WSP-SUR-032
Header 3: RCT:NEOTTI
Calibration Due Date: 4/21/2017

Sample #	Date	Time	Alpha Count	Beta Count	Count Time	Type	Comment
11	2/4/2017	15:44:56	0	34	1	S	
12	2/4/2017	15:46:21	1	27	1	S	
13	2/4/2017	15:47:42	2	31	1	S	
14	2/4/2017	15:50:48	1	33	1	S	
15	2/4/2017	15:56:42	0	29	1	S	
16	2/4/2017	15:58:32	1	31	1	S	
17	2/4/2017	15:59:58	0	26	1	S	
18	2/4/2017	16:01:49	0	37	1	S	
19	2/4/2017	16:04:39	0	38	1	S	
20	2/4/2017	16:06:42	1	25	1	S	

Ludlum Measurements,Inc.
Model 3030 Sample Data

2/4/2016
3:25:04 PM

Header 1: 3030 S/N:224340
Header 2: WSP-SUR-032
Header 3: RCT:NEOTTI
Calibration Due Date: 4/21/2017

Sample #	Date	Time	Alpha Count	Beta Count	Count Time	Type	Comment
21	2/4/2016	14:49:10	1	34	1	S	
22	2/4/2016	14:50:23	0	43	1	S	
23	2/4/2016	14:51:43	0	34	1	S	
24	2/4/2016	14:53:48	0	41	1	S	
25	2/4/2016	14:56:50	0	34	1	S	
26	2/4/2016	14:58:19	0	41	1	S	
27	2/4/2016	15:00:05	0	37	1	S	
28	2/4/2016	15:02:24	0	21	1	S	
29	2/4/2016	15:04:53	0	27	1	S	
30	2/4/2016	15:08:49	0	39	1	S	
31	2/4/2016	15:13:29	0	36	1	S	
32	2/4/2016	15:16:38	0	34	1	S	
33	2/4/2016	15:18:01	0	43	1	S	
34	2/4/2016	15:19:14	0	33	1	S	

Surveyor
(Printed Name) Antonio Neotti
(Signature)
Date: 3/1/16

Survey Number: **TIRS- 01272016 WSP SUR 032**

Ludlum Measurements,Inc.
Model 3030 Sample Data

2/22/2016
2:14:13 PM

Header 1: 3030 S/N:224340
Header 2: WSP-SUR-032-3
Header 3: RCT:A.NEOTTI
Calibration Due Date: 4/21/2016

Sample #	Date	Time	Alpha Count	Beta Count	Count Time	Type	Comment
35	2/22/2016	14:04:02	1	27	1	S	
36	2/22/2016	14:05:14	0	50	1	S	
37	2/22/2016	14:06:28	0	30	1	S	
38	2/22/2016	14:08:07	1	25	1	S	
39	2/22/2016	14:09:37	0	25	1	S	
40	2/22/2016	14:10:49	0	26	1	S	
41	2/22/2016	14:12:02	1	33	1	S	
42	2/22/2016	14:13:18	0	31	1	S	
43	2/22/2016	14:14:28	0	33	1	S	
44	2/22/2016	14:15:38	0	43	1	S	

Ludlum Measurements,Inc.
Model 3030 Sample Data

2/5/2016
7:52:02 AM

Header 1: 3030 S/N:224340
Header 2: WSP-SUR-032
Header 3: RCT:A.N

Calibration Due Date: 4/21/2017

Sample #	Date	Time	Alpha Count	Beta Count	Count Time	Type	Comment
45	2/5/2016	07:38:36	0	20	1	S	
46	2/5/2016	07:39:49	1	32	1	S	
47	2/5/2016	07:40:59	0	48	1	S	
48	2/5/2016	07:42:10	0	32	1	S	
49	2/5/2016	07:43:56	0	23	1	S	
50	2/5/2016	07:45:07	1	28	1	S	
51	2/5/2016	07:46:19	1	30	1	S	
52	2/5/2016	07:47:28	0	25	1	S	
53	2/5/2016	07:48:37	1	35	1	S	

Surveyor
(Printed Name) Antonio Neotti
(Signature)
Date: 3/1/16

Survey Number: **TIRS- 01272016 WSP SUR 032**

Appendix C
Final Status Survey and Background Data

Naval Station Treasure Island, Wood Stave Pipe Removal
RSY and Excavation Data Report

Contract No. D2005 CTO-0012		
RSY Unit: RSY #233A	RSY Unit Use Number: USE 1	First Submittal ☐ Second Submittal ☑
Data attached and submitted by: Lisa Coffey/Tina Piquet/Jeff Guillory		Data Report Submittal Date: 04/05/2016

Systematic Soil Sample Analytical Data – RSY Pad 233A Use 1 (Systematic Sample Survey Map)

Sample Identification	Location	Type Of Sample	Static 2221 Meter Serial Number	One Minute Static Reading (CPM)	Static Count Over Static Mean + 3σ	^{226}Ra Analytical Results (pCi/g)
TITO12-RSY233A_1CH-S001	1	Systematic	97290	13,033	No	0.393
TITO12-RSY233A_1CH-S002	2	Systematic	97290	11,360	No	0.358
TITO12-RSY233A_1CH-S003	3	Systematic	97290	13,691	No	0.465
TITO12-RSY233A_1CH-S004	4	Systematic	97290	13,210	No	0.364
TITO12-RSY233A_1CH-S005	5	Systematic	97290	12,599	No	0.295
TITO12-RSY233A_1CH-S006	6	Systematic	97290	13,440	No	0.184
TITO12-RSY233A_1CH-S007	7	Systematic	97290	13,589	No	0.360
TITO12-RSY233A_1CH-S008	8	Systematic	97290	12,348	No	0.338
TITO12-RSY233A_1CH-S009	9	Systematic	97290	13,868	No	0.403
TITO12-RSY233A_1CH-S010	10	Systematic	97290	13,387	No	0.400
TITO12-RSY233A_1CH-S011	11	Systematic	97290	13,538	No	0.413
TITO12-RSY233A_1CH-S012	12	Systematic	97290	12,512	No	0.347
TITO12-RSY233A_1CH-S013	13	Systematic	97290	14,112	No	0.492
TITO12-RSY233A_1CH-S014	14	Systematic	97290	13,897	No	0.309
TITO12-RSY233A_1CH-S015	15	Systematic	97290	14,442	No	0.403
TITO12-RSY233A_1CH-S016	16	Systematic	97290	14,499	No	0.478
TITO12-RSY233A_1CH-S017	17	Systematic	97290	14,436	No	0.404
TITO12-RSY233A_1CH-S018	18	Systematic	97290	14,730	No	0.298
TITO12-RSY233A_1CH-S019	19	Systematic	97290	15,949	No	0.448
TITO12-RSY233A_1CH-S020	20	Systematic	97290	14,421	No	0.472

Survey and Instrument Data – RSY Pad 233A Use 1

Activity	Survey #	Date	Meter	Calibration Due Date	Serial #	Static Background (CPM)	Static Background Plus 3σ (CPM)	Scan Background	Scan Background Plus 3σ	Range
Initial Gamma Walkover	TIRS-02122016-WSP-ROV-051	2/12/2016	RS-701/ RSX-1	N/A	Console: 7236 / Detectors: 5447, 5448	N/A	N/A	7,534 CPS	8,275 CPS	3,615 – 6,861 CPS
Follow-up Static Survey	TIRS-02152016-WSP-JSS-054	2/15/2016	2221	4/28/2016	97290	18,301	20,154	N/A	N/A	14,245 – 16,690 CPM
One-Minute Systematic Sampling Survey	TIRS-02152016-WSP-JSS-052	2/15/2016 – 2/16/2016	2221	4/28/2016	97290	18,301	20,154	N/A	N/A	11,360 – 15,949 CPM

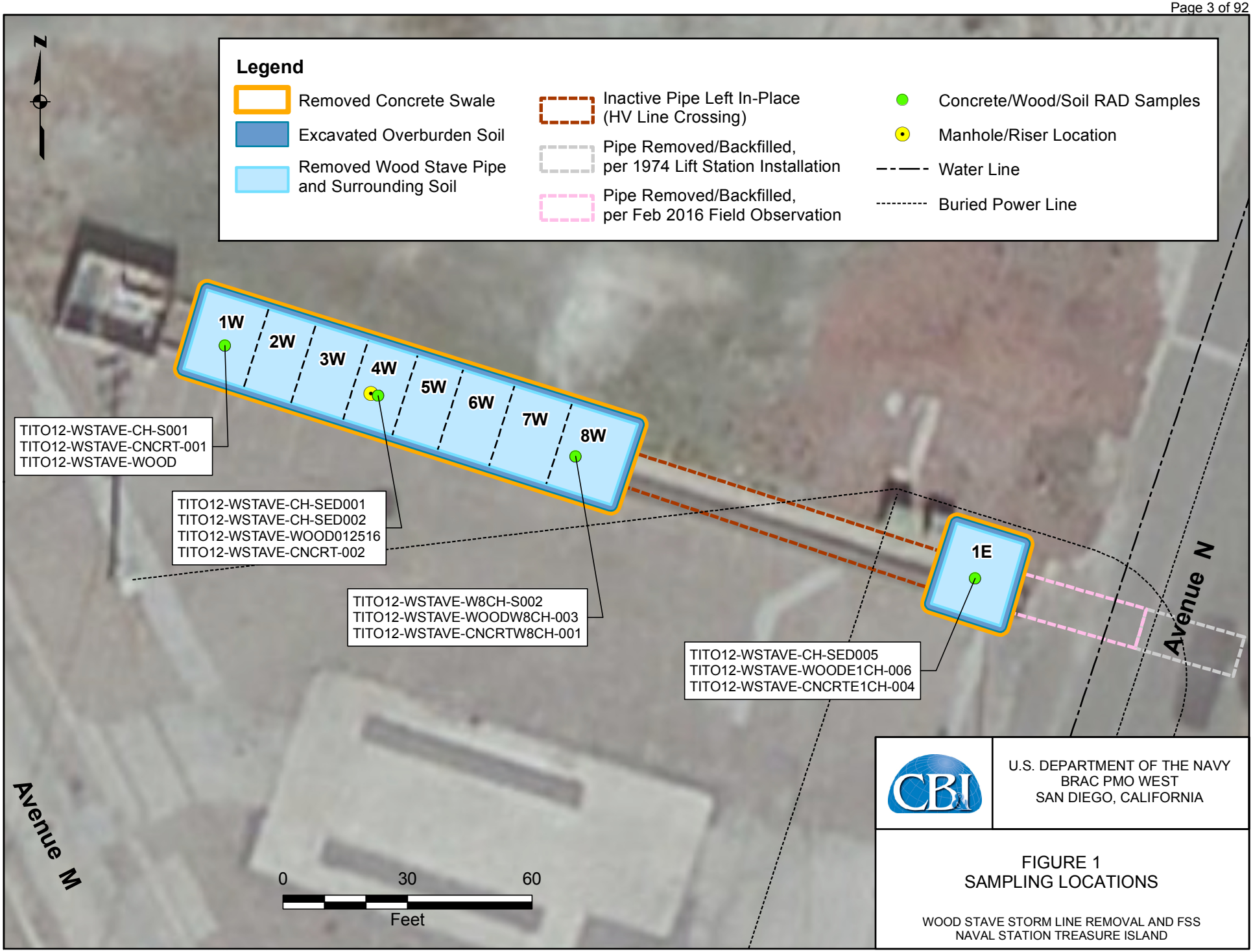
CPM = Counts Per Minute
CPS = Counts Per Second

In-Process Sample Analytical Data – Wood Stave Pipe Excavation (Figure 1)

Sample Identification	Excavation Section	Material Type	^{226}Ra Analytical Results (pCi/g)	Data Package
TITO12-WSTAVE-CH-S001	1W	Soil (Adjacent to Pipe)	0.430	160-15772 (page 47)
TITO12-WSTAVE-WOOD	1W	Wood	-0.0765 U	160-15772 (page 47)
TITO12-WSTAVE-CNCRT-001	1W	Concrete	0.218 U	160-15947 (page 60)
TITO12-WSTAVE-CH-SED001	4W	Sediment (Within Pipe)	0.472	160-15883 (page 76)
TITO12-WSTAVE-CH-SED002	4W	Sediment (Within Pipe)	0.412	160-15883 (page 74)
TITO12-WSTAVE-WOOD012516	4W	Wood	-0.0127 U	160-15883 (page 73)
TITO12-WSTAVE-CNCRT-002	4W	Concrete	0.423	160-15947 (page 60)
TITO12-WSTAVE-W8CH-S002	8W	Soil (Adjacent to Pipe)	0.371	160-16018 (page 87)
TITO12-WSTAVE-WOODW8CH-003	8W	Wood	-0.0713 U	160-16018 (page 88)
TITO12-WSTAVE-CNCRTW8CH-001	8W	Concrete	0.375	160-16018 (page 87)
TITO12-WSTAVE-CH-SED005	1E	Sediment (Within Pipe)	0.365	160-16018 (page 89)
TITO12-WSTAVE-WOODE1CH-006	1E	Wood	0.484	160-16018 (page 89)
TITO12-WSTAVE-CNCRTE1CH-004	1E	Concrete	0.280	160-16018 (page 89)

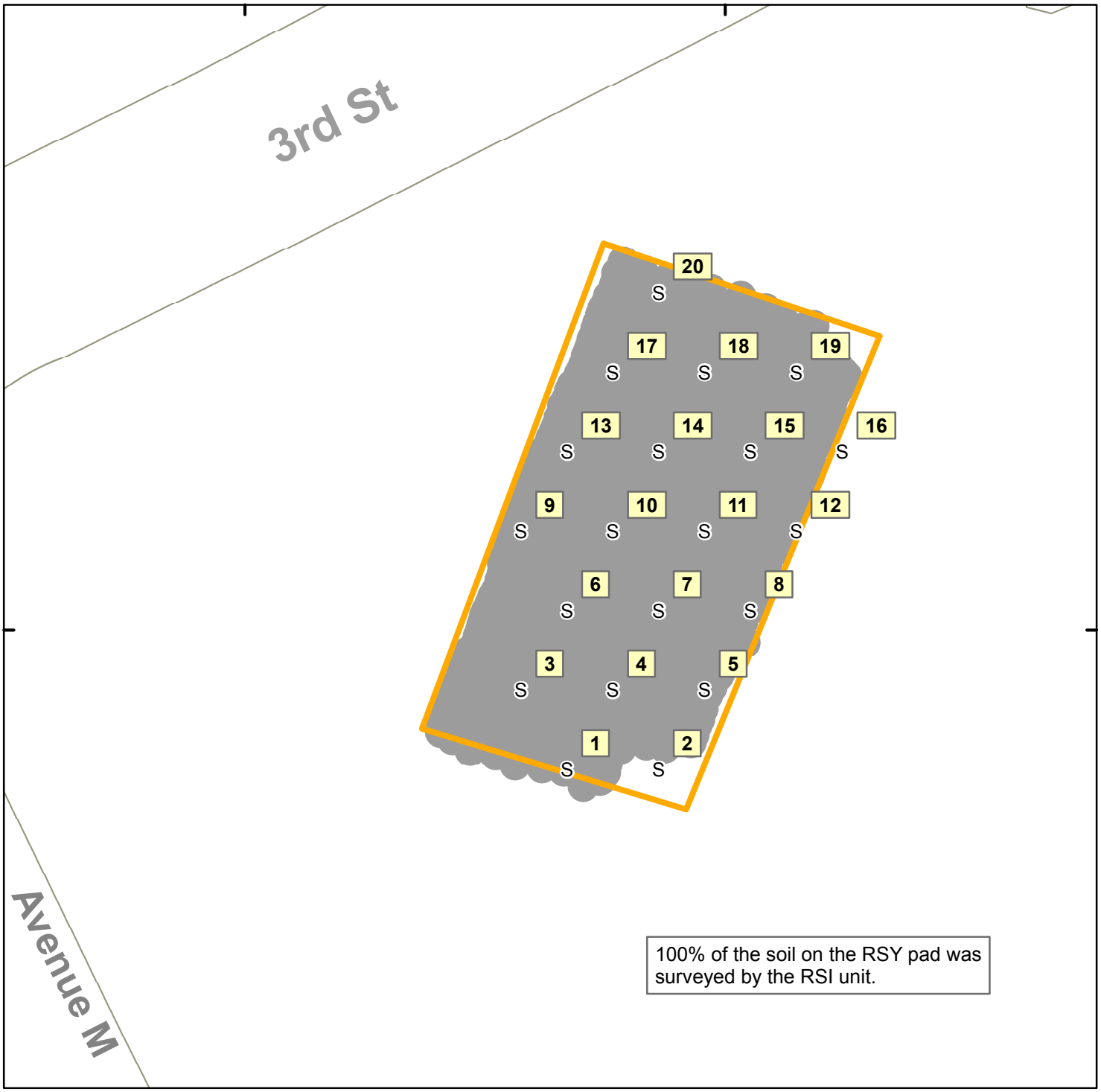
U = ^{226}Ra was reported below the minimum detectable concentration for that sample

Summary
1) RSI gamma scan and data review of excavated soil on RSY Pad 233A Use 1—upon review of initial scan data, follow-up static investigations were deemed necessary, and investigation locations were identified as per the RSI Data Evaluation Process (pages 5-6). Gamma scan coverage shown on Systematic Sample Survey map (page 4).Contour maps of initial scan data are shown on RSI Data Plots (page 7). Data review results are summarized on RSI Review Summary (page 8).
2) Follow-up static survey on RSY Pad 233A Use 1—nine locations identified during the data review process were investigated, resulting in all locations < static IL. Follow-up locations are shown on the Follow-up Static Survey map (page 9).
3) Systematic sampling survey on RSY Pad 233A Use 1—twenty systematic soil samples (001-020) obtained and submitted for gamma spectroscopy analysis. Static measurements were performed at all systematic sample locations. Sample locations for systematic samples are shown on the Systematic Sample Survey map (page 4). Test America sample results are attached (pages 14-37).
4) In-Process sampling of Wood Stave Pipe excavation site—thirteen in-process samples were obtained at the excavation site for characterization and submitted for gamma spectroscopy analysis, including: two soil samples adjacent to the pipe, four wood samples of pipe material, three sediment samples from inside the pipe, and four concrete samples from concrete slurry material identified during excavation. Sample locations are shown in Figure 1 (page 3). Test America sample results are attached (pages 38-92).
Conclusions: **All locations on RSY 233A (Use 1) with elevated Z-scores identified by the RSI gamma scan were deemed comparable to background. 9 follow-up static locations were investigated following the initial data review, with readings < static IL at all locations.** **Additional locations on RSY 233A Use 1 (a-b, page 7) with elevated Z-scores that did not meet the criteria for a follow-up investigation were evaluated by spectral analysis of the RSI gamma scan data, which did not indicate the presence of Ra-226 above background levels (pages 12-13).** **Analytical results for systematic samples from RSY 233A (Use 1) are concluded to be comparable to background, based on the Wilcoxon Rank Sum test, Quantile test, Retrospective Power Curve calculation, and histogram, as shown on pages 10-11. These statistical tools were utilized to verify the appropriate level of reasonable effort.** **RSY 233A (Use 1) contains soil from the Wood Stave Pipe Removal excavation.** **Soil on RSY 233A (Use 1) consists of all excavated impacted soil (defined as soil within one foot of the pipe), plus an additional 6 inches of over-excavation from the bottom and sidewalls of the Wood Stave Pipe Removal excavation. No visible debris and/or staining was identified during excavations. Data from in-process sampling of adjacent soil, sediment, wooden pipe material, and concrete slurry material (In-Process Sample Analytical Data table, page 1) are also comparable with background Ra-226 concentrations at Treasure Island; sample locations are shown in Figure 1 (page 3). This report and concurrence will therefore be utilized as part of the Final Status Survey Report.** **Disposition: Soil from RSY 233A (Use 1) shall be dispositioned as non-LLRW waste to be disposed of offsite following appropriate chemical characterization.** **CB&I requests RASO concurrence to release soil from RSY 233A (Use 1) as Non-LLRW, and to backfill the Wood Stave Pipe excavation using clean import backfill material.**


N
Legend
Removed Concrete Swale
Excavated Overburden Soil
Removed Wood Stave Pipe and Surrounding Soil
Inactive Pipe Left In-Place (HV Line Crossing)
Pipe Removed/Backfilled, per 1974 Lift Station Installation
Pipe Removed/Backfilled, per Feb 2016 Field Observation
Concrete/Wood/Soil RAD Samples
Manhole/Riser Location
Water Line
Buried Power Line
1W
2W
3W
4W
5W
6W
7W
8W
1E
TITO12-WSTAVE-CH-S001
TITO12-WSTAVE-CNCRT-001
TITO12-WSTAVE-WOOD
TITO12-WSTAVE-CH-SED001
TITO12-WSTAVE-CH-SED002
TITO12-WSTAVE-WOOD012516
TITO12-WSTAVE-CNCRT-002
TITO12-WSTAVE-W8CH-S002
TITO12-WSTAVE-WOODW8CH-003
TITO12-WSTAVE-CNCRTW8CH-001
TITO12-WSTAVE-CH-SED005
TITO12-WSTAVE-WOODE1CH-006
TITO12-WSTAVE-CNCRTE1CH-004
Avenue N
Avenue M
0
30
60
Feet
CBI
U.S. DEPARTMENT OF THE NAVY
BRAC PMO WEST
SAN DIEGO, CALIFORNIA
FIGURE 1
SAMPLING LOCATIONS
WOOD STAVE STORM LINE REMOVAL AND FSS
NAVAL STATION TREASURE ISLAND

RSYPAD 233A Use 1

Survey Number:
TIRS-02152016-WPS-JSS-052



Instrument # 97290

S Systematic Samples Locations

RSI Coverage

RSY Pad Boundaries

Investigation Point ID

CB&I Federal Services, LLC

N

0 5 10 20 Feet

Coordinate system: CSP Zone III. NAD83, US Survey Foot

Data Processed In Treasure Island Office

RS-700 Mobile Radiation Monitoring System

- Self-contained gamma-ray radiation detection and monitoring system
- Built-in GPS receiver
- (2) RSX-1 4-liter NaI(Tl) gamma detectors oriented perpendicular to the direction of travel (VD1 denotes both detectors summed; VD3 refers to the left detector; and VD4 refers to the right detector)
- Multi-Channel Analyzer, allowing for monitoring of energy-specific regions of interest (ROIs)
- RadAssist survey software for control, monitoring, and recording

Ten ROIs have been established for radium and progeny as well as other naturally-occurring or anthropogenic gamma-emitting radionuclides that may be of interest:

ROI	Description	Energy Range (keV)	Primary Peak (keV)
1	Total counts	411 – 2811	N/A
2	Potassium	1371 – 1569	1460
3	U/Ra-226	1659 – 1860	1764 (Bi-214)
4	Thorium	2409 – 2811	2614 (Tl-208)
5	Annihilation	456 – 570	511
6	Ra-226	546 – 666	609 (Bi-214)
7	Cs-137	549 – 741	662
8	Pb-214/Ra-226	327 – 399	351
9	Range	45 – 1980	N/A
10	Gross Counts	3 – 3072	N/A

A tiered approach is used during data review to identify follow-up locations. Raw data are exported to a comma delimited format using RadAsssist and imported into an Excel spreadsheet for review and analysis. Count rate data are compared with ROI- and material-specific investigation levels (ILs). In addition, the following review steps are completed to determine if additional follow-up measurements are necessary:

- **Playback Review**: The data file is replayed in RadAssist and reviewed for elevated count rates in ROIs 1, 3, 6, and 10 for virtual detector (VD) 1 (both detectors summed). The scan screen is also monitored for elevated count rates and alarms.
- **Count Rate Time Series Review**: The count rates for ROIs 1, 3, 6, and 10 for VDs 1, 3 (detector 1), and 4 (detector 2) are plotted in a time series and reviewed for additional peaks in count rate.
- **All ROIs**:
    - **Z-Scores**: The Z-Scores are calculated for each location in all ROIs for VDs 1, 3, and 4. Any location with four or more ROIs having a Z-Score greater than three (Z>3) is marked for follow-up.
    - **Local Z-Scores**: Local Z-Scores are calculated using a moving average for each data point in all ROIs for VDs 1, 3, and 4 to identify elevated count rates where the background is variable (e.g. multiple surface types). Any location (in a survey unit that meets this condition) with four or more ROIs having a local Z>3 is marked for follow-up.
    - **Semi-local Z-Scores**: Semi- local Z-Scores are calculated using the global average, but with a moving average for the standard deviation for VDs 1, 3, and 4. This is used for survey data that have a consistent background but an area or areas of highly elevated count rates, in order to identify smaller areas of elevated count rates that may not otherwise be identified by the initial Z-score review. Any location (in a survey unit that meets this condition) with four or more ROIs having a semi-local Z>3 is marked for follow-up.

- **ROIs 3, 6, 8, and 10 (radium-specific ROIs):**
  - Z-Scores: The Z-Scores are calculated for each location in the radium-specific ROIs for VDs 1, 3, and 4. Any location with three or more radium-specific ROIs having a Z>3 is marked for follow-up.
  - Local Z-Scores: Local Z-Scores are calculated using a moving average for each data point in the radium-specific ROIs for VDs 1, 3, and 4 to identify elevated count rates where the background is variable (e.g. multiple surface types). Any location (in a survey unit that meets this condition) with three or more radium-specific ROIs having a local Z>3 is marked for follow-up.
  - Semi-local Z-Scores: Semi- local Z-Scores are calculated using the global average, but with a moving average for the standard deviation for VDs 1, 3, and 4. This is used for survey data that have a consistent background but an area or areas of highly elevated count rates, in order to identify smaller areas of elevated count rates that may not otherwise be identified by the initial Z-score review. Any location (in a survey unit that meets this condition) with three or more radium-specific ROIs having a semi-local Z>3 is marked for follow-up.
- **Z-Score Time Series Review**: The three types of Z-Scores for ROIs 1, 3, 6, and 10 for VDs 1, 3, and 4 are plotted in a time series and reviewed for additional peaks in Z-Scores.

Follow-up locations will be plotted on contour maps depicting all locations with any radium-specific ROI Z>3. Any location selected for follow-up, or any location with a radium-specific ROI Z>3 will undergo spectral analysis to determine if it is statistically likely that there is radium present at that location in quantities greater than the background.

A background spectrum, obtained from NSTI Reference Area 7, is subtracted from the local spectral data for a given location, and the resulting net spectrum is plotted. Critical levels, as defined in Section 6.7.1 of the Multi Agency Radiation Survey and Site Investigation Manual are calculated and plotted based on background levels. The critical level is the level, in counts, at which there is a statistical probability (with a predetermined confidence) of incorrectly identifying a measurement system background value as greater than background. Any response above this level is considered to be greater than background. The critical level is calculated for ROIs 3, 6, and 8 according to the equation shown below:

$$L_C = 2.33\sqrt{B}$$

Where:

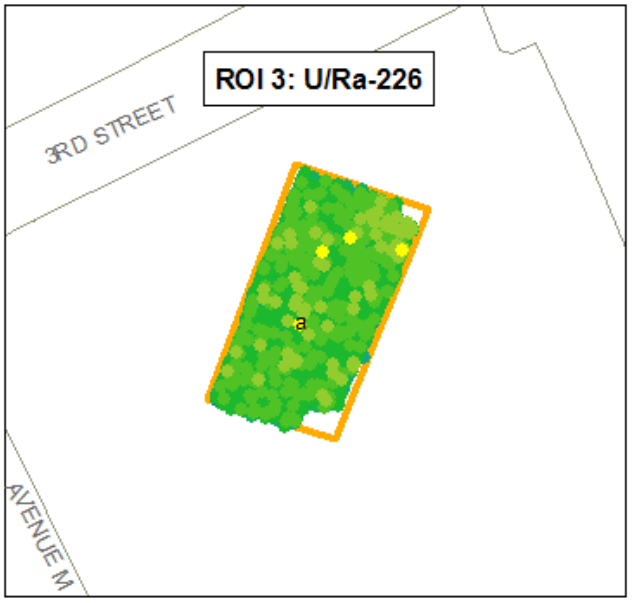
LC	=	critical level (counts)
B	=	average background in the ROI

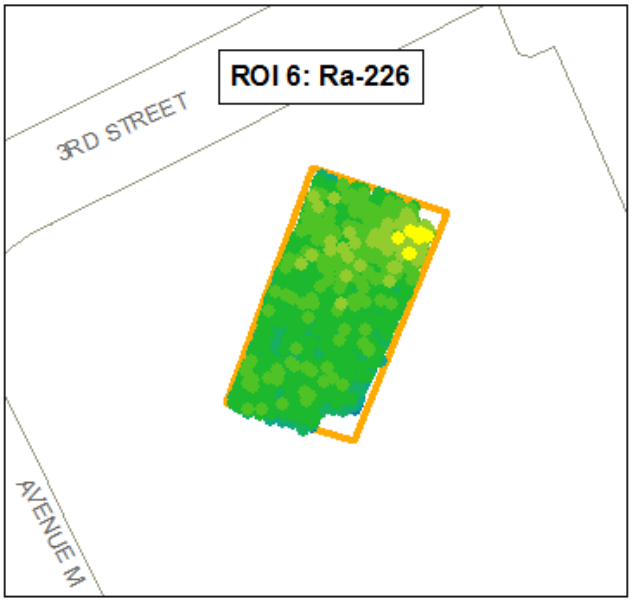
The ROI ranges for ROIs 3, 6, and 8 are then plotted on the net spectrum graph with their respective critical levels. When count rates in the net gamma spectrum at a given location do not exceed critical levels for any radium-specific energy ranges, it is unlikely that radium exists at that location above background.

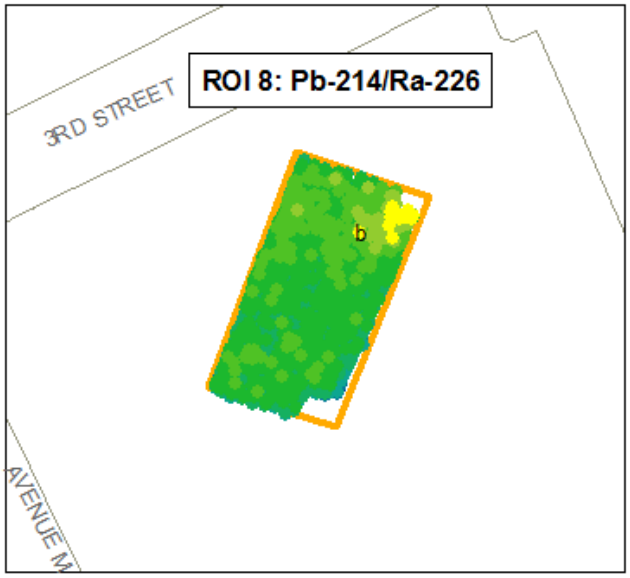
Any data point that is both above the critical level and within the energy range of a given ROI is considered above background for that radionuclide and will be flagged for further investigation in the field.

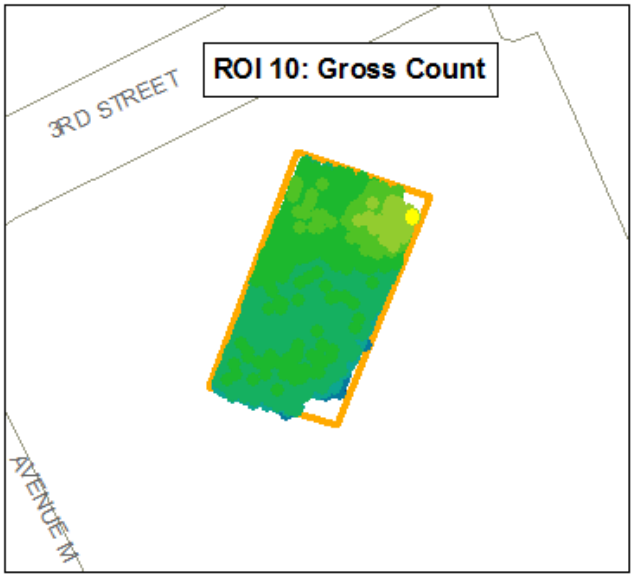
RSI DATA PLOT

RSY-233A Use 1









ROI from RSI Walkover Survey (VD1)

> 3 std dev	> 0 to < 1 std dev	> -3 to < -2 std dev
> 2 to < 3 std dev	> -1 to < 0 std dev	< -3 std dev
> 1 to < 2 std dev	> -2 to < -1 std dev	Areas

RSI Review Summary

Summary:
9 locations were selected for follow-up investigation. Locations were identified by elevated peaks noted in the playback review and/or time series charts, and by using the Z-Score, Local Z-Score, and Semi-Local Z-Score reviews as described in the RSI Data Evaluation Process on pages 4-5. The table below details the reasons for each investigation by location.

Locations denoted a-b on the RSI Data Plots page (see previous page) did not meet the evaluation criteria for further investigation. Elevated Z-scores at these locations were identified only in specific ROIs, including: one location exclusive to ROI 3 (a), and one location exclusive to ROI 8 (b). Elevated gross count rates at these locations were not identified, and a review of the data did not reveal any additional indicators warranting a follow-up investigation. Furthermore, spectral analyses performed on data obtained from these locations did not confirm the presence of Radium-226; figures are provided on pages 12-13.

RSY 233A Use 1 Investigation								Follow-up			
Location	Longitude	Latitude	Details	Maximum Result (Ra/Tot)				Meter SN	Static Count	Static IL (cpm)	Comments
				VD	ROI	Z-Score	Type:				
1	2127137.94446	6023254.35543	3 ROIs Z>3 (Ra/Tot), Highest Z-Score, time series and playback review peaks	4	8	5.00	Normal	97290	16,690	20,154	< IL
2	2127130.46136	6023254.58855	Time Series Peak					97290	15,858	20,154	< IL
3	2127130.52464	6023251.41195	>4 ROIs Z>3 (all ROIs), spectral analysis location					97290	16,204	20,154	< IL
4	2127134.96231	6023248.03361	Time Series Peak					97290	15,735	20,154	< IL
5	2127136.19254	6023241.12462	Time Series Peak, Playback Review Peak					97290	15,837	20,154	< IL
6	2127129.43665	6023232.90094	Time Series Peak					97290	14,261	20,154	< IL
7	2127131.36622	6023227.45036	Time Series Peak					97290	14,475	20,154	< IL
8	2127120.35678	6023213.36401	Time Series Peak, Playback Review Peak					97290	14,245	20,154	< IL
9	2127147.70254	6023230.08700	Time Series Peak, Playback Review Peak					97290	14,565	20,154	< IL

RSYPAD 233A Use 1

Survey Number:
TIRS-02152016-WPS-JSS-054

Instrument # 97290

- Investigation Points
- Data Points Not Requiring Further Investigation
- RSY Pad Boundaries
- # Investigation Point ID

CB&I Federal Services, LLC

N

0 5 10 20 Feet

Coordinate system: CSP Zone III. NAD83, US Survey Foot

Data Processed In Treasure Island Office

WILCOXON RANK SUM TEST

Nuclide: Ra-226 Location: RSY 233A-1

LBGR: 0.483 pCi/g

DATA	AREA	ADJUSTED DATA	RANKS	SURVEY UNIT RANKS	Sorted Ranks	Location Associated with Sorted Rank
0.49	R	0.49	22	0	1	S
0.98	R	0.98	40	0	2	S
0.83	R	0.83	35.5	0	3	S
0.54	R	0.54	25	0	4	S
0.57	R	0.57	27.5	0	5	S
0.55	R	0.55	26	0	6	S
0.57	R	0.57	27.5	0	7	S
0.46	R	0.46	21	0	8	S
0.50	R	0.5	23	0	9	S
0.66	R	0.66	29.5	0	10	S
0.75	R	0.75	33	0	11	S
0.70	R	0.7	32	0	12.5	S
0.86	R	0.86	37	0	12.5	S
0.51	R	0.51	24	0	14	S
0.91	R	0.91	39	0	15	S
0.83	R	0.83	35.5	0	16	S
0.79	R	0.79	34	0	17	S
0.90	R	0.9	38	0	18	S
0.66	R	0.66	29.5	0	19	S
0.69	R	0.69	31	0	20	S
0.393	S	-0.089939192	10	10	21	R
0.358	S	-0.124939192	7	7	22	R
0.465	S	-0.017939192	17	17	23	R
0.364	S	-0.118939192	9	9	24	R
0.295	S	-0.187939192	2	2	25	R
0.184	S	-0.298939192	1	1	26	R
0.360	S	-0.122939192	8	8	27.5	R
0.338	S	-0.144939192	5	5	27.5	R
0.403	S	-0.079939192	12.5	12.5	29.5	R
0.400	S	-0.082939192	11	11	29.5	R
0.413	S	-0.069939192	15	15	31	R
0.347	S	-0.135939192	6	6	32	R
0.492	S	0.009060808	20	20	33	R
0.309	S	-0.173939192	4	4	34	R
0.403	S	-0.079939192	12.5	12.5	35.5	R
0.478	S	-0.004939192	19	19	35.5	R
0.404	S	-0.078939192	14	14	37	R
0.298	S	-0.184939192	3	3	38	R
0.448	S	-0.034939192	16	16	39	R
0.472	S	-0.010939192	18	18	40	R
		Sum =	820	210		

* This spreadsheet is designed to work with a set of twenty measurements, 10 from the survey unit (S) and 10 from the background reference area (R). If a different number of measurements have been performed, it is necessary to modify the spreadsheet to account for the change in the number of measurements.

# of R:	20	*n*
# of S:	20	*m*
Avg Rank R:	30.5	
Avg Rank S:	10.5	

For *m* or *n* greater than 20, the critical value (k) can be calculated for Scenario B from

$$\frac{m(n+m+1)}{2} + z\sqrt{\frac{nm(n+m+1)}{12}}$$

z = 97.5% percentile of standard normal distribution = 1.960

k = 482.5

$\alpha_W = \alpha/2 =$ 0.025

$\beta =$ 0.05

Since the sum of survey unit ranks is less than the critical value, the null hypothesis that the survey unit concentrations do not exceed the LBGR is accepted (i.e., survey unit passes). Scenario B

DCGL 1

LBGR = 3x Background Std Deviation

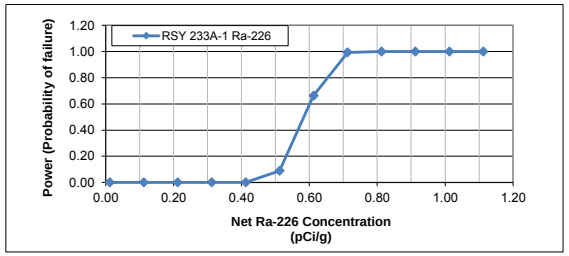
LBGR = 0.483

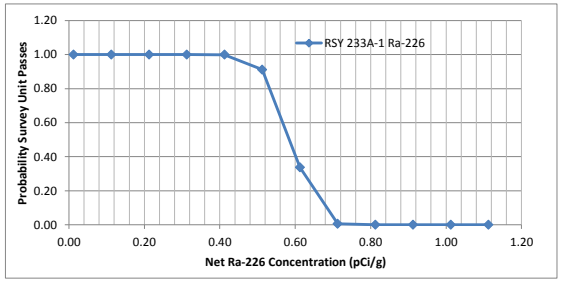
POWER CURVE CALCULATION

The power curve demonstrates that at a Ra-226 concentration above background of 0.81 pCi/g or greater, the SU will fail the WRS test with a 100% probability. At the DCGL of 1.00 pCi/g above background and estimated LBGR of 0.483, the SU will pass the WRS test at a 00% probability.

	SU Stats		Concentration	Concentration above Background (C)	(C-LBGR)/SD	p1	p2	E(Wmw)	Var(Wmw)	SD(Wmw)	z	Power	Probability of passing
Count	20	*m*	0.7	0.01	-2.9	0.01695	0.00269	6.7788	43.18647	6.5716411	40.3521	0.00	1.00
SD	0.075		0.8	0.11	-2.3	0.03855	0.00847	15.42	120.9048	10.995672	23.3308	0.00	1.00
Median	0.397		0.9	0.21	-1.7	0.11467	0.03935	45.8664	438.8427	20.948572	10.7927	0.00	1.00
			1.0	0.31	-1.1	0.21834	0.09889	87.3352	846.8185	29.100146	6.3444	0.00	1.00
	Ref Stats		1.1	0.41	-0.4	0.38865	0.22917	155.4596	1282.524	35.812351	3.25303	0.00	1.00
Count	20	*n*	1.2	0.51	0.2	0.55623	0.39139	222.4924	1345.121	36.675894	1.34873	0.09	0.91
SD	0.161		1.3	0.61	0.8	0.71420	0.57447	285.6784	1060.423	32.564133	-0.42133	0.66	0.34
			1.4	0.71	1.4	0.83890	0.74170	335.5604	630.7938	25.115608	-2.53238	0.99	0.01
Critical Value	482.5		1.5	0.81	2.0	0.92135	0.86577	368.54	285.5796	16.8991	-5.71521	1.00	0.00
			1.6	0.91	2.7	0.97188	0.94921	388.7524	81.69222	9.0383749	-12.922	1.00	0.00
			1.7	1.01	3.3	0.99019	0.98164	396.0752	21.5749	4.6448794	-26.7213	1.00	0.00
			1.8	1.11	3.9	0.99766	0.99550	399.0644	3.510254	1.8735671	-67.8418	1.00	0.00

Number of Samples	
σ	0.161
LBGR	0.483
Δ/σ	3.21
Pr	0.983039
N	22.28
N/2	12
Actual N	20
SU σ	0.075
Z(1-alpha)	1.960
Z(1-beta)	1.645





QUANTILE TEST

From NUREG 1505, Table A.7c Values of r and k for the Quantile Test When α Is Approximately 0.05

20	n (number of survey unit measurements)
20	m (number of reference area measurements)

Use:

m =	20
n =	20
4	r
4	k
0.053	alpha

If *k* or more of the *r* largest measurements in the combined ranked data set are from the survey unit, the null hypothesis of the Quantile test (that there is no residual radioactivity above the LBGR in any part of the survey unit) is rejected.

0 of the largest 4 adjusted measurements are from S.	The null hypothesis is accepted.

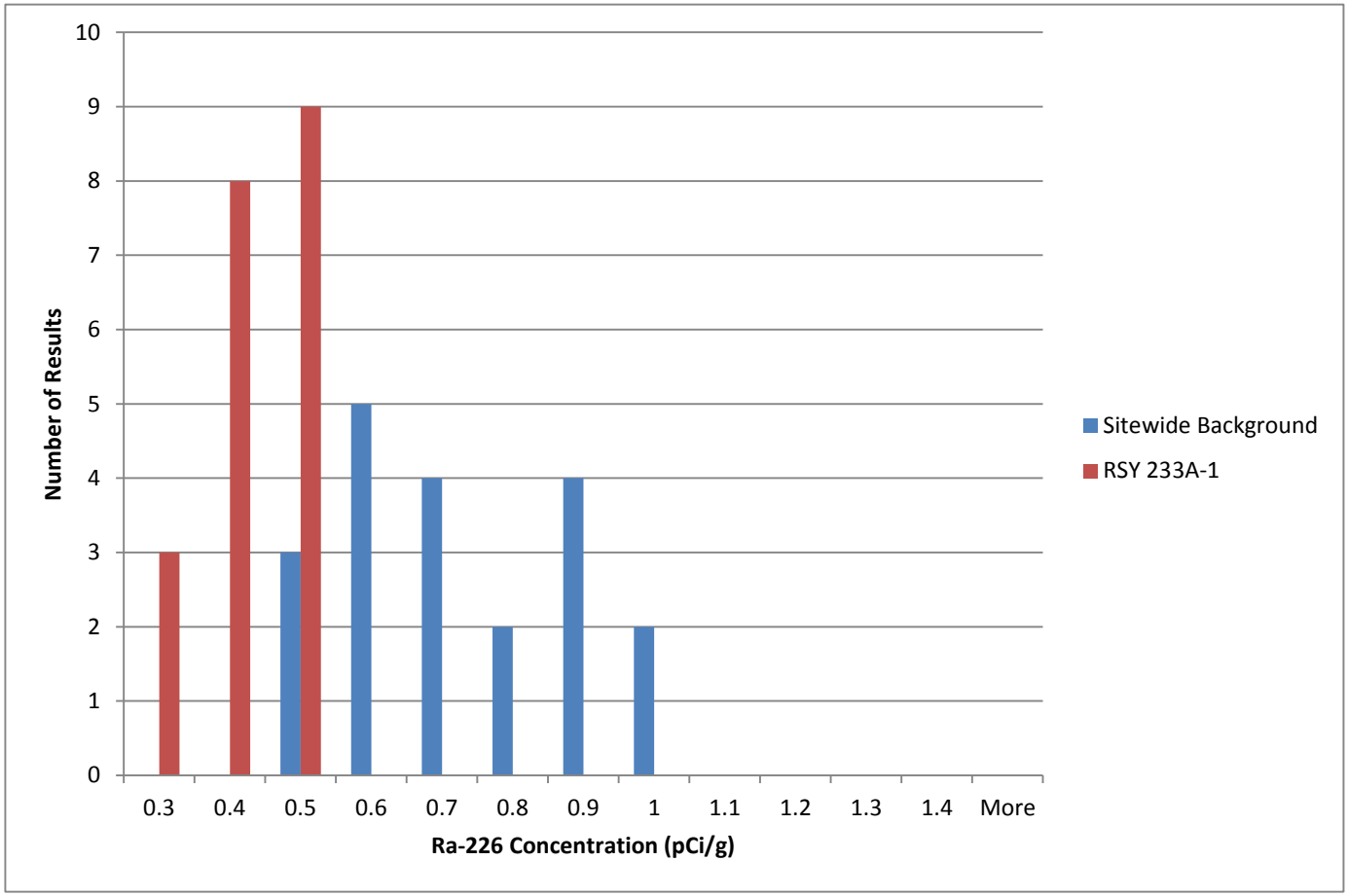
Histogram, RSY 233A-1 vs. Sitewide Background

Background

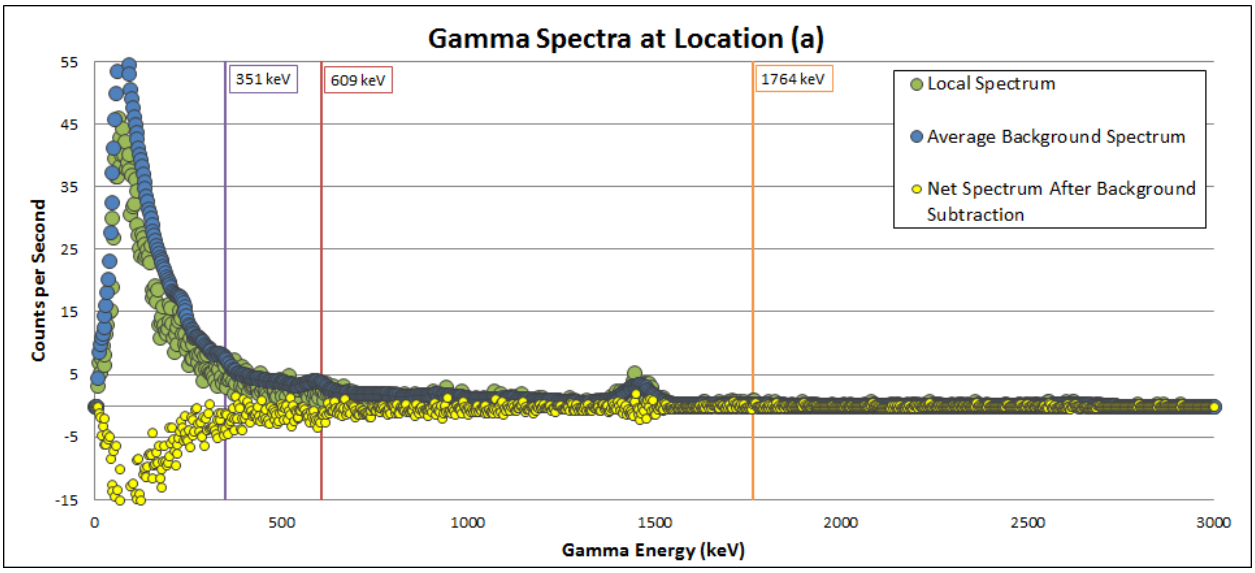
Bin	Frequency
0.3	0
0.4	0
0.5	3
0.6	5
0.7	4
0.8	2
0.9	4
1	2
1.1	0
1.2	0
1.3	0
1.4	0
More	0

RSY 233A-1

Bin	Frequency
0.3	3
0.4	8
0.5	9
0.6	0
0.7	0
0.8	0
0.9	0
1	0
1.1	0
1.2	0
1.3	0
1.4	0
More	0

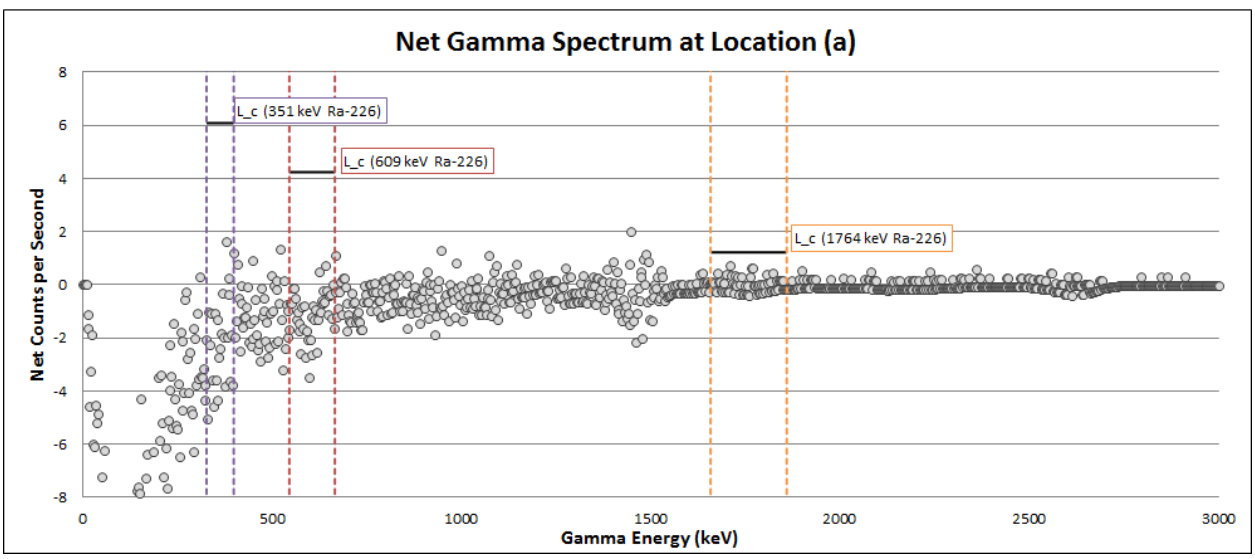


RSI Spectral Analysis Results: RSY 233A Use 1 – **Gamma Spectra at Location (a)**
(VD1 – Right and Left Detectors Summed)



Gamma spectra for **Location (a)**: local – background* = net

*Average background spectrum obtained from scan of Reference Area 7.



Net spectrum for **Location (a)**: net count rate does not exceed critical levels (L_c) at any of the indicated energy ranges

MARSSIM 6.7.1

L_c: Critical level above which a net count is considered above background (lower bound on a 95% detection interval)

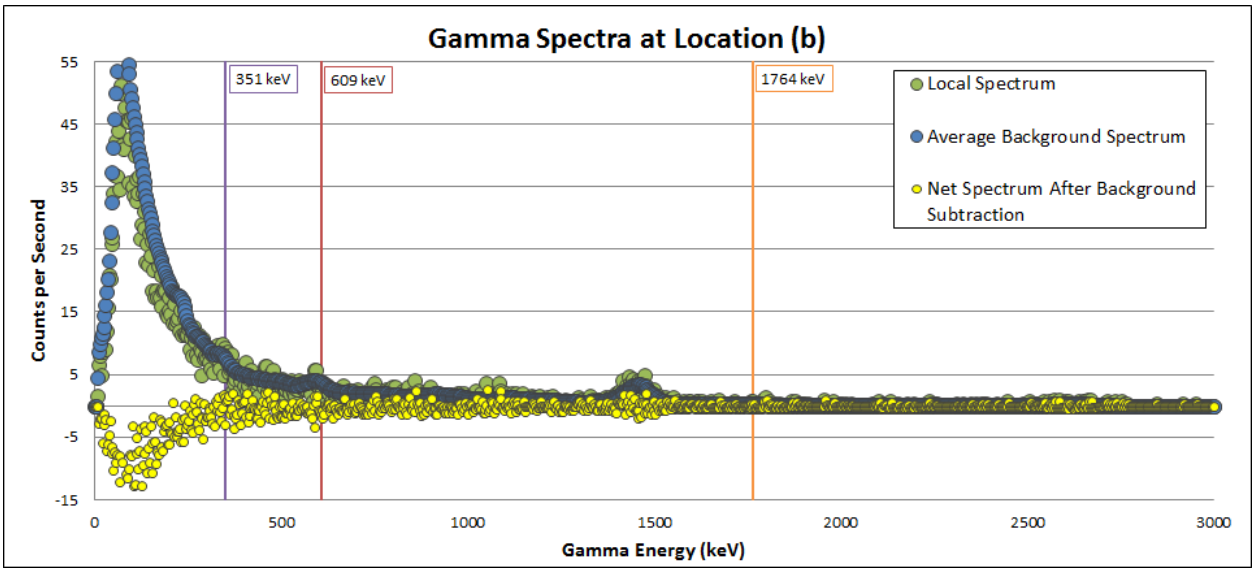
B: number of background counts that are expected to occur while performing an actual measurement (mean value)

{**B** = background counts for each channel averaged over all locations in background scan, then averaged over specified energy ranges}

MARSSIM APPENDIX I, TABLE I.1

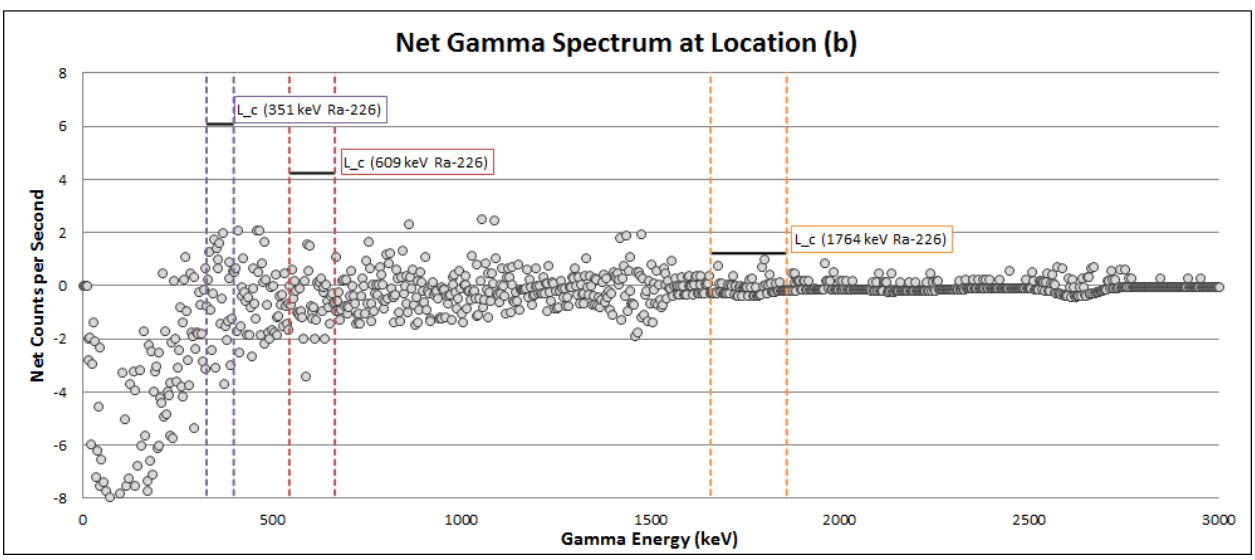
$$L_c = 2.33\sqrt{B}$$

RSI Spectral Analysis Results: RSY 233A Use 1 – **Gamma Spectra at Location (b)**
(VD1 – Right and Left Detectors Summed)



Gamma spectra for **Location (b)**: local – background* = net

*Average background spectrum obtained from scan of Reference Area 7.



Net spectrum for **Location (b)**: net count rate does not exceed critical levels (L_c) at any of the indicated energy ranges.

MARSSIM 6.7.1

L_c: Critical level above which a net count is considered above background (lower bound on a 95% detection interval)

B: number of background counts that are expected to occur while performing an actual measurement (mean value)

{**B** = background counts for each channel averaged over all locations in background scan, then averaged over specified energy ranges}

MARSSIM APPENDIX I, TABLE I.1

$$L_c = 2.33\sqrt{B}$$

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica St. Louis
13715 Rider Trail North
Earth City, MO 63045
Tel: (314)298-8566

TestAmerica Job ID: 160-16133-2
Client Project/Site: Treasure Island - 500475

For:
CB&I Environmental & Infrastructure, Inc
4005 Port Chicago Hwy
Concord, California 94520

Attn: Patricia Flynn

Authorized for release by:
3/18/2016 2:09:14 PM

Erika Gish, Project Manager II
(314)298-8566
erika.gish@testamericainc.com

LINKS

Review your project results through TotalAccess

Have a Question? Ask The Expert

Visit us at: www.testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

Table of Contents

Cover Page 1
Table of Contents 2
Case Narrative 3
Chain of Custody 5
Receipt Checklists 8
Definitions/Glossary 9
Method Summary 10
Sample Summary 11
Client Sample Results 12
QC Sample Results 22
QC Association Summary 24

Job ID: 160-16133-2

Laboratory: TestAmerica St. Louis

Narrative

CASE NARRATIVE

Client: CB&I Environmental & Infrastructure, Inc

Project: Treasure Island - 500475

Report Number: 160-16133-2

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In some cases, due to interference or analytes present at high concentrations, samples were diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

TestAmerica St. Louis attests to the validity of the laboratory data generated by TestAmerica facilities reported herein. All analyses performed by TestAmerica facilities were done using established laboratory SOPs that incorporate QA/QC procedures described in the application methods. TestAmerica's operations groups have reviewed the data for compliance with the laboratory QA/QC plan, and data have been found to be compliant with laboratory protocols unless otherwise noted below.

The test results in this report meet all NELAP requirements for parameters for which accreditation is required or available. Any exceptions to NELAP requirements are noted in this report. Pursuant to NELAP, this report may not be reproduced, except in full, without the written approval of the laboratory.

Calculations are performed before rounding to avoid round-off errors in calculated results.

All holding times were met and proper preservation noted for the methods performed on these samples, unless otherwise detailed in the individual sections below.

All solid sample results for Chemistry analyses are reported on an "as received" basis unless otherwise indicated by the presence of a % solids value in the method header. All soil/sediment sample results for radiochemistry analyses are based upon sample as dried and disaggregated with the exception of tritium, carbon-14, and iodine-129 by gamma spectroscopy unless requested as wet weight by the client."

Reference the chain of custody and condition upon receipt report for any variations on receipt conditions and temperature of samples on receipt
Manual Integrations were performed only when necessary and are in compliance with the laboratory's standard operating procedure. Detailed information can be found in the raw data section of the level IV report.

The following clean-up methods for Organic analyses may have been used on the samples in this data set. Specific methods employed are documented on the batch extraction logs:

Method 3600C: Cleanup
Method 3620C: Florisil Cleanup
Method 3630C: Silica Gel Cleanup
Method 3640A: Gel-Permeation Cleanup
Method 3650B: Acid-Base Partition Cleanup
Method 3660B: Sulfur Cleanup
Method 3665A: Sulfuric Acid/Permanganate Cleanup

This laboratory report is confidential and is intended for the sole use of TestAmerica and its client.

Job ID: 160-16133-2 (Continued)

Laboratory: TestAmerica St. Louis (Continued)

RECEIPT

The samples were received on 2/17/2016 8:40 AM; the samples arrived in good condition, properly preserved. The temperature of the cooler at receipt was 21.0º C.

RADIUM-226 BY GAMMA SPEC (21 DAY INGROWTH)

Samples TITO12-RSY233A_1CH-S001 (160-16133-1), TITO12-RSY233A_1CH-S002 (160-16133-2), TITO12-RSY233A_1CH-S003 (160-16133-3), TITO12-RSY233A_1CH-S004 (160-16133-4), TITO12-RSY233A_1CH-S005 (160-16133-5), TITO12-RSY233A_1CH-S006 (160-16133-6), TITO12-RSY233A_1CH-S007 (160-16133-7), TITO12-RSY233A_1CH-S008 (160-16133-8), TITO12-RSY233A_1CH-S009 (160-16133-9), TITO12-RSY233A_1CH-S010 (160-16133-10), TITO12-RSY233A_1CH-S011 (160-16133-11), TITO12-RSY233A_1CH-S012 (160-16133-12), TITO12-RSY233A_1CH-S013 (160-16133-13), TITO12-RSY233A_1CH-S014 (160-16133-14), TITO12-RSY233A_1CH-S015 (160-16133-15), TITO12-RSY233A_1CH-S016 (160-16133-16), TITO12-RSY233A_1CH-S017 (160-16133-17), TITO12-RSY233A_1CH-S018 (160-16133-18), TITO12-RSY233A_1CH-S019 (160-16133-19) and TITO12-RSY233A_1CH-S020 (160-16133-20) were analyzed for Radium-226 by gamma spec (21 day ingrowth) in accordance with EPA GA_01_R. The samples were dried on 02/17/2016, prepared on 02/18/2016 and analyzed on 03/14/2016.

No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

CHAIN OF CUSTODY

Ref. Document # TI_WOOD STAVE_RSY233 U1 #008

Page 1 of 3

Shaw Environmental and Infrastructure Inc. (a CB&I company)
Federal Services Division
4005 Port Chicago Hwy
Concord, CA 94520

Project Number: 500475
Project Name / Location: TI WOOD STAVE RSY 233 USE 1
Purchase Order #: 202220

Project Manager: John Hackett (Name & phone #)

Shipment Date: 2/16/2016
Waybill Number: 1Z 89V 462 01 9043
Lab Destination: TestAmerica St Loius 1029
Lab Contact Name / ph. #: Erika Gish

Send Report To: Patricia Flynn
Phone/Fax Number: 925-288-2037
Address: 4005 Port Chicago Hwy
City: Concord, CA, 94520

Sampler's Name(s): BR/AK/AN

Sample ID Number	Sample Description	Collection Information: Date	Time	Method	Matrix	# of containers	Preservative (water) / Preservative (soil) / Container Type	Analyses Requested: Gamma Scan							Dose Rate µR/Hr		
							Preservative (water)										
							Preservative (soil)	N/A									
							Container Type										
TITO12-RSY233A_1CH-S001	Wood Stave RSY 233 USE 1	02/15/16	1255	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S002	Wood Stave RSY 233 USE 1	02/15/16	1303	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S003	Wood Stave RSY 233 USE 1	02/15/16	1245	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S004	Wood Stave RSY 233 USE 1	02/15/16	1302	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S005	Wood Stave RSY 233 USE 1	02/15/16	1305	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S006	Wood Stave RSY 233 USE 1	02/15/16	1252	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S007	Wood Stave RSY 233 USE 1	02/15/16	1256	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S008	Wood Stave RSY 233 USE 1	02/15/16	1250	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S009	Wood Stave RSY 233 USE 1	02/15/16	1240	G	SO	1	16 oz Plastic	X							5		

Special Instructions: 7 days ingrown draft and follow with 21 days final

☐ 24-hr X 48-hr
Standard TAT ☐ ☐ 3-day ☐ 7-day

Level Of QC Required: I II III
Project Specific:

Relinquished By: [signature] Date: 2/16/16 Time: 1030
Received By: [signature] Date: 2.17.16 Time: 0840
Relinquished By: Date: Time:
Received By: Date:

Method Codes
C = Composite G = Grab

Matrix Codes
DW = Drinking Water SO = Soil
GW = Ground Water SL = Sludge
WW = Waste Water CP = Chip Samples
A = Air ABS=Asbestos, PO=Pipe Openning

160-16133 Chain of Custody

CHAIN OF CUSTODY

Ref. Document # TI_WOOD STAVE_RSY233 U1 #008

Page 2 of 3

Shaw Environmental and Infrastructure Inc. (a CB&I company)
Federal Services Division
4005 Port Chicago Hwy
Concord, CA 94520

Project Number: 500475
Project Name / Location: TI WOOD STAVE RSY 233 USE 1
Purchase Order #: 202220

Project Manager: John Hackett (Name & phone #)

Shipment Date: 2/16/2016
Waybill Number: 1Z89V462 019043 1029
Lab Destination: TestAmerica St Loius
Lab Contact Name / ph. #: Erika Gish

Send Report To: Patricia Flynn
Phone/Fax Number: 925-288-2037
Address: 4005 Port Chicago Hwy
City: Concord, CA, 94520

Sampler's Name(s): BR/AK/AN

Sample ID Number	Sample Description	Collection Information Date	Time	Method	Matrix	# of containers	Preservative (water) / Preservative (soil) / Container Type	Gamma Scan							Dose Rate µR/Hr		
							Preservative (water)										
							Preservative (soil)	N/A									
							Container Type										
TITO12-RSY233A_1CH-S010	Wood Stave RSY 233 USE 1	02/15/16	1257	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S011	Wood Stave RSY 233 USE 1	02/15/16	1253	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S012	Wood Stave RSY 233 USE 1	02/15/16	1259	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S013	Wood Stave RSY 233 USE 1	02/15/16	1230	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S014	Wood Stave RSY 233 USE 1	02/15/16	1258	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S015	Wood Stave RSY 233 USE 1	02/15/16	1307	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S016	Wood Stave RSY 233 USE 1	02/15/16	1300	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S017	Wood Stave RSY 233 USE 1	02/15/16	1225	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S018	Wood Stave RSY 233 USE 1	02/15/16	1247	G	SO	1	16 oz Plastic	X							5		

Analyses Requested

Special Instructions: 7 days ingrown draft and follow with 21 days final

☐ 24-hr X 48-hr

Standard TAT ☐ ☐ 3-day ☐ 7-day

Level Of QC Required: I II III Project Specific:

Relinquished By: Date: 2/16/16 Time: 1030
Received By: Date: 2.17.16 Time: 0840
Relinquished By: Date: Time:
Received By: Date: Time:

Method Codes

C = Composite G = Grab

Matrix Codes

DW = Drinking Water SO =Soil
GW = Ground Water SL = Sludge
WW = Waste Water CP = Chip Samples
A = Air ABS=Asbestos, PO=Pipe Openning

CHAIN OF CUSTODY

Ref. Document # TI_WOOD STAVE_RSY233 U1 #008

Page 3 of 3

Shaw Environmental and Infrastructure Inc. (a CB&I company)
Federal Services Division
4005 Port Chicago Hwy
Concord, CA 94520

Project Number: 500475
Project Name / Location: TI WOOD STAVE RSY 233 USE 1
Purchase Order #: 202220

Project Manager: John Hackett (Name & phone #)

Shipment Date: 2/16/2016
Waybill Number: 1Z89V4620194431029
Lab Destination: TestAmerica St Loius
Lab Contact Name / ph. #: Erika Gish

Send Report To: Patricia Flynn
Phone/Fax Number: 925-288-2037
Address: 4005 Port Chicago Hwy
City: Concord, CA, 94520

Sampler's Name(s): BR/AK/AN

Sample ID Number	Sample Description	Collection Information Date	Time	Method	Matrix	# of containers	Preservative (water) / Preservative (soil) / Container Type	Analyses Requested: Gamma Scan							Dose Rate µR/Hr		
							Preservative (soil)	N/A									
TITO12-RSY233A_1CH-S019	Wood Stave RSY 233 USE 1	02/15/16	1306	G	SO	1	16 oz Plastic	X							5		
TITO12-RSY233A_1CH-S020	Wood Stave RSY 233 USE 1	02/15/16	1220	G	SO	1	16 oz Plastic	X							5		

Special Instructions: 7 days ingrown draft and follow with 21 days final

☐ 24-hr X 48-hr
Standard TAT ☐ ☐ 3-day ☐ 7-day

Level Of QC Required: I II III Project Specific:

Relinquished By: Date: 2/16/16 Time: 1030
Received By: Date: 2-17-16 Time: 0840
Relinquished By: Date: Time:
Received By: Date: Time:

Method Codes
C = Composite G = Grab

Matrix Codes
DW = Drinking Water SO = Soil
GW = Ground Water SL = Sludge
WW = Waste Water CP = Chip Samples
A = Air ABS=Asbestos, PO=Pipe Openning

Login Sample Receipt Checklist

Client: CB&I Environmental & Infrastructure, Inc

Job Number: 160-16133-2

Login Number: 16133
List Number: 1
Creator: Clarke, Jill C

List Source: TestAmerica St. Louis

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	N/A	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Definitions/Glossary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Qualifiers

Rad

Qualifier	Qualifier Description
U	Undetected at the Limit of Detection.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains no Free Liquid
DER	Duplicate error ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision level concentration
MDA	Minimum detectable activity
EDL	Estimated Detection Limit
MDC	Minimum detectable concentration
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative error ratio
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Method Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Method	Method Description	Protocol	Laboratory
GA-01-R	Radium-226 & Other Gamma Emitters (GS)	DOE	TAL SL

Protocol References:

DOE = U.S. Department of Energy

Laboratory References:

TAL SL = TestAmerica St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Sample Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
160-16133-1	TITO12-RSY233A_1CH-S001	Solid	02/15/16 12:55	02/17/16 08:40
160-16133-2	TITO12-RSY233A_1CH-S002	Solid	02/15/16 13:03	02/17/16 08:40
160-16133-3	TITO12-RSY233A_1CH-S003	Solid	02/15/16 12:45	02/17/16 08:40
160-16133-4	TITO12-RSY233A_1CH-S004	Solid	02/15/16 13:02	02/17/16 08:40
160-16133-5	TITO12-RSY233A_1CH-S005	Solid	02/15/16 13:05	02/17/16 08:40
160-16133-6	TITO12-RSY233A_1CH-S006	Solid	02/15/16 12:52	02/17/16 08:40
160-16133-7	TITO12-RSY233A_1CH-S007	Solid	02/15/16 12:56	02/17/16 08:40
160-16133-8	TITO12-RSY233A_1CH-S008	Solid	02/15/16 12:50	02/17/16 08:40
160-16133-9	TITO12-RSY233A_1CH-S009	Solid	02/15/16 12:40	02/17/16 08:40
160-16133-10	TITO12-RSY233A_1CH-S010	Solid	02/15/16 12:57	02/17/16 08:40
160-16133-11	TITO12-RSY233A_1CH-S011	Solid	02/15/16 12:53	02/17/16 08:40
160-16133-12	TITO12-RSY233A_1CH-S012	Solid	02/15/16 12:59	02/17/16 08:40
160-16133-13	TITO12-RSY233A_1CH-S013	Solid	02/15/16 12:30	02/17/16 08:40
160-16133-14	TITO12-RSY233A_1CH-S014	Solid	02/15/16 12:58	02/17/16 08:40
160-16133-15	TITO12-RSY233A_1CH-S015	Solid	02/15/16 13:07	02/17/16 08:40
160-16133-16	TITO12-RSY233A_1CH-S016	Solid	02/15/16 13:00	02/17/16 08:40
160-16133-17	TITO12-RSY233A_1CH-S017	Solid	02/15/16 12:25	02/17/16 08:40
160-16133-18	TITO12-RSY233A_1CH-S018	Solid	02/15/16 12:47	02/17/16 08:40
160-16133-19	TITO12-RSY233A_1CH-S019	Solid	02/15/16 13:06	02/17/16 08:40
160-16133-20	TITO12-RSY233A_1CH-S020	Solid	02/15/16 12:20	02/17/16 08:40

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Client Sample ID: TITO12-RSY233A_1CH-S001

Lab Sample ID: 160-16133-1
Date Collected: 02/15/16 12:55
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.642**		0.221	0.231		0.369	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Actinium-227	0.0125	U	0.0760	0.0761		0.973	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Bismuth-212	1.17	U	0.855	0.864		1.25	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Bismuth-214	**0.393**		0.148	0.153		0.170	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Cesium-137	0.000	U	0.0153	0.0153		0.104	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Lead-210	-1.37	U	54.8	54.8		2.92	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Lead-212	**0.610**		0.142	0.162		0.149	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Lead-214	**0.431**		0.144	0.151		0.144	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Potassium-40	**14.0**		2.18	2.61		1.05	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Protactinium-231	0.333	U	0.591	0.592		2.29	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Radium-226	**0.393**		0.148	0.153	0.500	0.170	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Radium-228	**0.642**		0.221	0.231		0.369	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Thallium-208	**0.275**		0.0736	0.0790		0.0362	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Thorium-228	**0.610**		0.142	0.162		0.149	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Thorium-232	**0.642**		0.221	0.231		0.369	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Thorium-234	0.396	U	0.713	0.714		2.26	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Uranium-235	0.00760	U	0.0483	0.0483		0.431	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Uranium-238	0.396	U	0.713	0.714		2.26	pCi/g	02/18/16 15:46	03/14/16 17:27	1

Client Sample ID: TITO12-RSY233A_1CH-S002

Lab Sample ID: 160-16133-2
Date Collected: 02/15/16 13:03
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.283**		0.146	0.148		0.230	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Actinium-227	-0.0210	U	0.530	0.530		0.926	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Bismuth-212	0.268	U	0.482	0.483		0.824	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Bismuth-214	**0.358**		0.105	0.111		0.118	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Cesium-137	-0.00281	U	0.0649	0.0649		0.0874	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Lead-210	-0.519	U	2.26	2.27		2.32	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Lead-212	**0.393**		0.0915	0.105		0.0987	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Lead-214	**0.395**		0.113	0.120		0.128	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Potassium-40	**10.0**		1.40	1.74		0.842	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Protactinium-231	0.367	U	0.612	0.614		2.00	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Radium-226	**0.358**		0.105	0.111	0.500	0.118	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Radium-228	**0.283**		0.146	0.148		0.230	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Thallium-208	**0.188**		0.0619	0.0649		0.0630	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Thorium-228	**0.393**		0.0915	0.105		0.0987	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Thorium-232	**0.283**		0.146	0.148		0.230	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Thorium-234	0.224	U	0.554	0.555		1.82	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Uranium-235	-0.103	U	1.83	1.84		0.356	pCi/g	02/18/16 15:46	03/14/16 17:27	1
Uranium-238	0.224	U	0.554	0.555		1.82	pCi/g	02/18/16 15:46	03/14/16 17:27	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Client Sample ID: TITO12-RSY233A_1CH-S003

Lab Sample ID: 160-16133-3
Date Collected: 02/15/16 12:45
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.589**		0.162	0.173		0.0988	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Actinium-227	0.277	U	0.493	0.493		0.830	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Bismuth-212	0.000	U	0.577	0.577		1.03	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Bismuth-214	**0.465**		0.125	0.134		0.116	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Cesium-137	-0.00750	U	0.0447	0.0447		0.0813	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Lead-210	0.678	U	1.14	1.14		2.01	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Lead-212	**0.376**		0.102	0.113		0.113	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Lead-214	**0.486**		0.133	0.142		0.112	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Potassium-40	**10.8**		1.52	1.88		0.729	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Protactinium-231	0.170	U	0.244	0.245		2.01	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Radium-226	**0.465**		0.125	0.134	0.500	0.116	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Radium-228	**0.589**		0.162	0.173		0.0988	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Thallium-208	**0.154**		0.0480	0.0506		0.0395	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Thorium-228	**0.376**		0.102	0.113		0.113	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Thorium-232	**0.589**		0.162	0.173		0.0988	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Thorium-234	1.15	U	1.19	1.20		1.74	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Uranium-235	0.0946	U	0.183	0.184		0.318	pCi/g	02/18/16 15:46	03/14/16 17:29	1
Uranium-238	1.15	U	1.19	1.20		1.74	pCi/g	02/18/16 15:46	03/14/16 17:29	1

Client Sample ID: TITO12-RSY233A_1CH-S004

Lab Sample ID: 160-16133-4
Date Collected: 02/15/16 13:02
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.443**		0.165	0.171		0.164	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Actinium-227	0.150	U	0.442	0.442		0.761	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Bismuth-212	0.193	U	0.538	0.538		0.952	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Bismuth-214	**0.364**		0.132	0.137		0.136	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Cesium-137	0.00584	U	0.0411	0.0411		0.0758	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Lead-210	-0.924	U	37.0	37.0		2.13	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Lead-212	**0.308**		0.0938	0.102		0.128	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Lead-214	**0.511**		0.119	0.130		0.107	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Potassium-40	**11.8**		1.64	2.04		0.707	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Protactinium-231	0.000	U	0.568	0.568		2.06	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Radium-226	**0.364**		0.132	0.137	0.500	0.136	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Radium-228	**0.443**		0.165	0.171		0.164	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Thallium-208	**0.0817**		0.0673	0.0678		0.0755	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Thorium-228	**0.308**		0.0938	0.102		0.128	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Thorium-232	**0.443**		0.165	0.171		0.164	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Thorium-234	0.564	U	0.821	0.823		1.45	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Uranium-235	0.107	U	0.166	0.166		0.278	pCi/g	02/18/16 15:46	03/14/16 18:26	1
Uranium-238	0.564	U	0.821	0.823		1.45	pCi/g	02/18/16 15:46	03/14/16 18:26	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Client Sample ID: TITO12-RSY233A_1CH-S005

Lab Sample ID: 160-16133-5
Date Collected: 02/15/16 13:05
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.525**		0.155	0.164		0.243	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Actinium-227	0.000	U	0.276	0.276		1.08	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Bismuth-212	0.154	U	0.461	0.461		0.820	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Bismuth-214	**0.295**		0.113	0.117		0.138	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Cesium-137	-0.00923	U	0.145	0.145		0.0742	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Lead-210	0.226	U	1.12	1.12		2.12	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Lead-212	**0.372**		0.0952	0.107		0.102	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Lead-214	**0.500**		0.134	0.144		0.136	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Potassium-40	**11.6**		1.49	1.90		0.821	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Protactinium-231	0.195	U	0.287	0.288		1.78	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Radium-226	**0.295**		0.113	0.117	0.500	0.138	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Radium-228	**0.525**		0.155	0.164		0.243	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Thallium-208	**0.149**		0.0544	0.0566		0.0597	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Thorium-228	**0.372**		0.0952	0.107		0.102	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Thorium-232	**0.525**		0.155	0.164		0.243	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Thorium-234	1.12	U	1.15	1.16		1.55	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Uranium-235	0.0953	U	0.224	0.224		0.390	pCi/g	02/18/16 15:46	03/14/16 18:23	1
Uranium-238	1.12	U	1.15	1.16		1.55	pCi/g	02/18/16 15:46	03/14/16 18:23	1

Client Sample ID: TITO12-RSY233A_1CH-S006

Lab Sample ID: 160-16133-6
Date Collected: 02/15/16 12:52
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.174	U	0.137	0.138		0.279	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Actinium-227	0.159	U	0.288	0.289		0.808	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Bismuth-212	0.389	U	0.474	0.476		0.772	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Bismuth-214	**0.184**		0.108	0.110		0.176	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Cesium-137	0.00995	U	0.0454	0.0454		0.0816	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Lead-210	1.10	U	1.35	1.36		2.06	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Lead-212	**0.420**		0.0960	0.110		0.0975	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Lead-214	**0.474**		0.122	0.132		0.133	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Potassium-40	**11.4**		1.53	1.93		0.663	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Protactinium-231	0.0695	U	0.149	0.150		1.87	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Radium-226	**0.184**		0.108	0.110	0.500	0.176	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Radium-228	0.174	U	0.137	0.138		0.279	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Thallium-208	**0.115**		0.0467	0.0482		0.0528	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Thorium-228	**0.420**		0.0960	0.110		0.0975	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Thorium-232	0.174	U	0.137	0.138		0.279	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Thorium-234	1.11	U	0.977	0.984		1.66	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Uranium-235	0.0766	U	0.154	0.154		0.423	pCi/g	02/18/16 15:46	03/14/16 18:25	1
Uranium-238	1.11	U	0.977	0.984		1.66	pCi/g	02/18/16 15:46	03/14/16 18:25	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Client Sample ID: TITO12-RSY233A_1CH-S007

Lab Sample ID: 160-16133-7
Date Collected: 02/15/16 12:56
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.358**		0.176	0.180		0.232	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Actinium-227	0.000	U	0.204	0.204		0.947	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Bismuth-212	**1.15**		0.408	0.425		0.266	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Bismuth-214	**0.360**		0.107	0.114		0.111	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Cesium-137	0.00326	U	0.0412	0.0412		0.0752	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Lead-210	-0.651	U	3.26	3.26		2.03	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Lead-212	**0.350**		0.0855	0.0968		0.0961	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Lead-214	**0.418**		0.0921	0.102		0.0819	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Potassium-40	**11.0**		1.40	1.79		0.571	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Protactinium-231	0.279	U	0.301	0.303		1.62	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Radium-226	**0.360**		0.107	0.114	0.500	0.111	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Radium-228	**0.358**		0.176	0.180		0.232	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Thallium-208	**0.161**		0.0435	0.0466		0.0337	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Thorium-228	**0.350**		0.0855	0.0968		0.0961	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Thorium-232	**0.358**		0.176	0.180		0.232	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Thorium-234	0.418	U	0.951	0.952		1.67	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Uranium-235	0.214	U	0.199	0.200		0.297	pCi/g	02/18/16 15:46	03/14/16 20:21	1
Uranium-238	0.418	U	0.951	0.952		1.67	pCi/g	02/18/16 15:46	03/14/16 20:21	1

Client Sample ID: TITO12-RSY233A_1CH-S008

Lab Sample ID: 160-16133-8
Date Collected: 02/15/16 12:50
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.315**		0.153	0.156		0.261	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Actinium-227	0.268	U	0.345	0.346		0.568	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Bismuth-212	0.314	U	0.549	0.550		0.939	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Bismuth-214	**0.338**		0.108	0.114		0.114	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Cesium-137	-0.000152	U	0.0375	0.0375		0.0720	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Lead-210	1.02	U	1.25	1.26		1.81	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Lead-212	**0.400**		0.0911	0.105		0.0908	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Lead-214	**0.375**		0.114	0.120		0.113	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Potassium-40	**8.92**		1.48	1.74		0.855	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Protactinium-231	-0.368	U	1.08	1.08		1.88	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Radium-226	**0.338**		0.108	0.114	0.500	0.114	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Radium-228	**0.315**		0.153	0.156		0.261	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Thallium-208	**0.164**		0.0564	0.0589		0.0411	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Thorium-228	**0.400**		0.0911	0.105		0.0908	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Thorium-232	**0.315**		0.153	0.156		0.261	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Thorium-234	0.613	U	0.890	0.892		1.56	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Uranium-235	0.0489	U	0.127	0.127		0.268	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Uranium-238	0.613	U	0.890	0.892		1.56	pCi/g	02/18/16 15:46	03/14/16 20:22	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Client Sample ID: TITO12-RSY233A_1CH-S009

Lab Sample ID: 160-16133-9
Date Collected: 02/15/16 12:40
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.517**		0.133	0.143		0.124	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Actinium-227	0.0638	U	0.461	0.461		0.803	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Bismuth-212	0.269	U	0.448	0.449		0.761	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Bismuth-214	**0.403**		0.125	0.132		0.135	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Cesium-137	-0.00905	U	0.167	0.167		0.0819	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Lead-210	-0.125	U	1.29	1.29		2.12	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Lead-212	**0.336**		0.0958	0.105		0.105	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Lead-214	**0.532**		0.109	0.122		0.0897	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Potassium-40	**10.9**		1.43	1.82		0.805	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Protactinium-231	0.321	U	0.970	0.970		1.68	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Radium-226	**0.403**		0.125	0.132	0.500	0.135	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Radium-228	**0.517**		0.133	0.143		0.124	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Thallium-208	**0.0875**		0.0494	0.0502		0.0756	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Thorium-228	**0.336**		0.0958	0.105		0.105	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Thorium-232	**0.517**		0.133	0.143		0.124	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Thorium-234	0.269	U	0.415	0.416		1.87	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Uranium-235	0.0822	U	0.232	0.232		0.354	pCi/g	02/18/16 15:46	03/14/16 20:22	1
Uranium-238	0.269	U	0.415	0.416		1.87	pCi/g	02/18/16 15:46	03/14/16 20:22	1

Client Sample ID: TITO12-RSY233A_1CH-S010

Lab Sample ID: 160-16133-10
Date Collected: 02/15/16 12:57
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.601**		0.147	0.159		0.102	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Actinium-227	-0.0857	U	0.618	0.619		1.07	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Bismuth-212	0.301	U	0.430	0.431		0.718	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Bismuth-214	**0.400**		0.139	0.145		0.145	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Cesium-137	-0.00498	U	0.0408	0.0408		0.0758	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Lead-210	-0.279	U	1.92	1.92		2.59	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Lead-212	**0.363**		0.105	0.115		0.119	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Lead-214	**0.473**		0.121	0.131		0.125	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Potassium-40	**11.2**		1.57	1.95		0.752	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Protactinium-231	-0.304	U	0.979	0.979		1.72	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Radium-226	**0.400**		0.139	0.145	0.500	0.145	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Radium-228	**0.601**		0.147	0.159		0.102	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Thallium-208	**0.162**		0.0624	0.0646		0.0652	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Thorium-228	**0.363**		0.105	0.115		0.119	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Thorium-232	**0.601**		0.147	0.159		0.102	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Thorium-234	0.852	U	1.08	1.09		1.67	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Uranium-235	0.219	U	0.209	0.211		0.328	pCi/g	02/18/16 15:46	03/14/16 20:23	1
Uranium-238	0.852	U	1.08	1.09		1.67	pCi/g	02/18/16 15:46	03/14/16 20:23	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Client Sample ID: TITO12-RSY233A_1CH-S011

Lab Sample ID: 160-16133-11
Date Collected: 02/15/16 12:53
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.446**		0.134	0.142		0.128	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Actinium-227	-0.00888	U	0.424	0.424		0.752	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Bismuth-212	0.161	U	0.445	0.446		0.788	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Bismuth-214	**0.413**		0.107	0.116		0.101	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Cesium-137	0.00467	U	0.0332	0.0332		0.0615	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Lead-210	0.507	U	1.24	1.24		2.25	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Lead-212	**0.341**		0.0926	0.103		0.107	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Lead-214	**0.358**		0.102	0.109		0.107	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Potassium-40	**11.8**		1.47	1.90		0.585	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Protactinium-231	0.147	U	0.148	0.149		1.82	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Radium-226	**0.413**		0.107	0.116	0.500	0.101	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Radium-228	**0.446**		0.134	0.142		0.128	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Thallium-208	**0.169**		0.0523	0.0552		0.0444	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Thorium-228	**0.341**		0.0926	0.103		0.107	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Thorium-232	**0.446**		0.134	0.142		0.128	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Thorium-234	0.342	U	0.460	0.461		1.58	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Uranium-235	0.173	U	0.184	0.185		0.318	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Uranium-238	0.342	U	0.460	0.461		1.58	pCi/g	02/18/16 15:46	03/14/16 21:05	1

Client Sample ID: TITO12-RSY233A_1CH-S012

Lab Sample ID: 160-16133-12
Date Collected: 02/15/16 12:59
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.333**		0.184	0.187		0.239	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Actinium-227	0.266	U	0.430	0.431		0.722	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Bismuth-212	0.153	U	0.552	0.552		0.991	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Bismuth-214	**0.347**		0.129	0.134		0.147	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Cesium-137	0.00764	U	0.0387	0.0387		0.0714	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Lead-210	0.233	U	1.00	1.00		1.70	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Lead-212	**0.485**		0.113	0.129		0.112	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Lead-214	**0.390**		0.109	0.116		0.105	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Potassium-40	**11.5**		1.65	2.02		0.735	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Protactinium-231	0.155	U	0.266	0.267		1.60	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Radium-226	**0.347**		0.129	0.134	0.500	0.147	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Radium-228	**0.333**		0.184	0.187		0.239	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Thallium-208	**0.161**		0.0624	0.0646		0.0576	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Thorium-228	**0.485**		0.113	0.129		0.112	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Thorium-232	**0.333**		0.184	0.187		0.239	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Thorium-234	0.409	U	0.391	0.393		1.61	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Uranium-235	0.177	U	0.212	0.213		0.290	pCi/g	02/18/16 15:46	03/14/16 21:05	1
Uranium-238	0.409	U	0.391	0.393		1.61	pCi/g	02/18/16 15:46	03/14/16 21:05	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Client Sample ID: TITO12-RSY233A_1CH-S013

Lab Sample ID: 160-16133-13
Date Collected: 02/15/16 12:30
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.252	U	0.158	0.160		0.303	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Actinium-227	0.00946	U	0.0300	0.0300		0.971	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Bismuth-212	0.566	U	0.576	0.579		0.919	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Bismuth-214	**0.492**		0.136	0.145		0.136	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Cesium-137	-0.0142	U	0.877	0.877		0.0844	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Lead-210	0.764	U	1.42	1.42		2.09	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Lead-212	**0.377**		0.101	0.112		0.113	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Lead-214	**0.445**		0.142	0.149		0.140	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Potassium-40	**12.1**		1.53	1.97		0.839	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Protactinium-231	0.00534	U	0.0137	0.0137		1.75	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Radium-226	**0.492**		0.136	0.145	0.500	0.136	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Radium-228	0.252	U	0.158	0.160		0.303	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Thallium-208	**0.180**		0.0686	0.0711		0.0714	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Thorium-228	**0.377**		0.101	0.112		0.113	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Thorium-232	0.252	U	0.158	0.160		0.303	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Thorium-234	0.771	U	0.526	0.532		1.72	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Uranium-235	0.0931	U	0.176	0.176		0.405	pCi/g	02/18/16 15:46	03/14/16 21:06	1
Uranium-238	0.771	U	0.526	0.532		1.72	pCi/g	02/18/16 15:46	03/14/16 21:06	1

Client Sample ID: TITO12-RSY233A_1CH-S014

Lab Sample ID: 160-16133-14
Date Collected: 02/15/16 12:58
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.238**		0.141	0.143		0.214	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Actinium-227	0.230	U	0.349	0.350		0.925	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Bismuth-212	0.0437	U	0.504	0.504		0.931	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Bismuth-214	**0.309**		0.117	0.121		0.129	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Cesium-137	-0.00349	U	0.0394	0.0394		0.0731	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Lead-210	0.310	U	1.54	1.54		2.33	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Lead-212	**0.390**		0.111	0.122		0.120	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Lead-214	**0.461**		0.0949	0.106		0.0554	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Potassium-40	**10.7**		1.49	1.85		0.699	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Protactinium-231	0.277	U	0.330	0.332		1.51	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Radium-226	**0.309**		0.117	0.121	0.500	0.129	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Radium-228	**0.238**		0.141	0.143		0.214	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Thallium-208	**0.200**		0.0565	0.0602		0.0460	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Thorium-228	**0.390**		0.111	0.122		0.120	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Thorium-232	**0.238**		0.141	0.143		0.214	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Thorium-234	0.819	U	0.929	0.933		1.64	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Uranium-235	0.257	U	0.212	0.214		0.335	pCi/g	02/18/16 15:46	03/14/16 21:07	1
Uranium-238	0.819	U	0.929	0.933		1.64	pCi/g	02/18/16 15:46	03/14/16 21:07	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Client Sample ID: TITO12-RSY233A_1CH-S015

Lab Sample ID: 160-16133-15
Date Collected: 02/15/16 13:07
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.476**		0.112	0.122		0.0869	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Actinium-227	-0.0656	U	0.512	0.512		0.893	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Bismuth-212	0.437	U	0.522	0.524		0.850	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Bismuth-214	**0.403**		0.115	0.122		0.115	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Cesium-137	-0.00196	U	0.0368	0.0368		0.0687	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Lead-210	-0.131	U	1.46	1.46		2.26	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Lead-212	**0.411**		0.106	0.119		0.113	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Lead-214	**0.406**		0.0923	0.101		0.118	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Potassium-40	**11.9**		1.60	2.01		0.822	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Protactinium-231	0.486	U	0.474	0.477		1.76	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Radium-226	**0.403**		0.115	0.122	0.500	0.115	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Radium-228	**0.476**		0.112	0.122		0.0869	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Thallium-208	**0.190**		0.0555	0.0589		0.0471	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Thorium-228	**0.411**		0.106	0.119		0.113	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Thorium-232	**0.476**		0.112	0.122		0.0869	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Thorium-234	0.331	U	0.531	0.532		1.75	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Uranium-235	0.0792	U	0.201	0.201		0.323	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Uranium-238	0.331	U	0.531	0.532		1.75	pCi/g	02/18/16 15:46	03/14/16 21:48	1

Client Sample ID: TITO12-RSY233A_1CH-S016

Lab Sample ID: 160-16133-16
Date Collected: 02/15/16 13:00
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.251	U	0.143	0.145		0.299	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Actinium-227	-0.193	U	0.432	0.433		0.737	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Bismuth-212	-0.00229	U	0.525	0.525		0.986	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Bismuth-214	**0.478**		0.148	0.156		0.132	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Cesium-137	0.000	U	0.0344	0.0344		0.0878	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Lead-210	**1.72**		1.23	1.25		1.71	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Lead-212	**0.354**		0.103	0.113		0.141	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Lead-214	**0.375**		0.0953	0.103		0.0879	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Potassium-40	**9.93**		1.51	1.82		0.712	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Protactinium-231	0.265	U	0.407	0.408		1.53	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Radium-226	**0.478**		0.148	0.156	0.500	0.132	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Radium-228	0.251	U	0.143	0.145		0.299	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Thallium-208	**0.168**		0.0529	0.0557		0.0361	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Thorium-228	**0.354**		0.103	0.113		0.141	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Thorium-232	0.251	U	0.143	0.145		0.299	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Thorium-234	-0.0254	U	0.212	0.212		1.67	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Uranium-235	0.155	U	0.196	0.196		0.295	pCi/g	02/18/16 15:46	03/14/16 21:48	1
Uranium-238	-0.0254	U	0.212	0.212		1.67	pCi/g	02/18/16 15:46	03/14/16 21:48	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Client Sample ID: TITO12-RSY233A_1CH-S017

Lab Sample ID: 160-16133-17
Date Collected: 02/15/16 12:25
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.414**		0.201	0.205		0.268	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Actinium-227	-0.0112	U	0.509	0.509		0.892	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Bismuth-212	0.145	U	0.502	0.502		0.895	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Bismuth-214	**0.404**		0.145	0.151		0.156	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Cesium-137	-0.000547	U	0.0454	0.0454		0.0825	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Lead-210	1.38	U	1.42	1.43		2.05	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Lead-212	**0.434**		0.125	0.137		0.131	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Lead-214	**0.475**		0.117	0.127		0.120	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Potassium-40	**11.4**		1.52	1.91		0.950	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Protactinium-231	0.646	U	0.828	0.831		1.36	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Radium-226	**0.404**		0.145	0.151	0.500	0.156	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Radium-228	**0.414**		0.201	0.205		0.268	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Thallium-208	**0.0941**		0.0574	0.0582		0.0849	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Thorium-228	**0.434**		0.125	0.137		0.131	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Thorium-232	**0.414**		0.201	0.205		0.268	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Thorium-234	0.663	U	1.02	1.02		1.79	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Uranium-235	-0.149	U	0.893	0.894		0.443	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Uranium-238	0.663	U	1.02	1.02		1.79	pCi/g	02/18/16 15:46	03/14/16 21:49	1

Client Sample ID: TITO12-RSY233A_1CH-S018

Lab Sample ID: 160-16133-18
Date Collected: 02/15/16 12:47
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.400**		0.143	0.148		0.201	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Actinium-227	0.0670	U	0.271	0.271		0.837	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Bismuth-212	0.237	U	0.511	0.511		0.887	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Bismuth-214	**0.298**		0.0918	0.0969		0.0995	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Cesium-137	-0.00891	U	0.0455	0.0456		0.0819	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Lead-210	1.96	U	1.57	1.59		2.14	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Lead-212	**0.309**		0.0905	0.0990		0.103	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Lead-214	**0.424**		0.109	0.118		0.112	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Potassium-40	**11.4**		1.51	1.90		0.678	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Protactinium-231	0.343	U	0.486	0.487		1.37	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Radium-226	**0.298**		0.0918	0.0969	0.500	0.0995	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Radium-228	**0.400**		0.143	0.148		0.201	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Thallium-208	**0.166**		0.0542	0.0568		0.0487	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Thorium-228	**0.309**		0.0905	0.0990		0.103	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Thorium-232	**0.400**		0.143	0.148		0.201	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Thorium-234	0.503	U	0.557	0.559		1.78	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Uranium-235	-0.00368	U	0.190	0.190		0.338	pCi/g	02/18/16 15:46	03/14/16 21:49	1
Uranium-238	0.503	U	0.557	0.559		1.78	pCi/g	02/18/16 15:46	03/14/16 21:49	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Client Sample ID: TITO12-RSY233A_1CH-S019

Lab Sample ID: 160-16133-19
Date Collected: 02/15/16 13:06
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.340**		0.138	0.143		0.212	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Actinium-227	0.111	U	0.480	0.480		0.833	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Bismuth-212	0.313	U	0.509	0.510		0.862	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Bismuth-214	**0.448**		0.151	0.158		0.158	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Cesium-137	-0.00639	U	0.0415	0.0415		0.0755	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Lead-210	0.345	U	1.17	1.17		1.92	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Lead-212	**0.386**		0.103	0.115		0.113	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Lead-214	**0.412**		0.122	0.129		0.136	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Potassium-40	**12.6**		1.56	2.02		0.620	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Protactinium-231	0.0771	U	0.772	0.772		1.40	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Radium-226	**0.448**		0.151	0.158	0.500	0.158	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Radium-228	**0.340**		0.138	0.143		0.212	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Thallium-208	**0.169**		0.0674	0.0696		0.0647	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Thorium-228	**0.386**		0.103	0.115		0.113	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Thorium-232	**0.340**		0.138	0.143		0.212	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Thorium-234	0.171	U	0.384	0.385		1.88	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Uranium-235	0.0723	U	0.190	0.190		0.373	pCi/g	02/18/16 15:46	03/14/16 22:24	1
Uranium-238	0.171	U	0.384	0.385		1.88	pCi/g	02/18/16 15:46	03/14/16 22:24	1

Client Sample ID: TITO12-RSY233A_1CH-S020

Lab Sample ID: 160-16133-20
Date Collected: 02/15/16 12:20
Matrix: Solid
Date Received: 02/17/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.290**		0.159	0.162		0.254	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Actinium-227	0.265	U	0.425	0.426		0.712	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Bismuth-212	0.000	U	0.581	0.581		1.10	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Bismuth-214	**0.472**		0.126	0.136		0.116	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Cesium-137	-0.00589	U	0.0405	0.0405		0.0750	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Lead-210	0.583	U	1.02	1.02		1.85	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Lead-212	0.0260	U	0.101	0.102		0.177	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Lead-214	**0.379**		0.0968	0.105		0.0819	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Potassium-40	**12.8**		1.71	2.15		0.715	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Protactinium-231	0.492	U	0.483	0.486		1.47	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Radium-226	**0.472**		0.126	0.136	0.500	0.116	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Radium-228	**0.290**		0.159	0.162		0.254	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Thallium-208	**0.120**		0.0603	0.0615		0.0514	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Thorium-228	0.0260	U	0.101	0.102		0.177	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Thorium-232	**0.290**		0.159	0.162		0.254	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Thorium-234	0.562	U	0.925	0.927		1.62	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Uranium-235	0.0777	U	0.175	0.175		0.267	pCi/g	02/18/16 15:46	03/14/16 22:25	1
Uranium-238	0.562	U	0.925	0.927		1.62	pCi/g	02/18/16 15:46	03/14/16 22:25	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Lab Sample ID: MB 160-237251/1-A — **Client Sample ID: Method Blank**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 240380 — **Prep Batch: 237251**

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.07153	U	0.0722	0.0726		0.144	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Actinium-227	0.1411	U	0.249	0.249		0.426	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Bismuth-212	-0.006475	U	0.401	0.401		0.768	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Bismuth-214	-0.009263	U	0.0904	0.0904		0.140	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Cesium-137	-0.004344	U	0.0251	0.0251		0.0484	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Lead-210	0.1153	U	0.525	0.525		0.958	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Lead-212	-0.03706	U	0.240	0.240		0.0900	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Lead-214	0.02539	U	0.0519	0.0520		0.103	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Potassium-40	-0.01112	U	0.417	0.417		0.933	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Protactinium-231	0.05455	U	0.135	0.135		1.19	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Radium-226	-0.009263	U	0.0904	0.0904	0.500	0.140	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Radium-228	0.07153	U	0.0722	0.0726		0.144	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Thallium-208	0.02041	U	0.0338	0.0339		0.0516	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Thorium-228	-0.03706	U	0.240	0.240		0.0900	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Thorium-232	0.07153	U	0.0722	0.0726		0.144	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Thorium-234	0.0000	U	0.293	0.293		0.936	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Uranium-235	0.02521	U	0.0832	0.0832		0.233	pCi/g	02/18/16 15:46	03/14/16 17:25	1
Uranium-238	0.0000	U	0.293	0.293		0.936	pCi/g	02/18/16 15:46	03/14/16 17:25	1

Lab Sample ID: LCS 160-237251/2-A — **Client Sample ID: Lab Control Sample**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 240464 — **Prep Batch: 237251**

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	%Rec	%Rec. Limits
Americium-241	97.2	96.59		10.2		1.22	pCi/g	99	87 - 116
Cesium-137	29.8	29.62		3.16		0.265	pCi/g	99	87 - 120
Cobalt-60	17.7	17.39		1.80		0.148	pCi/g	98	87 - 115

Lab Sample ID: 160-16133-1 DU — **Client Sample ID: TITO12-RSY233A_1CH-S001**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 240657 — **Prep Batch: 237251**

Analyte	Sample Result	Sample Qual	DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	RER	RER Limit
Actinium 228	0.642		0.6510		0.271		0.355	pCi/g	0.02	1
Actinium-227	0.0125	U	0.004904	U	0.630		1.11	pCi/g	0.01	1
Bismuth-212	1.17	U	0.5970	U	0.816		1.35	pCi/g	0.34	1
Bismuth-214	0.393		0.6400		0.207		0.198	pCi/g	0.69	1
Cesium-137	0.000	U	-0.03907	U	0.214		0.116	pCi/g	0.17	1
Lead-210	-1.37	U	0.4031	U	1.44		2.79	pCi/g	0.03	1
Lead-212	0.610		0.5489		0.172		0.175	pCi/g	0.18	1
Lead-214	0.431		0.6071		0.228		0.217	pCi/g	0.46	1
Potassium-40	14.0		12.82		2.37		1.53	pCi/g	0.24	1
Protactinium-231	0.333	U	0.6295	U	1.14		2.46	pCi/g	0.17	1
Radium-226	0.393		0.6400		0.207	0.500	0.198	pCi/g	0.69	1
Radium-228	0.642		0.6510		0.271		0.355	pCi/g	0.02	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS) (Continued)

Lab Sample ID: 160-16133-1 DU
Matrix: Solid
Analysis Batch: 240657

Client Sample ID: TITO12-RSY233A_1CH-S001
Prep Type: Total/NA
Prep Batch: 237251

Analyte	Sample Result	Sample Qual		DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit			RER	RER Limit
Thallium-208	0.275			0.1731		0.0895		0.103	pCi/g			0.61	1
Thorium-228	0.610			0.5489		0.172		0.175	pCi/g			0.18	1
Thorium-232	0.642			0.6510		0.271		0.355	pCi/g			0.02	1
Thorium-234	0.396	U		0.5546	U	0.784		2.34	pCi/g			0.11	1
Uranium-235	0.00760	U		0.01459	U	0.0726		0.586	pCi/g			0.06	1
Uranium-238	0.396	U		0.5546	U	0.784		2.34	pCi/g			0.11	1

QC Association Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16133-2

Rad

Leach Batch: 237024

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-16133-1	TITO12-RSY233A_1CH-S001	Total/NA	Solid	Dry and Grind	
160-16133-1 DU	TITO12-RSY233A_1CH-S001	Total/NA	Solid	Dry and Grind	
160-16133-2	TITO12-RSY233A_1CH-S002	Total/NA	Solid	Dry and Grind	
160-16133-3	TITO12-RSY233A_1CH-S003	Total/NA	Solid	Dry and Grind	
160-16133-4	TITO12-RSY233A_1CH-S004	Total/NA	Solid	Dry and Grind	
160-16133-5	TITO12-RSY233A_1CH-S005	Total/NA	Solid	Dry and Grind	
160-16133-6	TITO12-RSY233A_1CH-S006	Total/NA	Solid	Dry and Grind	
160-16133-7	TITO12-RSY233A_1CH-S007	Total/NA	Solid	Dry and Grind	
160-16133-8	TITO12-RSY233A_1CH-S008	Total/NA	Solid	Dry and Grind	
160-16133-9	TITO12-RSY233A_1CH-S009	Total/NA	Solid	Dry and Grind	
160-16133-10	TITO12-RSY233A_1CH-S010	Total/NA	Solid	Dry and Grind	
160-16133-11	TITO12-RSY233A_1CH-S011	Total/NA	Solid	Dry and Grind	
160-16133-12	TITO12-RSY233A_1CH-S012	Total/NA	Solid	Dry and Grind	
160-16133-13	TITO12-RSY233A_1CH-S013	Total/NA	Solid	Dry and Grind	
160-16133-14	TITO12-RSY233A_1CH-S014	Total/NA	Solid	Dry and Grind	
160-16133-15	TITO12-RSY233A_1CH-S015	Total/NA	Solid	Dry and Grind	
160-16133-16	TITO12-RSY233A_1CH-S016	Total/NA	Solid	Dry and Grind	
160-16133-17	TITO12-RSY233A_1CH-S017	Total/NA	Solid	Dry and Grind	
160-16133-18	TITO12-RSY233A_1CH-S018	Total/NA	Solid	Dry and Grind	
160-16133-19	TITO12-RSY233A_1CH-S019	Total/NA	Solid	Dry and Grind	
160-16133-20	TITO12-RSY233A_1CH-S020	Total/NA	Solid	Dry and Grind	

Prep Batch: 237251

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-16133-1	TITO12-RSY233A_1CH-S001	Total/NA	Solid	Fill_Geo-21	237024
160-16133-1 DU	TITO12-RSY233A_1CH-S001	Total/NA	Solid	Fill_Geo-21	237024
160-16133-2	TITO12-RSY233A_1CH-S002	Total/NA	Solid	Fill_Geo-21	237024
160-16133-3	TITO12-RSY233A_1CH-S003	Total/NA	Solid	Fill_Geo-21	237024
160-16133-4	TITO12-RSY233A_1CH-S004	Total/NA	Solid	Fill_Geo-21	237024
160-16133-5	TITO12-RSY233A_1CH-S005	Total/NA	Solid	Fill_Geo-21	237024
160-16133-6	TITO12-RSY233A_1CH-S006	Total/NA	Solid	Fill_Geo-21	237024
160-16133-7	TITO12-RSY233A_1CH-S007	Total/NA	Solid	Fill_Geo-21	237024
160-16133-8	TITO12-RSY233A_1CH-S008	Total/NA	Solid	Fill_Geo-21	237024
160-16133-9	TITO12-RSY233A_1CH-S009	Total/NA	Solid	Fill_Geo-21	237024
160-16133-10	TITO12-RSY233A_1CH-S010	Total/NA	Solid	Fill_Geo-21	237024
160-16133-11	TITO12-RSY233A_1CH-S011	Total/NA	Solid	Fill_Geo-21	237024
160-16133-12	TITO12-RSY233A_1CH-S012	Total/NA	Solid	Fill_Geo-21	237024
160-16133-13	TITO12-RSY233A_1CH-S013	Total/NA	Solid	Fill_Geo-21	237024
160-16133-14	TITO12-RSY233A_1CH-S014	Total/NA	Solid	Fill_Geo-21	237024
160-16133-15	TITO12-RSY233A_1CH-S015	Total/NA	Solid	Fill_Geo-21	237024
160-16133-16	TITO12-RSY233A_1CH-S016	Total/NA	Solid	Fill_Geo-21	237024
160-16133-17	TITO12-RSY233A_1CH-S017	Total/NA	Solid	Fill_Geo-21	237024
160-16133-18	TITO12-RSY233A_1CH-S018	Total/NA	Solid	Fill_Geo-21	237024
160-16133-19	TITO12-RSY233A_1CH-S019	Total/NA	Solid	Fill_Geo-21	237024
160-16133-20	TITO12-RSY233A_1CH-S020	Total/NA	Solid	Fill_Geo-21	237024
LCS 160-237251/2-A	Lab Control Sample	Total/NA	Solid	Fill_Geo-21	
MB 160-237251/1-A	Method Blank	Total/NA	Solid	Fill_Geo-21	

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica St. Louis
13715 Rider Trail North
Earth City, MO 63045
Tel: (314)298-8566

TestAmerica Job ID: 160-15772-2
Client Project/Site: Treasure Island - 500475

For:
CB&I Environmental & Infrastructure, Inc
4005 Port Chicago Hwy
Concord, California 94520

Attn: Patricia Flynn

Authorized for release by:
2/29/2016 12:30:58 PM

Erika Gish, Project Manager II
(314)298-8566
erika.gish@testamericainc.com

LINKS

Review your project results through TotalAccess

Have a Question? Ask The Expert

Visit us at:
www.testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

Table of Contents

Cover Page 1
Table of Contents 2
Case Narrative 3
Chain of Custody 5
Receipt Checklists 6
Definitions/Glossary 7
Method Summary 8
Sample Summary 9
Client Sample Results 10
QC Sample Results 11
QC Association Summary 13

Job ID: 160-15772-2

Laboratory: TestAmerica St. Louis

Narrative

CASE NARRATIVE

Client: CB&I Environmental & Infrastructure, Inc

Project: Treasure Island - 500475

Report Number: 160-15772-2

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In some cases, due to interference or analytes present at high concentrations, samples were diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

TestAmerica St. Louis attests to the validity of the laboratory data generated by TestAmerica facilities reported herein. All analyses performed by TestAmerica facilities were done using established laboratory SOPs that incorporate QA/QC procedures described in the application methods. TestAmerica's operations groups have reviewed the data for compliance with the laboratory QA/QC plan, and data have been found to be compliant with laboratory protocols unless otherwise noted below.

The test results in this report meet all NELAP requirements for parameters for which accreditation is required or available. Any exceptions to NELAP requirements are noted in this report. Pursuant to NELAP, this report may not be reproduced, except in full, without the written approval of the laboratory.

Calculations are performed before rounding to avoid round-off errors in calculated results.

All holding times were met and proper preservation noted for the methods performed on these samples, unless otherwise detailed in the individual sections below.

All solid sample results for Chemistry analyses are reported on an "as received" basis unless otherwise indicated by the presence of a % solids value in the method header. All soil/sediment sample results for radiochemistry analyses are based upon sample as dried and disaggregated with the exception of tritium, carbon-14, and iodine-129 by gamma spectroscopy unless requested as wet weight by the client."

Reference the chain of custody and condition upon receipt report for any variations on receipt conditions and temperature of samples on receipt
Manual Integrations were performed only when necessary and are in compliance with the laboratory's standard operating procedure. Detailed information can be found in the raw data section of the level IV report.

The following clean-up methods for Organic analyses may have been used on the samples in this data set. Specific methods employed are documented on the batch extraction logs:

Method 3600C: Cleanup
Method 3620C: Florisil Cleanup
Method 3630C: Silica Gel Cleanup
Method 3640A: Gel-Permeation Cleanup
Method 3650B: Acid-Base Partition Cleanup
Method 3660B: Sulfur Cleanup
Method 3665A: Sulfuric Acid/Permanganate Cleanup

This laboratory report is confidential and is intended for the sole use of TestAmerica and its client.

Job ID: 160-15772-2 (Continued)

Laboratory: TestAmerica St. Louis (Continued)

RECEIPT
The samples were received on 1/19/2016 8:35 AM; the samples arrived in good condition, properly preserved. The temperature of the cooler at receipt was 18.9º C.

RADIUM 226 (21 DAY INGROWTH)
Samples TITO12-WSTAVE-CH-S001 (160-15772-1) and TITO12-WSTAVE-WOOD (160-15772-2) were analyzed for Radium 226 (21 day ingrowth) in accordance with DOE GA-01-R. The samples were prepared on 01/21/2016 and analyzed on 02/18/2016 and 02/28/2016.

Sample was prepped as received rather than the project specified dry/grind. TITO12-WSTAVE-WOOD (160-15772-2)

The detection goal for radium-226 was not met for the following sample due to insufficient sample available for analysis: TITO12-WSTAVE-WOOD (160-15772-2). The sample is a low-density wood splinters. Analytical results are reported with the detection limit achieved.

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

CHAIN OF CUSTODY

Ref. Document # TI_WOOD STAVE_001

Page 1 of 1

Shaw Environmental and Infrastructure Inc. (a CB&I company)
Federal Services Division
4005 Port Chicago Hwy
Concord, CA 94520

Project Number: 500475
Project Name / Location: TI WOOD STAVE
Purchase Order #: 202220

Project Manager: John Hackett (Name & phone #)

Shipment Date: 1/18/2016
Waybill Number: 1Z 897 462 01 9140 4851
Lab Destination: TestAmerica St Loius
Lab Contact Name / ph. #: Erika Gish

Send Report To: Patricia Flynn
Phone/Fax Number: 925-288-2037
Address: 4005 Port Chicago Hwy
City: Concord, CA, 94520

Sampler's Name(s):

Sample ID Number	Sample Description	Collection Information: Date	Time	Method	Matrix	# of containers	Preservative (water) / Preservative (soil) / Container Type	Analyses Requested: Gamma Scan							Dose Rate µR/Hr		
							Preservative (water)										
							Preservative (soil)	N/A									
							Container Type										
TITO12-WSTAVE-CH-S001	Soil sample from section 1 within 1 foot of the wooden stave pipe	1/18/16	0835	G	SO	1	16 oz Plastic	X							5		
TITO12-WSTAVE-WOOD	Wood from the pipe itself	1/18/16	0844	G	CP	1	Plastic Ziploc bag	X							4		

NR

Special instructions: 7 days ingrown draft and follow with 21 days final

Standard TAT ☐ ☐ 24-hr X 48-hr ☐ 3-day ☐ 7-day

Level Of QC Required: I II III Project Specific:

Relinquished By: [signature] Date: 1/18/16 Time: 1200
Received By: [signature] Date: 1.19.16 Time: 0835
Relinquished By: Date: Time:
Received By: Date:

Method Codes
C = Composite G = Grab

Matrix Codes
DW = Drinking Water SO =Soil
GW = Ground Water SL = Sludge
WW = Waste Water CP = Chip Samples
A = Air ABS=Asbestos, PO=Pipe Openning

160-15772 Chain of Custody

Login Sample Receipt Checklist

Client: CB&I Environmental & Infrastructure, Inc

Job Number: 160-15772-2

Login Number: 15772
List Number: 1
Creator: Clarke, Jill C

List Source: TestAmerica St. Louis

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	N/A	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Definitions/Glossary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15772-2

Qualifiers

Rad

Qualifier	Qualifier Description
U	Undetected at the Limit of Detection.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains no Free Liquid
DER	Duplicate error ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision level concentration
MDA	Minimum detectable activity
EDL	Estimated Detection Limit
MDC	Minimum detectable concentration
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative error ratio
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Method Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15772-2

Method	Method Description	Protocol	Laboratory
GA-01-R	Radium-226 & Other Gamma Emitters (GS)	DOE	TAL SL

Protocol References:

DOE = U.S. Department of Energy

Laboratory References:

TAL SL = TestAmerica St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Sample Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15772-2

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
160-15772-1	TITO12-WSTAVE-CH-S001	Solid	01/18/16 08:35	01/19/16 08:35
160-15772-2	TITO12-WSTAVE-WOOD	Solid	01/18/16 08:44	01/19/16 08:35

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15772-2

Client Sample ID: TITO12-WSTAVE-CH-S001

Lab Sample ID: 160-15772-1
Date Collected: 01/18/16 08:35
Matrix: Solid
Date Received: 01/19/16 08:35

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium-227	0.370	U	0.450	0.451		0.739	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Actinium 228	**0.346**		0.150	0.154		0.286	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Bismuth-212	0.512	U	0.510	0.513		0.808	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Bismuth-214	**0.430**		0.120	0.128		0.119	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Lead-210	1.34	U	1.49	1.50		2.00	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Lead-212	**0.424**		0.0970	0.111		0.106	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Lead-214	**0.431**		0.0961	0.106		0.110	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Potassium-40	**9.88**		1.38	1.71		0.934	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Protactinium-231	0.0610	U	0.109	0.109		1.58	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Radium-226	**0.430**		0.120	0.128	0.500	0.119	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Radium-228	**0.346**		0.150	0.154		0.286	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Thorium-232	**0.346**		0.150	0.154		0.286	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Thorium-234	0.439	U	0.534	0.536		1.68	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Thallium-208	**0.146**		0.0437	0.0463		0.0461	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Uranium-235	0.00953	U	0.122	0.122		0.437	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Uranium-238	0.439	U	0.534	0.536		1.68	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Cesium-137	0.00247	U	0.0419	0.0419		0.0767	pCi/g	01/21/16 12:37	02/18/16 21:09	1
Thorium-228	**0.424**		0.0970	0.111		0.106	pCi/g	01/21/16 12:37	02/18/16 21:09	1

Client Sample ID: TITO12-WSTAVE-WOOD

Lab Sample ID: 160-15772-2
Date Collected: 01/18/16 08:44
Matrix: Solid
Date Received: 01/19/16 08:35

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium-227	-0.0875	U	0.222	0.222		2.56	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Actinium 228	0.140	U	0.409	0.409		0.757	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Bismuth-212	0.000	U	1.34	1.34		4.59	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Bismuth-214	-0.0765	U	0.610	0.610		0.668	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Lead-210	1.23	U	2.84	2.85		4.94	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Lead-212	-0.00177	U	0.227	0.227		0.408	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Lead-214	-0.0237	U	0.189	0.189		0.555	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Potassium-40	-0.0893	U	1.79	1.79		4.01	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Protactinium-231	-0.0815	U	3.01	3.01		5.61	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Radium-226	-0.0765	U	0.610	0.610	0.500	0.668	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Radium-228	0.140	U	0.409	0.409		0.757	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Thorium-232	0.140	U	0.409	0.409		0.757	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Thorium-234	0.936	U	2.09	2.09		3.62	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Thallium-208	0.0882	U	0.181	0.181		0.209	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Uranium-235	-0.0463	U	0.219	0.219		0.954	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Uranium-238	0.936	U	2.09	2.09		3.62	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Cesium-137	-0.0299	U	0.150	0.150		0.277	pCi/g	01/21/16 12:37	02/28/16 04:01	1
Thorium-228	-0.00177	U	0.227	0.227		0.408	pCi/g	01/21/16 12:37	02/28/16 04:01	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15772-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Lab Sample ID: MB 160-233550/1-A — **Client Sample ID: Method Blank**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 238093 — **Prep Batch: 233550**

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium-227	0.2140	U	0.296	0.297		0.492	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Actinium 228	0.08161	U	0.0942	0.0945		0.185	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Bismuth-212	-0.1458	U	0.511	0.511		0.940	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Bismuth-214	0.05397	U	0.0795	0.0797		0.151	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Lead-210	-0.1488	U	1.07	1.07		1.77	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Lead-212	0.01173	U	0.0575	0.0575		0.110	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Lead-214	-0.01941	U	0.153	0.153		0.150	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Potassium-40	-0.3547	U	14.2	14.2		1.69	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Protactinium-231	-0.1487	U	0.862	0.862		1.58	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Radium-226	0.05397	U	0.0795	0.0797	0.500	0.151	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Radium-228	0.08161	U	0.0942	0.0945		0.185	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Thorium-232	0.08161	U	0.0942	0.0945		0.185	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Thorium-234	-0.3077	U	1.94	1.94		1.30	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Thallium-208	-0.002645	U	0.0587	0.0587		0.0850	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Uranium-235	-0.005476	U	0.165	0.165		0.301	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Uranium-238	-0.3077	U	1.94	1.94		1.30	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Cesium-137	0.01676	U	0.0345	0.0346		0.0615	pCi/g	01/21/16 12:37	02/18/16 18:13	1
Thorium-228	0.01173	U	0.0575	0.0575		0.110	pCi/g	01/21/16 12:37	02/18/16 18:13	1

Lab Sample ID: LCS 160-233550/2-A — **Client Sample ID: Lab Control Sample**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 238094 — **Prep Batch: 233550**

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	%Rec	%Rec. Limits
Americium-241	97.2	95.35		10.0		1.16	pCi/g	98	87 - 116
Cesium-137	29.9	29.45		3.13		0.191	pCi/g	99	87 - 120
Cobalt-60	17.8	17.01		1.76		0.128	pCi/g	95	87 - 115

Lab Sample ID: 160-15771-A-1-E DU — **Client Sample ID: Duplicate**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 238093 — **Prep Batch: 233550**

Analyte	Sample Result	Sample Qual	DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	RER	RER Limit
Actinium-227	-0.110	U	0.06451	U	0.146		0.693	pCi/g	0.26	1
Actinium 228	0.675		0.3869		0.152		0.268	pCi/g	0.87	1
Bismuth-212	0.230	U	0.2241	U	0.489		0.853	pCi/g	0.01	1
Bismuth-214	0.468		0.4797		0.145		0.129	pCi/g	0.04	1
Lead-210	1.10	U	0.8127	U	1.15		1.69	pCi/g	0.11	1
Lead-212	0.449		0.4812		0.115		0.0927	pCi/g	0.13	1
Lead-214	0.540		0.5374		0.129		0.147	pCi/g	0.01	1
Potassium-40	9.15		9.808		1.78		0.711	pCi/g	0.19	1
Protactinium-231	0.0548	U	0.3242	U	0.931		1.62	pCi/g	0.19	1
Radium-226	0.468		0.4797		0.145	0.500	0.129	pCi/g	0.04	1
Radium-228	0.675		0.3869		0.152		0.268	pCi/g	0.87	1
Thorium-232	0.675		0.3869		0.152		0.268	pCi/g	0.87	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15772-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS) (Continued)

Lab Sample ID: 160-15771-A-1-E DU
Matrix: Solid
Analysis Batch: 238093

Client Sample ID: Duplicate
Prep Type: Total/NA
Prep Batch: 233550

Analyte	Sample Result	Sample Qual		DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit			RER	RER Limit
Thorium-234	0.317	U		0.1237	U	0.204		1.74	pCi/g			0.35	1
Thallium-208	0.145			0.1917		0.0621		0.0501	pCi/g			0.40	1
Uranium-235	0.105	U		0.08810	U	0.133		0.354	pCi/g			0.06	1
Uranium-238	0.317	U		0.1237	U	0.204		1.74	pCi/g			0.35	1
Cesium-137	-0.0119	U		0.008316	U	0.0358		0.0657	pCi/g			0.25	1
Thorium-228	0.449			0.4812		0.115		0.0927	pCi/g			0.13	1

QC Association Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15772-2

Rad

Leach Batch: 233142

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-15771-A-1-E DU	Duplicate	Total/NA	Solid	Dry and Grind	

Prep Batch: 233550

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-15771-A-1-E DU	Duplicate	Total/NA	Solid	Fill_Geo-21	233142
160-15772-1	TITO12-WSTAVE-CH-S001	Total/NA	Solid	Fill_Geo-21	
160-15772-2	TITO12-WSTAVE-WOOD	Total/NA	Solid	Fill_Geo-21	
LCS 160-233550/2-A	Lab Control Sample	Total/NA	Solid	Fill_Geo-21	
MB 160-233550/1-A	Method Blank	Total/NA	Solid	Fill_Geo-21	

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica St. Louis
13715 Rider Trail North
Earth City, MO 63045
Tel: (314)298-8566

TestAmerica Job ID: 160-15947-2
Client Project/Site: Treasure Island - 500475

For:
CB&I Environmental & Infrastructure, Inc
4005 Port Chicago Hwy
Concord, California 94520

Attn: Patricia Flynn

Authorized for release by:
2/29/2016 6:27:10 PM

Erika Gish, Project Manager II
(314)298-8566
erika.gish@testamericainc.com

LINKS

Review your project results through TotalAccess

Have a Question? Ask The Expert

Visit us at:
www.testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

Table of Contents

Cover Page 1
Table of Contents 2
Case Narrative 3
Chain of Custody 5
Receipt Checklists 6
Definitions/Glossary 7
Method Summary 8
Sample Summary 9
Client Sample Results 10
QC Sample Results 11
QC Association Summary 13

Job ID: 160-15947-2

Laboratory: TestAmerica St. Louis

Narrative

CASE NARRATIVE

Client: CB&I Environmental & Infrastructure, Inc

Project: Treasure Island - 500475

Report Number: 160-15947-2

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In some cases, due to interference or analytes present at high concentrations, samples were diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

TestAmerica St. Louis attests to the validity of the laboratory data generated by TestAmerica facilities reported herein. All analyses performed by TestAmerica facilities were done using established laboratory SOPs that incorporate QA/QC procedures described in the application methods. TestAmerica's operations groups have reviewed the data for compliance with the laboratory QA/QC plan, and data have been found to be compliant with laboratory protocols unless otherwise noted below.

The test results in this report meet all NELAP requirements for parameters for which accreditation is required or available. Any exceptions to NELAP requirements are noted in this report. Pursuant to NELAP, this report may not be reproduced, except in full, without the written approval of the laboratory.

Calculations are performed before rounding to avoid round-off errors in calculated results.

All holding times were met and proper preservation noted for the methods performed on these samples, unless otherwise detailed in the individual sections below.

All solid sample results for Chemistry analyses are reported on an "as received" basis unless otherwise indicated by the presence of a % solids value in the method header. All soil/sediment sample results for radiochemistry analyses are based upon sample as dried and disaggregated with the exception of tritium, carbon-14, and iodine-129 by gamma spectroscopy unless requested as wet weight by the client."

Reference the chain of custody and condition upon receipt report for any variations on receipt conditions and temperature of samples on receipt
Manual Integrations were performed only when necessary and are in compliance with the laboratory's standard operating procedure. Detailed information can be found in the raw data section of the level IV report.

The following clean-up methods for Organic analyses may have been used on the samples in this data set. Specific methods employed are documented on the batch extraction logs:

Method 3600C: Cleanup
Method 3620C: Florisil Cleanup
Method 3630C: Silica Gel Cleanup
Method 3640A: Gel-Permeation Cleanup
Method 3650B: Acid-Base Partition Cleanup
Method 3660B: Sulfur Cleanup
Method 3665A: Sulfuric Acid/Permanganate Cleanup

This laboratory report is confidential and is intended for the sole use of TestAmerica and its client.

Job ID: 160-15947-2 (Continued)

Laboratory: TestAmerica St. Louis (Continued)

RECEIPT

The samples were received on 2/2/2016 8:40 AM; the samples arrived in good condition, properly preserved. The temperature of the cooler at receipt was 23.5º C.

RADIUM-226 BY GAMMA SPEC (21 DAY INGROWTH)

Samples TITO12-WSTAVE-CNCRT-001 (160-15947-1) and TITO12-WSTAVE-CNCRT-002 (160-15947-2) were analyzed for Radium-226 by gamma spec (21 day ingrowth) in accordance with EPA GA_01_R. The samples were dried on 02/02/2016, prepared on 02/04/2016 and analyzed on 02/25/2016.

No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

CHAIN OF CUSTODY

Ref. Document # TI_WOOD STAVE_003

Page 1 of 1

Shaw Environmental and Infrastructure Inc. (a CB&I company)
Federal Services Division
4005 Port Chicago Hwy
Concord, CA 94520

Project Number: 500475
Project Name / Location: TI WOOD STAVE
Purchase Order #: 202220

Project Manager: John Hackett (Name & phone #)

Send Report To: Patricia Flynn
Phone/Fax Number: 925-288-2037
Address: 4005 Port Chicago Hwy
City: Concord, CA, 94520

Shipment Date: 2/1/2016
Waybill Number: 1Z 89V 462 01 9713 0805
Lab Destination: TestAmerica St Loius
Lab Contact Name / ph. #: Erika Gish

Sampler's Name(s): A.N.

Sample ID Number	Sample Description	Collection Information: Date	Time	Method	Matrix	# of containers	Preservative (water) / Preservative (soil) / Container Type	Gamma Scan							Dose Rate µR/Hr.		
							Preservative (water)										
							Preservative (soil)	N/A									
							Container Type										
TITO12-WSTAVE-CNCRT-001	Concrete slurry from section 1W	01/29/16	10:10	G	CP	1	16 oz Plastic	X							5		
TITO12-WSTAVE-CNCRT-002	Concrete slurry from section 4W	01/29/16	10:00	G	CP	1	16 oz Plastic	X							5		

Analyses Requested

Special Instructions: 7 days ingrown draft and follow with 21 days final

Standard TAT ☐ ☐ 24-hr ☐ 48-hr ☐ 3-day ☐ 7-day

Level Of QC Required: I II III Project Specific:

Relinquished By: Bryon Rogers Date: 2/1/2016 Time: 1200
Relinquished By: Date: Time:

Received By: Gil Clarke Date: 2-2-16 Time: 0840
Received By: Date:

Method Codes
C = Composite G = Grab

Matrix Codes
DW = Drinking Water SO =Soil
GW = Ground Water SL = Sludge
WW = Waste Water CP = Chip Samples
A = Air ABS=Asbestos, PO=Pipe Openning

160-15947 Chain of Custody

Login Sample Receipt Checklist

Client: CB&I Environmental & Infrastructure, Inc

Job Number: 160-15947-2

Login Number: 15947
List Number: 1
Creator: Clarke, Jill C

List Source: TestAmerica St. Louis

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	N/A	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Definitions/Glossary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15947-2

Qualifiers

Rad

Qualifier	Qualifier Description
U	Undetected at the Limit of Detection.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains no Free Liquid
DER	Duplicate error ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision level concentration
MDA	Minimum detectable activity
EDL	Estimated Detection Limit
MDC	Minimum detectable concentration
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative error ratio
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Method Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15947-2

Method	Method Description	Protocol	Laboratory
GA-01-R	Radium-226 & Other Gamma Emitters (GS)	DOE	TAL SL

Protocol References:

DOE = U.S. Department of Energy

Laboratory References:

TAL SL = TestAmerica St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Sample Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15947-2

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
160-15947-1	TITO12-WSTAVE-CNCRT-001	Solid	01/29/16 10:10	02/02/16 08:40
160-15947-2	TITO12-WSTAVE-CNCRT-002	Solid	01/29/16 10:00	02/02/16 08:40

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15947-2

Client Sample ID: TITO12-WSTAVE-CNCRT-001

Lab Sample ID: 160-15947-1
Date Collected: 01/29/16 10:10
Matrix: Solid
Date Received: 02/02/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.193	U	0.187	0.188		0.460	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Actinium-227	0.263	U	0.365	0.366		0.607	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Bismuth-212	0.000	U	0.226	0.226		2.24	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Bismuth-214	0.218	U	0.163	0.165		0.220	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Cesium-137	-0.0509	U	0.275	0.275		0.138	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Lead-210	1.31	U	1.16	1.17		1.99	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Lead-212	**0.301**		0.0959	0.104		0.0973	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Lead-214	**0.368**		0.124	0.129		0.105	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Potassium-40	**4.30**		1.50	1.57		1.60	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Protactinium-231	0.113	U	0.655	0.655		2.36	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Radium-226	0.218	U	0.163	0.165	0.500	0.220	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Radium-228	0.193	U	0.187	0.188		0.460	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Thallium-208	0.0285	U	0.0576	0.0577		0.101	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Thorium-228	**0.301**		0.0959	0.104		0.0973	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Thorium-232	0.193	U	0.187	0.188		0.460	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Thorium-234	0.533	U	0.448	0.452		1.64	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Uranium-235	0.0951	U	0.222	0.222		0.398	pCi/g	02/04/16 12:56	02/25/16 09:32	1
Uranium-238	0.533	U	0.448	0.452		1.64	pCi/g	02/04/16 12:56	02/25/16 09:32	1

Client Sample ID: TITO12-WSTAVE-CNCRT-002

Lab Sample ID: 160-15947-2
Date Collected: 01/29/16 10:00
Matrix: Solid
Date Received: 02/02/16 08:40

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.248	U	0.160	0.162		0.302	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Actinium-227	0.0922	U	0.341	0.341		0.847	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Bismuth-212	-0.169	U	6.78	6.78		1.09	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Bismuth-214	**0.423**		0.151	0.157		0.161	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Cesium-137	0.0577	U	0.0529	0.0532		0.0822	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Lead-210	-0.322	U	1.92	1.92		2.10	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Lead-212	**0.357**		0.101	0.111		0.116	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Lead-214	**0.533**		0.142	0.152		0.132	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Potassium-40	**5.67**		1.21	1.34		1.04	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Protactinium-231	-0.423	U	1.03	1.03		1.79	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Radium-226	**0.423**		0.151	0.157	0.500	0.161	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Radium-228	0.248	U	0.160	0.162		0.302	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Thallium-208	**0.0933**		0.0571	0.0579		0.0817	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Thorium-228	**0.357**		0.101	0.111		0.116	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Thorium-232	0.248	U	0.160	0.162		0.302	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Thorium-234	0.265	U	0.226	0.227		2.04	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Uranium-235	0.0916	U	0.205	0.205		0.350	pCi/g	02/04/16 12:56	02/25/16 09:29	1
Uranium-238	0.265	U	0.226	0.227		2.04	pCi/g	02/04/16 12:56	02/25/16 09:29	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15947-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Lab Sample ID: MB 160-236334/1-A — **Client Sample ID: Method Blank**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 238294 — **Prep Batch: 236334**

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.01682	U	0.137	0.137		0.271	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Actinium-227	-0.1469	U	0.435	0.435		0.761	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Bismuth-212	-0.2076	U	0.612	0.612		1.10	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Bismuth-214	-0.01220	U	0.147	0.147		0.152	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Cesium-137	-0.01753	U	0.103	0.103		0.0911	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Lead-210	-0.03956	U	0.719	0.719		1.34	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Lead-212	-0.01074	U	0.112	0.112		0.108	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Lead-214	0.03896	U	0.0559	0.0560		0.114	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Potassium-40	-0.2332	U	9.33	9.33		0.843	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Protactinium-231	0.03194	U	0.107	0.107		1.86	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Radium-226	-0.01220	U	0.147	0.147	0.500	0.152	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Radium-228	0.01682	U	0.137	0.137		0.271	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Thallium-208	0.005866	U	0.0155	0.0155		0.0752	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Thorium-228	-0.01074	U	0.112	0.112		0.108	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Thorium-232	0.01682	U	0.137	0.137		0.271	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Thorium-234	-0.009564	U	0.0242	0.0242		1.48	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Uranium-235	0.01178	U	0.152	0.152		0.303	pCi/g	02/04/16 12:56	02/25/16 09:30	1
Uranium-238	-0.009564	U	0.0242	0.0242		1.48	pCi/g	02/04/16 12:56	02/25/16 09:30	1

Lab Sample ID: LCS 160-236334/2-A — **Client Sample ID: Lab Control Sample**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 238293 — **Prep Batch: 236334**

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	%Rec	%Rec. Limits
Americium-241	97.2	95.58		10.0		1.00	pCi/g	98	87 - 116
Cesium-137	29.9	28.43		3.03		0.211	pCi/g	95	87 - 120
Cobalt-60	17.8	17.01		1.77		0.109	pCi/g	96	87 - 115

Lab Sample ID: 160-15947-1 DU — **Client Sample ID: TITO12-WSTAVE-CNCRT-001**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 238294 — **Prep Batch: 236334**

Analyte	Sample Result	Sample Qual	DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	RER	RER Limit
Actinium 228	0.193	U	0.1550	U	0.190		0.401	pCi/g	0.1	1
Actinium-227	0.263	U	-0.002258	U	0.472		0.859	pCi/g	0.32	1
Bismuth-212	0.000	U	0.4285	U	0.798		1.37	pCi/g	0.42	1
Bismuth-214	0.218	U	0.2472		0.134		0.186	pCi/g	0.1	1
Cesium-137	-0.0509	U	-0.01092	U	0.0862		0.109	pCi/g	0.11	1
Lead-210	1.31	U	-0.3999	U	1.24		2.14	pCi/g	0.71	1
Lead-212	0.301		0.2555		0.105		0.121	pCi/g	0.22	1
Lead-214	0.368		0.4293		0.137		0.0875	pCi/g	0.23	1
Potassium-40	4.30		5.129		1.44		0.903	pCi/g	0.27	1
Protactinium-231	0.113	U	0.07138	U	0.0945		2.27	pCi/g	0.06	1
Radium-226	0.218	U	0.2472		0.134	0.500	0.186	pCi/g	0.1	1
Radium-228	0.193	U	0.1550	U	0.190		0.401	pCi/g	0.1	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15947-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS) (Continued)

Lab Sample ID: 160-15947-1 DU
Matrix: Solid
Analysis Batch: 238294

Client Sample ID: TITO12-WSTAVE-CNCRT-001
Prep Type: Total/NA
Prep Batch: 236334

Analyte	Sample Result	Sample Qual		DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit			RER	RER Limit
Thallium-208	0.0285	U		0.1020		0.0585		0.0732	pCi/g			0.63	1
Thorium-228	0.301			0.2555		0.105		0.121	pCi/g			0.22	1
Thorium-232	0.193	U		0.1550	U	0.190		0.401	pCi/g			0.1	1
Thorium-234	0.533	U		1.067	U	0.628		1.80	pCi/g			0.49	1
Uranium-235	0.0951	U		0.1288	U	0.248		0.381	pCi/g			0.07	1
Uranium-238	0.533	U		1.067	U	0.628		1.80	pCi/g			0.49	1

QC Association Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15947-2

Rad

Leach Batch: 235441

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-15947-1	TITO12-WSTAVE-CNCRT-001	Total/NA	Solid	Dry and Grind	
160-15947-1 DU	TITO12-WSTAVE-CNCRT-001	Total/NA	Solid	Dry and Grind	
160-15947-2	TITO12-WSTAVE-CNCRT-002	Total/NA	Solid	Dry and Grind	

Prep Batch: 236334

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-15947-1	TITO12-WSTAVE-CNCRT-001	Total/NA	Solid	Fill_Geo-21	235441
160-15947-1 DU	TITO12-WSTAVE-CNCRT-001	Total/NA	Solid	Fill_Geo-21	235441
160-15947-2	TITO12-WSTAVE-CNCRT-002	Total/NA	Solid	Fill_Geo-21	235441
LCS 160-236334/2-A	Lab Control Sample	Total/NA	Solid	Fill_Geo-21	
MB 160-236334/1-A	Method Blank	Total/NA	Solid	Fill_Geo-21	

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica St. Louis
13715 Rider Trail North
Earth City, MO 63045
Tel: (314)298-8566

TestAmerica Job ID: 160-15883-2
Client Project/Site: Treasure Island - 500475

For:
CB&I Environmental & Infrastructure, Inc
4005 Port Chicago Hwy
Concord, California 94520

Attn: Patricia Flynn

Authorized for release by:
3/1/2016 2:16:13 PM

Erika Gish, Project Manager II
(314)298-8566
erika.gish@testamericainc.com

LINKS

Review your project results through TotalAccess

Have a Question? Ask The Expert

Visit us at:
www.testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

Table of Contents

Cover Page 1
Table of Contents 2
Case Narrative 3
Chain of Custody 5
Receipt Checklists 6
Definitions/Glossary 7
Method Summary 8
Sample Summary 9
Client Sample Results 10
QC Sample Results 12
QC Association Summary 14

Job ID: 160-15883-2

Laboratory: TestAmerica St. Louis

Narrative

CASE NARRATIVE

Client: CB&I Environmental & Infrastructure, Inc

Project: Treasure Island - 500475

Report Number: 160-15883-2

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In some cases, due to interference or analytes present at high concentrations, samples were diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

TestAmerica St. Louis attests to the validity of the laboratory data generated by TestAmerica facilities reported herein. All analyses performed by TestAmerica facilities were done using established laboratory SOPs that incorporate QA/QC procedures described in the application methods. TestAmerica's operations groups have reviewed the data for compliance with the laboratory QA/QC plan, and data have been found to be compliant with laboratory protocols unless otherwise noted below.

The test results in this report meet all NELAP requirements for parameters for which accreditation is required or available. Any exceptions to NELAP requirements are noted in this report. Pursuant to NELAP, this report may not be reproduced, except in full, without the written approval of the laboratory.

Calculations are performed before rounding to avoid round-off errors in calculated results.

All holding times were met and proper preservation noted for the methods performed on these samples, unless otherwise detailed in the individual sections below.

All solid sample results for Chemistry analyses are reported on an "as received" basis unless otherwise indicated by the presence of a % solids value in the method header. All soil/sediment sample results for radiochemistry analyses are based upon sample as dried and disaggregated with the exception of tritium, carbon-14, and iodine-129 by gamma spectroscopy unless requested as wet weight by the client."

Reference the chain of custody and condition upon receipt report for any variations on receipt conditions and temperature of samples on receipt
Manual Integrations were performed only when necessary and are in compliance with the laboratory's standard operating procedure. Detailed information can be found in the raw data section of the level IV report.

The following clean-up methods for Organic analyses may have been used on the samples in this data set. Specific methods employed are documented on the batch extraction logs:

Method 3600C: Cleanup
Method 3620C: Florisil Cleanup
Method 3630C: Silica Gel Cleanup
Method 3640A: Gel-Permeation Cleanup
Method 3650B: Acid-Base Partition Cleanup
Method 3660B: Sulfur Cleanup
Method 3665A: Sulfuric Acid/Permanganate Cleanup

This laboratory report is confidential and is intended for the sole use of TestAmerica and its client.

Job ID: 160-15883-2 (Continued)

Laboratory: TestAmerica St. Louis (Continued)

RECEIPT
The samples were received on 1/27/2016 8:30 AM; the samples arrived in good condition, properly preserved. The temperature of the cooler at receipt was 18.1º C.

RADIUM-226 BY GAMMA SPEC (21 DAY INGROWTH)
Samples TITO12-WSTAVE-CH-SED001 (160-15883-2) and TITO12-WSTAVE-CH-SED002 (160-15883-3) were analyzed for Radium-226 by gamma spec (21 day ingrowth) in accordance with EPA GA_01_R. The samples were dried on 01/27/2016, prepared on 01/29/2016 and analyzed on 02/19/2016 and 02/27/2016.

No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

RADIUM 226 (21 DAY INGROWTH)
Sample TITO12-WSTAVE-WOOD012516 (160-15883-1) was analyzed for Radium 226 (21 day ingrowth) in accordance with DOE GA-01-R. The samples were prepared on 01/29/2016 and analyzed on 02/19/2016.

Prep Batch: 160-235061
Sample was prepped as received rather than the project specified dry/grind. TITO12-WSTAVE-WOOD012516 (160-15883-1)

The radium-226 detection goal was not met for the following sample due to the low density of the sample:
TITO12-WSTAVE-WOOD012516 (160-15883-1). Analytical results are reported with the detection limit achieved.

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

CHAIN OF CUSTODY

Ref. Document # TI_WOOD STAVE_002

Page 1 of 1

Shaw Environmental and Infrastructure Inc. (a CB&I company)
Federal Services Division
4005 Port Chicago Hwy
Concord, CA 94520

Project Number: 500475
Project Name / Location: TI WOOD STAVE
Purchase Order #: 202220

Project Manager: John Hackett (Name & phone #)

Shipment Date: 1/26/16
Waybill Number: 1Z89V4620197290786
Lab Destination: TestAmerica St Loius
Lab Contact Name / ph. #: Erika Gish

Send Report To: Patricia Flynn
Phone/Fax Number: 925-288-2037
Address: 4005 Port Chicago Hwy
City: Concord, CA, 94520

Sampler's Name(s): BC

Sample ID Number	Sample Description	Collection Information: Date	Time	Method	Matrix	# of containers	Container Type	Preservative (water) / Preservative (soil)	Gamma Scan							Dose Rate µR/Hr		
								Preservative (soil)	N/A									
TITO12-WSTAVE-WOOD012516	Wood from bottom of wood stave	1/25/16	0905	G	CP	1	Plastic Ziploc bag		X							5		
TITO12-WSTAVE-CH-SED001	Sediment inside bottom of wood stave	1/25/16	0850	G	SL	1	16 oz Plastic		X							5		
TITO12-WSTAVE-CH-SED002	Sediment inside bottom of wood stave	1/25/16	0856	G	SL	1	16 oz Plastic		X							5		

Special Instructions: 7 days ingrown draft and follow with 21 days final

☐ 24-hr ☐ 48-hr

Standard TAT ☐ ☐ 3-day ☐ 7-day

Level Of QC Required: I II III Project Specific:

Relinquished By:	Date: 1-26-16 Time: 1200	Received By:	Date: 1-27-16 Time: 0830
Relinquished By:	Date: Time:	Received By:	Date: Time:

Method Codes

C = Composite G = Grab

Matrix Codes

DW = Drinking Water SO =Soil
GW = Ground Water SL = Sludge
WW = Waste Water CP = Chip Samples
A = Air ABS=Asbestos, PO=Pipe Openning

160-15883 Chain of Custody

Login Sample Receipt Checklist

Client: CB&I Environmental & Infrastructure, Inc

Job Number: 160-15883-2

Login Number: 15883
List Number: 1
Creator: Clarke, Jill C

List Source: TestAmerica St. Louis

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	N/A	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Definitions/Glossary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Qualifiers

Rad

Qualifier	Qualifier Description
U	Undetected at the Limit of Detection.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains no Free Liquid
DER	Duplicate error ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision level concentration
MDA	Minimum detectable activity
EDL	Estimated Detection Limit
MDC	Minimum detectable concentration
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative error ratio
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Method Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Method	Method Description	Protocol	Laboratory
GA-01-R	Radium-226 & Other Gamma Emitters (GS)	DOE	TAL SL

Protocol References:

DOE = U.S. Department of Energy

Laboratory References:

TAL SL = TestAmerica St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Sample Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
160-15883-1	TITO12-WSTAVE-WOOD012516	Solid	01/25/16 09:05	01/27/16 08:30
160-15883-2	TITO12-WSTAVE-CH-SED001	Solid	01/25/16 08:50	01/27/16 08:30
160-15883-3	TITO12-WSTAVE-CH-SED002	Solid	01/25/16 08:56	01/27/16 08:30

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Client Sample ID: TITO12-WSTAVE-WOOD012516

Lab Sample ID: 160-15883-1
Date Collected: 01/25/16 09:05
Matrix: Solid
Date Received: 01/27/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium-227	-0.161	U	1.24	1.24		2.22	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Actinium 228	0.0576	U	0.124	0.124		0.952	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Bismuth-212	0.000	U	0.432	0.432		1.13	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Bismuth-214	-0.0127	U	0.0823	0.0823		0.604	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Lead-210	3.86	U	4.62	4.65		6.97	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Lead-212	0.107	U	0.229	0.229		0.421	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Lead-214	0.0823	U	0.0978	0.0982		0.577	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Potassium-40	1.56	U	1.96	1.96		3.82	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Protactinium-231	0.000	U	0.846	0.846		5.91	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Radium-226	-0.0127	U	0.0823	0.0823	0.500	0.604	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Radium-228	0.0576	U	0.124	0.124		0.952	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Thorium-232	0.0576	U	0.124	0.124		0.952	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Thorium-234	1.64	U	1.49	1.50		4.16	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Thallium-208	0.0259	U	0.0494	0.0495		0.278	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Uranium-235	0.0865	U	0.271	0.271		0.929	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Uranium-238	1.64	U	1.49	1.50		4.16	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Cesium-137	0.000	U	0.0619	0.0619		0.304	pCi/g	01/29/16 09:35	02/19/16 08:22	1
Thorium-228	0.107	U	0.229	0.229		0.421	pCi/g	01/29/16 09:35	02/19/16 08:22	1

Client Sample ID: TITO12-WSTAVE-CH-SED001

Lab Sample ID: 160-15883-2
Date Collected: 01/25/16 08:50
Matrix: Solid
Date Received: 01/27/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.486**		0.171	0.178		0.228	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Actinium-227	0.329	U	0.401	0.403		0.657	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Bismuth-212	0.0769	U	0.456	0.456		0.900	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Bismuth-214	**0.472**		0.145	0.153		0.146	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Cesium-137	**0.225**		0.0650	0.0691		0.0425	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Lead-210	0.792	U	1.16	1.17		1.85	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Lead-212	**0.400**		0.104	0.116		0.115	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Lead-214	**0.562**		0.116	0.130		0.102	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Potassium-40	**10.0**		1.52	1.83		0.981	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Protactinium-231	-0.0307	U	0.107	0.107		1.87	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Radium-226	**0.472**		0.145	0.153	0.500	0.146	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Radium-228	**0.486**		0.171	0.178		0.228	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Thallium-208	**0.164**		0.0474	0.0503		0.0252	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Thorium-228	**0.400**		0.104	0.116		0.115	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Thorium-232	**0.486**		0.171	0.178		0.228	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Thorium-234	0.669	U	0.434	0.440		1.64	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Uranium-235	0.184	U	0.138	0.139		0.524	pCi/g	01/29/16 09:35	02/27/16 08:52	1
Uranium-238	0.669	U	0.434	0.440		1.64	pCi/g	01/29/16 09:35	02/27/16 08:52	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Client Sample ID: TITO12-WSTAVE-CH-SED002

Lab Sample ID: 160-15883-3

Date Collected: 01/25/16 08:56

Matrix: Solid

Date Received: 01/27/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.520**		0.159	0.167		0.146	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Actinium-227	0.0223	U	0.595	0.595		1.03	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Bismuth-212	0.337	U	0.468	0.469		0.777	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Bismuth-214	**0.412**		0.117	0.125		0.110	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Cesium-137	0.0491	U	0.0388	0.0391		0.0578	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Lead-210	0.590	U	1.20	1.20		1.96	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Lead-212	**0.265**		0.0931	0.0992		0.111	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Lead-214	**0.515**		0.128	0.139		0.115	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Potassium-40	**8.31**		1.24	1.51		0.602	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Protactinium-231	0.000	U	0.330	0.330		1.72	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Radium-226	**0.412**		0.117	0.125	0.500	0.110	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Radium-228	**0.520**		0.159	0.167		0.146	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Thallium-208	**0.165**		0.0538	0.0565		0.0428	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Thorium-228	**0.265**		0.0931	0.0992		0.111	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Thorium-232	**0.520**		0.159	0.167		0.146	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Thorium-234	1.04	U	0.813	0.820		1.40	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Uranium-235	0.112	U	0.171	0.171		0.292	pCi/g	01/29/16 09:35	02/19/16 09:00	1
Uranium-238	1.04	U	0.813	0.820		1.40	pCi/g	01/29/16 09:35	02/19/16 09:00	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Lab Sample ID: MB 160-235061/1-A — **Client Sample ID: Method Blank**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 238201 — **Prep Batch: 235061**

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.0000	U	0.0313	0.0313		0.115	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Actinium-227	0.1240	U	0.290	0.291		0.512	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Bismuth-212	-0.1090	U	0.629	0.629		1.14	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Bismuth-214	-0.04373	U	1.20	1.20		0.174	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Lead-210	-0.2306	U	1.29	1.29		2.18	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Lead-212	0.03418	U	0.0624	0.0625		0.114	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Lead-214	0.01511	U	0.0627	0.0627		0.124	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Potassium-40	0.08161	U	0.436	0.436		0.986	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Protactinium-231	0.1993	U	0.773	0.773		1.40	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Radium-226	-0.04373	U	1.20	1.20	0.500	0.174	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Radium-228	0.0000	U	0.0313	0.0313		0.115	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Thallium-208	0.01480	U	0.0397	0.0398		0.0710	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Thorium-232	0.0000	U	0.0313	0.0313		0.115	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Cesium-137	0.007907	U	0.0288	0.0288		0.0548	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Thorium-234	0.3964	U	0.479	0.481		1.44	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Uranium-235	0.0000	U	0.170	0.170		0.331	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Thorium-228	0.03418	U	0.0624	0.0625		0.114	pCi/g	01/29/16 09:35	02/19/16 01:54	1
Uranium-238	0.3964	U	0.479	0.481		1.44	pCi/g	01/29/16 09:35	02/19/16 01:54	1

Lab Sample ID: LCS 160-235061/2-A — **Client Sample ID: Lab Control Sample**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 238199 — **Prep Batch: 235061**

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	%Rec	%Rec. Limits
Americium-241	97.2	96.29		10.1		1.05	pCi/g	99	87 - 116
Cesium-137	29.9	29.59		3.16		0.248	pCi/g	99	87 - 120
Cobalt-60	17.8	17.32		1.80		0.0807	pCi/g	97	87 - 115

Lab Sample ID: 160-15883-2 DU — **Client Sample ID: TITO12-WSTAVE-CH-SED001**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 238200 — **Prep Batch: 235061**

Analyte	Sample Result	Sample Qual	DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	RER	RER Limit
Actinium 228	0.486		0.1457	U	0.161		0.356	pCi/g	1.00	1
Actinium-227	0.329	U	-0.02715	U	0.0496		0.939	pCi/g	0.79	1
Bismuth-212	0.0769	U	0.3120	U	0.474		0.796	pCi/g	0.25	1
Bismuth-214	0.472		0.4987		0.130		0.112	pCi/g	0.1	1
Lead-210	0.792	U	-0.3113	U	1.77		2.48	pCi/g	0.38	1
Lead-212	0.400		0.4429		0.159		0.148	pCi/g	0.16	1
Lead-214	0.562		0.4548		0.123		0.151	pCi/g	0.42	1
Potassium-40	10.0		9.883		1.80		0.938	pCi/g	0.04	1
Protactinium-231	-0.0307	U	-0.1449	U	0.989		1.77	pCi/g	0.10	1
Radium-226	0.472		0.4987		0.130	0.500	0.112	pCi/g	0.1	1
Radium-228	0.486		0.1457	U	0.161		0.356	pCi/g	1.00	1
Thallium-208	0.164		0.1617		0.0744		0.0765	pCi/g	0.02	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS) (Continued)

Lab Sample ID: 160-15883-2 DU
Matrix: Solid
Analysis Batch: 238200

Client Sample ID: TITO12-WSTAVE-CH-SED001
Prep Type: Total/NA
Prep Batch: 235061

Analyte	Sample Result	Sample Qual		DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit			RER	RER Limit
Thorium-232	0.486			0.1457	U	0.161		0.356	pCi/g			1.00	1
Cesium-137	0.225			0.2877		0.0713		0.0268	pCi/g			0.45	1
Thorium-234	0.669	U		1.312	U	1.14		1.93	pCi/g			0.41	1
Uranium-235	0.184	U		0.2166	U	0.257		0.378	pCi/g			0.08	1
Thorium-228	0.400			0.4429		0.159		0.148	pCi/g			0.16	1
Uranium-238	0.669	U		1.312	U	1.14		1.93	pCi/g			0.41	1

QC Association Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-15883-2

Rad

Leach Batch: 234629

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-15883-2	TITO12-WSTAVE-CH-SED001	Total/NA	Solid	Dry and Grind	
160-15883-2 DU	TITO12-WSTAVE-CH-SED001	Total/NA	Solid	Dry and Grind	
160-15883-3	TITO12-WSTAVE-CH-SED002	Total/NA	Solid	Dry and Grind	

Prep Batch: 235061

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-15883-1	TITO12-WSTAVE-WOOD012516	Total/NA	Solid	Fill_Geo-21	
160-15883-2	TITO12-WSTAVE-CH-SED001	Total/NA	Solid	Fill_Geo-21	234629
160-15883-2 DU	TITO12-WSTAVE-CH-SED001	Total/NA	Solid	Fill_Geo-21	234629
160-15883-3	TITO12-WSTAVE-CH-SED002	Total/NA	Solid	Fill_Geo-21	234629
LCS 160-235061/2-A	Lab Control Sample	Total/NA	Solid	Fill_Geo-21	
MB 160-235061/1-A	Method Blank	Total/NA	Solid	Fill_Geo-21	

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica St. Louis
13715 Rider Trail North
Earth City, MO 63045
Tel: (314)298-8566

TestAmerica Job ID: 160-16018-2
Client Project/Site: Treasure Island - 500475

For:
CB&I Environmental & Infrastructure, Inc
4005 Port Chicago Hwy
Concord, California 94520

Attn: Patricia Flynn

Authorized for release by:
3/8/2016 4:53:44 PM

Erika Gish, Project Manager II
(314)298-8566
erika.gish@testamericainc.com

LINKS

Review your project results through TotalAccess

Have a Question? Ask The Expert

Visit us at:
www.testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

Table of Contents

Cover Page 1
Table of Contents 2
Case Narrative 3
Chain of Custody 5
Receipt Checklists 6
Definitions/Glossary 7
Method Summary 8
Sample Summary 9
Client Sample Results 10
QC Sample Results 13
QC Association Summary 15

Job ID: 160-16018-2

Laboratory: TestAmerica St. Louis

Narrative

CASE NARRATIVE

Client: CB&I Environmental & Infrastructure, Inc

Project: Treasure Island - 500475

Report Number: 160-16018-2

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In some cases, due to interference or analytes present at high concentrations, samples were diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

TestAmerica St. Louis attests to the validity of the laboratory data generated by TestAmerica facilities reported herein. All analyses performed by TestAmerica facilities were done using established laboratory SOPs that incorporate QA/QC procedures described in the application methods. TestAmerica's operations groups have reviewed the data for compliance with the laboratory QA/QC plan, and data have been found to be compliant with laboratory protocols unless otherwise noted below.

The test results in this report meet all NELAP requirements for parameters for which accreditation is required or available. Any exceptions to NELAP requirements are noted in this report. Pursuant to NELAP, this report may not be reproduced, except in full, without the written approval of the laboratory.

Calculations are performed before rounding to avoid round-off errors in calculated results.

All holding times were met and proper preservation noted for the methods performed on these samples, unless otherwise detailed in the individual sections below.

All solid sample results for Chemistry analyses are reported on an "as received" basis unless otherwise indicated by the presence of a % solids value in the method header. All soil/sediment sample results for radiochemistry analyses are based upon sample as dried and disaggregated with the exception of tritium, carbon-14, and iodine-129 by gamma spectroscopy unless requested as wet weight by the client."

Reference the chain of custody and condition upon receipt report for any variations on receipt conditions and temperature of samples on receipt
Manual Integrations were performed only when necessary and are in compliance with the laboratory's standard operating procedure. Detailed information can be found in the raw data section of the level IV report.

The following clean-up methods for Organic analyses may have been used on the samples in this data set. Specific methods employed are documented on the batch extraction logs:

Method 3600C: Cleanup
Method 3620C: Florisil Cleanup
Method 3630C: Silica Gel Cleanup
Method 3640A: Gel-Permeation Cleanup
Method 3650B: Acid-Base Partition Cleanup
Method 3660B: Sulfur Cleanup
Method 3665A: Sulfuric Acid/Permanganate Cleanup

This laboratory report is confidential and is intended for the sole use of TestAmerica and its client.

Job ID: 160-16018-2 (Continued)

Laboratory: TestAmerica St. Louis (Continued)

RECEIPT
The samples were received on 2/5/2016 8:30 AM; the samples arrived in good condition, properly preserved. The temperature of the cooler at receipt was 23.0º C.

RADIUM-226 BY GAMMA SPEC (21 DAY INGROWTH)
Samples TITO12-WSTAVE-CNCRTW8CH-001 (160-16018-1), TITO12-WSTAVE-W8CH-S002 (160-16018-2), TITO12-WSTAVE-CNCRTE1CH-004 (160-16018-4) and TITO12-WSTAVE-CH-SED005 (160-16018-5) were analyzed for Radium-226 by gamma spec (21 day ingrowth) in accordance with EPA GA_01_R. The samples were dried on 02/10/2016, prepared on 02/12/2016 and analyzed on 03/04/2016.

No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

RADIUM 226 (21 DAY INGROWTH)
Samples TITO12-WSTAVE-WOODW8CH-003 (160-16018-3) and TITO12-WSTAVE-WOODE1CH-006 (160-16018-6) were analyzed for Radium 226 (21 day ingrowth) in accordance with DOE GA-01-R. The samples were prepared on 02/12/2016 and analyzed on 03/04/2016.

Due to the matrix, the samples were not dried and ground as per the project requirements.

No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

CHAIN OF CUSTODY

Ref. Document # TI_WOOD STAVE_006

Page 1 of 1

Shaw Environmental and Infrastructure Inc. (a CB&I company)
Federal Services Division
4005 Port Chicago Hwy
Concord, CA 94520

Project Number: 500475
Project Name / Location: TI WOOD STAVE Backfill
Purchase Order #: 202220

Project Manager: John Hackett (Name & phone #)

Shipment Date: 2/4/2016
Waybill Number: 1Z 89V46201971866827
Lab Destination: TestAmerica St Loius
Lab Contact Name / ph. #: Erika Gish

Send Report To: Patricia Flynn
Phone/Fax Number: 925-288-2037
Address: 4005 Port Chicago Hwy
City: Concord, CA, 94520

Sampler's Name(s): A. Neotti

Sample ID Number	Sample Description	Collection Information Date	Time	Method	Matrix	# of containers	Preservative (water) / Preservative (soil) / Container Type	Gamma Scan							Dose Rate µR/Hr		
							Preservative (water)										
							Preservative (soil)	N/A									
							Container Type										
TITO12-WSTAVE-CNCRTW8CH-001	Concrete slurry chracterization section West 8 inside pipe	02/03/16	8:10	G	CP	1	16 oz Plastic	X							5		
TITO12-WSTAVE-W8CH-S002	Soil characterization section West 8 within 1 foot of the pipe	02/03/16	9:05	G	S	1	16 oz Plastic	X							5		
TITO12-WSTAVE-WOODW8CH-003	Wood characterization section West 8 bottom of pipe	02/03/16	8:25	G	CP	1	16 oz Plastic	X							5		
TITO12-WSTAVE-CNCRTE1CH-004	Concrete slurry chracterization section East 1 inside pipe	02/03/16	8:00	G	CP	1	16 oz Plastic	X							5		
TITO12-WSTAVE-CH-SED005	Sediment Section East 1 inside bottom of pipe	02/02/16	13:30	G	S	1	16 oz Plastic	X							5		
TITO12-WSTAVE-WOODE1CH-006	Wood characterization section East 1 bottom of pipe	02/03/16	8:17	G	CP	1	16 oz Plastic	X							5		

Analyses Requested

160-16018 Chain of Custody

Special Instructions: 7 days ingrown draft and follow with 21 days final

Standard TAT ☐ ☐ 24-hr ☐ 48-hr ☐ 3-day ☐ 7-day

Level Of QC Required: I II III Project Specific:

Relinquished By: Bryon Rogers Date: 2/4/2016 Time: 1200
Relinquished By: Date: Time:
Received By: C McG Date: 020516 Time: 0830
Received By: Date: Time:

Method Codes
C = Composite G = Grab

Matrix Codes
DW = Drinking Water SO =Soil
GW = Ground Water SL = Sludge
WW = Waste Water CP = Chip Samples
A = Air ABS=Asbestos, PO=Pipe Openning

Login Sample Receipt Checklist

Client: CB&I Environmental & Infrastructure, Inc

Job Number: 160-16018-2

Login Number: 16018
List Number: 1
Creator: Daniels, Brian J

List Source: TestAmerica St. Louis

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	N/A	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	N/A	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Definitions/Glossary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Qualifiers

Rad

Qualifier	Qualifier Description
U	Undetected at the Limit of Detection.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains no Free Liquid
DER	Duplicate error ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision level concentration
MDA	Minimum detectable activity
EDL	Estimated Detection Limit
MDC	Minimum detectable concentration
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative error ratio
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Method Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Method	Method Description	Protocol	Laboratory
GA-01-R	Radium-226 & Other Gamma Emitters (GS)	DOE	TAL SL

Protocol References:

DOE = U.S. Department of Energy

Laboratory References:

TAL SL = TestAmerica St. Louis, 13715 Rider Trail North, Earth City, MO 63045, TEL (314)298-8566

Sample Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
160-16018-1	TITO12-WSTAVE-CNCRTW8CH-001	Solid	02/03/16 08:10	02/05/16 08:30
160-16018-2	TITO12-WSTAVE-W8CH-S002	Solid	02/03/16 09:05	02/05/16 08:30
160-16018-3	TITO12-WSTAVE-WOODW8CH-003	Solid	02/03/16 08:25	02/05/16 08:30
160-16018-4	TITO12-WSTAVE-CNCRTE1CH-004	Solid	02/03/16 08:00	02/05/16 08:30
160-16018-5	TITO12-WSTAVE-CH-SED005	Solid	02/03/16 13:30	02/05/16 08:30
160-16018-6	TITO12-WSTAVE-WOODE1CH-006	Solid	02/03/16 08:17	02/05/16 08:30

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Client Sample ID: TITO12-WSTAVE-CNCRTW8CH-001

Lab Sample ID: 160-16018-1
Date Collected: 02/03/16 08:10
Matrix: Solid
Date Received: 02/05/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.249	U	0.108	0.111		0.251	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Actinium-227	0.0551	U	0.323	0.324		0.577	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Bismuth-212	0.288	U	0.479	0.479		0.815	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Bismuth-214	**0.375**		0.0960	0.104		0.0462	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Cesium-137	0.00527	U	0.0352	0.0352		0.0660	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Lead-210	0.0537	U	0.809	0.809		1.57	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Lead-212	**0.275**		0.0778	0.0856		0.0833	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Lead-214	**0.364**		0.0960	0.103		0.0912	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Potassium-40	**4.73**		1.10	1.20		0.612	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Protactinium-231	-0.224	U	0.838	0.838		1.48	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Radium-226	**0.375**		0.0960	0.104	0.500	0.0462	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Radium-228	0.249	U	0.108	0.111		0.251	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Thallium-208	**0.142**		0.0538	0.0558		0.0420	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Thorium-228	**0.275**		0.0778	0.0856		0.0833	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Thorium-232	0.249	U	0.108	0.111		0.251	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Thorium-234	0.358	U	0.310	0.313		1.15	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Uranium-235	0.125	U	0.146	0.147		0.179	pCi/g	02/12/16 08:34	03/04/16 06:02	1
Uranium-238	0.358	U	0.310	0.313		1.15	pCi/g	02/12/16 08:34	03/04/16 06:02	1

Client Sample ID: TITO12-WSTAVE-W8CH-S002

Lab Sample ID: 160-16018-2
Date Collected: 02/03/16 09:05
Matrix: Solid
Date Received: 02/05/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.331**		0.136	0.140		0.186	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Actinium-227	0.0427	U	0.254	0.254		0.456	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Bismuth-212	0.295	U	0.407	0.408		0.676	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Bismuth-214	**0.371**		0.0930	0.101		0.0878	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Cesium-137	-0.00167	U	0.0346	0.0346		0.0637	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Lead-210	0.685	U	0.744	0.748		1.21	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Lead-212	**0.353**		0.0858	0.0972		0.0904	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Lead-214	**0.412**		0.104	0.112		0.101	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Potassium-40	**10.6**		1.31	1.70		0.633	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Protactinium-231	0.0602	U	0.134	0.134		1.63	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Radium-226	**0.371**		0.0930	0.101	0.500	0.0878	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Radium-228	**0.331**		0.136	0.140		0.186	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Thallium-208	**0.180**		0.0418	0.0458		0.0179	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Thorium-228	**0.353**		0.0858	0.0972		0.0904	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Thorium-232	**0.331**		0.136	0.140		0.186	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Thorium-234	0.608	U	0.901	0.903		1.50	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Uranium-235	0.119	U	0.157	0.157		0.295	pCi/g	02/12/16 08:34	03/04/16 05:58	1
Uranium-238	0.608	U	0.901	0.903		1.50	pCi/g	02/12/16 08:34	03/04/16 05:58	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Client Sample ID: TITO12-WSTAVE-WOODW8CH-003

Lab Sample ID: 160-16018-3
Date Collected: 02/03/16 08:25
Matrix: Solid
Date Received: 02/05/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium-227	0.108	U	0.519	0.519		2.49	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Actinium 228	0.196	U	0.282	0.283		1.01	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Bismuth-212	0.245	U	2.10	2.10		3.85	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Bismuth-214	-0.0713	U	0.712	0.712		0.460	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Lead-210	1.85	U	3.87	3.87		6.97	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Lead-212	0.258	U	0.192	0.195		0.285	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Lead-214	0.0398	U	0.207	0.207		0.428	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Potassium-40	0.389	U	1.52	1.53		3.31	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Protactinium-231	-0.486	U	2.96	2.97		5.39	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Radium-226	-0.0713	U	0.712	0.712	0.500	0.460	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Radium-228	0.196	U	0.282	0.283		1.01	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Thorium-232	0.196	U	0.282	0.283		1.01	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Thorium-234	-1.74	U	6.59	6.59		5.84	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Thallium-208	-0.00281	U	0.112	0.112		0.229	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Uranium-235	0.322	U	0.544	0.545		0.922	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Uranium-238	-1.74	U	6.59	6.59		5.84	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Cesium-137	0.0313	U	0.127	0.127		0.235	pCi/g	02/12/16 12:18	03/04/16 05:58	1
Thorium-228	0.258	U	0.192	0.195		0.285	pCi/g	02/12/16 12:18	03/04/16 05:58	1

Client Sample ID: TITO12-WSTAVE-CNCRTE1CH-004

Lab Sample ID: 160-16018-4
Date Collected: 02/03/16 08:00
Matrix: Solid
Date Received: 02/05/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	0.219	U	0.138	0.140		0.277	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Actinium-227	-0.0442	U	0.0888	0.0889		0.829	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Bismuth-212	0.393	U	0.408	0.410		0.624	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Bismuth-214	**0.280**		0.126	0.130		0.140	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Cesium-137	0.0179	U	0.0418	0.0418		0.0738	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Lead-210	-0.186	U	1.39	1.39		1.83	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Lead-212	**0.261**		0.0863	0.0927		0.0979	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Lead-214	**0.268**		0.0949	0.0989		0.137	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Potassium-40	**4.16**		1.12	1.20		1.07	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Protactinium-231	0.0456	U	0.375	0.375		1.49	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Radium-226	**0.280**		0.126	0.130	0.500	0.140	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Radium-228	0.219	U	0.138	0.140		0.277	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Thallium-208	0.0229	U	0.0480	0.0481		0.0762	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Thorium-228	**0.261**		0.0863	0.0927		0.0979	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Thorium-232	0.219	U	0.138	0.140		0.277	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Thorium-234	0.114	U	0.445	0.445		1.64	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Uranium-235	0.0515	U	0.114	0.115		0.349	pCi/g	02/12/16 08:34	03/04/16 05:55	1
Uranium-238	0.114	U	0.445	0.445		1.64	pCi/g	02/12/16 08:34	03/04/16 05:55	1

Client Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Client Sample ID: TITO12-WSTAVE-CH-SED005

Lab Sample ID: 160-16018-5
Date Collected: 02/03/16 13:30
Matrix: Solid
Date Received: 02/05/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	**0.275**		0.146	0.149		0.204	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Actinium-227	0.0941	U	0.161	0.161		0.808	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Bismuth-212	0.352	U	0.510	0.511		0.851	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Bismuth-214	**0.365**		0.0998	0.107		0.103	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Cesium-137	-0.00756	U	0.0410	0.0410		0.0740	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Lead-210	-0.118	U	1.31	1.31		2.18	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Lead-212	**0.316**		0.113	0.120		0.132	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Lead-214	**0.517**		0.109	0.122		0.141	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Potassium-40	**7.53**		1.28	1.50		1.17	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Protactinium-231	0.326	U	0.916	0.917		1.59	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Radium-226	**0.365**		0.0998	0.107	0.500	0.103	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Radium-228	**0.275**		0.146	0.149		0.204	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Thallium-208	**0.181**		0.0639	0.0667		0.0642	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Thorium-228	**0.316**		0.113	0.120		0.132	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Thorium-232	**0.275**		0.146	0.149		0.204	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Thorium-234	0.802	U	0.443	0.451		1.45	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Uranium-235	0.0694	U	0.143	0.143		0.424	pCi/g	02/12/16 08:34	03/04/16 05:56	1
Uranium-238	0.802	U	0.443	0.451		1.45	pCi/g	02/12/16 08:34	03/04/16 05:56	1

Client Sample ID: TITO12-WSTAVE-WOODE1CH-006

Lab Sample ID: 160-16018-6
Date Collected: 02/03/16 08:17
Matrix: Solid
Date Received: 02/05/16 08:30

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Analyte	Result	Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium-227	-0.00172	U	0.990	0.990		1.84	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Actinium 228	0.314	U	0.302	0.304		0.592	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Bismuth-212	0.388	U	1.40	1.40		2.62	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Bismuth-214	**0.484**		0.241	0.246		0.295	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Lead-210	0.164	U	2.24	2.24		4.67	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Lead-212	0.0217	U	0.146	0.146		0.287	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Lead-214	**0.391**		0.191	0.195		0.234	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Potassium-40	0.0849	U	1.54	1.54		3.45	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Protactinium-231	-0.586	U	2.49	2.49		4.54	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Radium-226	**0.484**		0.241	0.246	0.500	0.295	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Radium-228	0.314	U	0.302	0.304		0.592	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Thorium-232	0.314	U	0.302	0.304		0.592	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Thorium-234	-0.149	U	0.356	0.356		3.67	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Thallium-208	0.0378	U	0.115	0.115		0.201	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Uranium-235	0.0581	U	0.396	0.396		0.762	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Uranium-238	-0.149	U	0.356	0.356		3.67	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Cesium-137	-0.0158	U	0.172	0.172		0.253	pCi/g	02/12/16 12:18	03/04/16 07:40	1
Thorium-228	0.0217	U	0.146	0.146		0.287	pCi/g	02/12/16 12:18	03/04/16 07:40	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS)

Lab Sample ID: MB 160-236499/1-A — **Client Sample ID: Method Blank**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 239242 — **Prep Batch: 236499**

Analyte	MB Result	MB Qualifier	Count Uncert. (2σ+/-)	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	Prepared	Analyzed	Dil Fac
Actinium 228	-0.06512	U	2.60	2.60		0.300	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Actinium-227	0.07114	U	0.120	0.120		0.878	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Bismuth-212	-0.09688	U	1.56	1.56		0.945	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Bismuth-214	-0.04155	U	0.317	0.317		0.178	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Lead-210	0.1172	U	0.784	0.784		1.65	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Lead-212	-0.03079	U	0.238	0.238		0.109	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Lead-214	-0.03970	U	1.59	1.59		0.183	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Potassium-40	-0.2212	U	1.05	1.05		1.27	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Protactinium-231	0.01604	U	0.704	0.704		1.34	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Radium-226	-0.04155	U	0.317	0.317	0.500	0.178	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Radium-228	-0.06512	U	2.60	2.60		0.300	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Thallium-208	0.006394	U	0.0368	0.0368		0.0610	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Thorium-232	-0.06512	U	2.60	2.60		0.300	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Cesium-137	0.01374	U	0.0355	0.0355		0.0640	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Thorium-234	-0.6046	U	2.21	2.22		1.46	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Uranium-235	0.05094	U	0.100	0.100		0.353	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Thorium-228	-0.03079	U	0.238	0.238		0.109	pCi/g	02/12/16 08:34	03/04/16 06:01	1
Uranium-238	-0.6046	U	2.21	2.22		1.46	pCi/g	02/12/16 08:34	03/04/16 06:01	1

Lab Sample ID: LCS 160-236499/2-A — **Client Sample ID: Lab Control Sample**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 239244 — **Prep Batch: 236499**

Analyte	Spike Added	LCS Result	LCS Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	%Rec	%Rec. Limits
Americium-241	97.2	100.1		10.5		1.24	pCi/g	103	87 - 116
Cesium-137	29.8	30.05		3.24		0.321	pCi/g	101	87 - 120
Cobalt-60	17.7	17.84		1.87		0.117	pCi/g	101	87 - 115

Lab Sample ID: 160-16018-1 DU — **Client Sample ID: TITO12-WSTAVE-CNCRTW8CH-001**
Matrix: Solid — **Prep Type: Total/NA**
Analysis Batch: 239242 — **Prep Batch: 236499**

Analyte	Sample Result	Sample Qual	DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit	RER	RER Limit
Actinium 228	0.249	U	0.2635		0.140		0.226	pCi/g	0.06	1
Actinium-227	0.0551	U	0.1980	U	0.382		0.650	pCi/g	0.20	1
Bismuth-212	0.288	U	0.04349	U	0.556		1.06	pCi/g	0.24	1
Bismuth-214	0.375		0.4768		0.140		0.124	pCi/g	0.42	1
Lead-210	0.0537	U	0.3025	U	1.02		1.92	pCi/g	0.14	1
Lead-212	0.275		0.2789		0.106		0.116	pCi/g	0.02	1
Lead-214	0.364		0.4303		0.126		0.125	pCi/g	0.29	1
Potassium-40	4.73		6.044		1.34		0.954	pCi/g	0.52	1
Protactinium-231	-0.224	U	0.2411	U	0.568		1.44	pCi/g	0.33	1
Radium-226	0.375		0.4768		0.140	0.500	0.124	pCi/g	0.42	1
Radium-228	0.249	U	0.2635		0.140		0.226	pCi/g	0.06	1
Thallium-208	0.142		0.1613		0.0490		0.0245	pCi/g	0.19	1

QC Sample Results

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Method: GA-01-R - Radium-226 & Other Gamma Emitters (GS) (Continued)

Lab Sample ID: 160-16018-1 DU
Matrix: Solid
Analysis Batch: 239242

Client Sample ID: TITO12-WSTAVE-CNCRTW8CH-001
Prep Type: Total/NA
Prep Batch: 236499

Analyte	Sample Result	Sample Qual		DU Result	DU Qual	Total Uncert. (2σ+/-)	LOQ	MDC	Unit			RER	RER Limit
Thorium-232	0.249	U		0.2635		0.140		0.226	pCi/g			0.06	1
Cesium-137	0.00527	U		0.003734	U	0.0350		0.0662	pCi/g			0.02	1
Thorium-234	0.358	U		0.2772	U	0.477		1.46	pCi/g			0.10	1
Uranium-235	0.125	U		0.03806	U	0.124		0.282	pCi/g			0.32	1
Thorium-228	0.275			0.2789		0.106		0.116	pCi/g			0.02	1
Uranium-238	0.358	U		0.2772	U	0.477		1.46	pCi/g			0.10	1

QC Association Summary

Client: CB&I Environmental & Infrastructure, Inc
Project/Site: Treasure Island - 500475

TestAmerica Job ID: 160-16018-2

Rad

Leach Batch: 236344

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-16018-1	TITO12-WSTAVE-CNCRTW8CH-001	Total/NA	Solid	Dry and Grind	
160-16018-1 DU	TITO12-WSTAVE-CNCRTW8CH-001	Total/NA	Solid	Dry and Grind	
160-16018-2	TITO12-WSTAVE-W8CH-S002	Total/NA	Solid	Dry and Grind	
160-16018-4	TITO12-WSTAVE-CNCRTE1CH-004	Total/NA	Solid	Dry and Grind	
160-16018-5	TITO12-WSTAVE-CH-SED005	Total/NA	Solid	Dry and Grind	

Prep Batch: 236499

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
160-16018-1	TITO12-WSTAVE-CNCRTW8CH-001	Total/NA	Solid	Fill_Geo-21	236344
160-16018-1 DU	TITO12-WSTAVE-CNCRTW8CH-001	Total/NA	Solid	Fill_Geo-21	236344
160-16018-2	TITO12-WSTAVE-W8CH-S002	Total/NA	Solid	Fill_Geo-21	236344
160-16018-3	TITO12-WSTAVE-WOODW8CH-003	Total/NA	Solid	Fill_Geo-21	
160-16018-4	TITO12-WSTAVE-CNCRTE1CH-004	Total/NA	Solid	Fill_Geo-21	236344
160-16018-5	TITO12-WSTAVE-CH-SED005	Total/NA	Solid	Fill_Geo-21	236344
160-16018-6	TITO12-WSTAVE-WOODE1CH-006	Total/NA	Solid	Fill_Geo-21	
LCS 160-236499/2-A	Lab Control Sample	Total/NA	Solid	Fill_Geo-21	
MB 160-236499/1-A	Method Blank	Total/NA	Solid	Fill_Geo-21	

Hackett, John R

From: Sevcik, Joseph T CIV SEA 04 04N <joseph.sevcik@navy.mil>
Sent: Wednesday, April 06, 2016 6:13 AM
To: Hackett, John R
Cc: Edwards, Zachary L CIV SEA 04 04N; Kimberly Noble; Guillory, Jeffrey; Schul, Raymond
Subject: RE: D2005 CTO 0012 NSTI Wood Stave Pipe Removal - RSY Soil Release and Backfill Concurrence Request
Signed By: joseph.sevcik@navy.mil

John,

As per my email yesterday- I concur with designating SY 233A (Use 1 Wood Stave soil) as non-LLRW as well as concurring with the backfill of the wood stave trenches with appropriate backfill material.

v/r,

Joe Sevcik
Environmental Protection Manager
NAVSEADET RASO
160 Main Road
Building 1959
NWS Yorktown, VA 23691
Office: (757) 887-4483
DSN: 953-4483
Fax: (757) 887-4900

CONFIDENTIALITY NOTICE: This electronic message is intended to be viewed only by the individual or entity to whom it is addressed. It may contain information that is privileged, confidential and exempt from disclosure under applicable law. Any dissemination, distribution or copying of this communication is strictly prohibited without prior permission. If the reader of this message is not the intended recipient, or the employee or agent responsible for delivering the message to the intended recipient, or if you have received this communication in error, please notify me immediately by return e-mail and delete the original message and any copies of it from your computer system.

-----Original Message-----
From: Hackett, John R [mailto:john.hackett@CBIFederalServices.com]
Sent: Tuesday, April 05, 2016 6:27 PM
To: Sevcik, Joseph T CIV SEA 04 04N
Cc: Edwards, Zachary L CIV SEA 04 04N; Kimberly Noble; Guillory, Jeffrey; Schul, Raymond
Subject: [Non-DoD Source] D2005 CTO 0012 NSTI Wood Stave Pipe Removal - RSY Soil Release and Backfill Concurrence Request

Joe,

Please find the revised data package which includes the data from the processing of excavated impacted soil on RSY 233A Use 1 as well as in-process soil, sediment, wood, and concrete analytical data, as well as incorporates your comment on the summary text. We are requesting concurrence to designate the soil as non-LLRW soil, as well as concurrence to backfill the excavation using clean import material. Due to elevated asbestos results in chemical reuse samples, we will not reuse the excavated soil for backfill.

If you have any questions, please let us know.

Thanks,

John

Description: Description: Description: Description: Description: Description:
cid:_1_0AD725A00AD721CC001388C386257B11

John R. Hackett, PE, CHP, PMP
Federal Services

Tel: +1 303-486-2512
Cell: +1 303-589-7217
john.hackett@cbifederalservices.com

CB&I
6380 South Fiddler's Green Circle
Greenwood Village, CO 80111
United States
www.CBI.com

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

TestAmerica Laboratories, Inc.

ANALYTICAL REPORT

REVISED

PROJECT NO. 122412-048.02

Treasure Island

Lot #: F1D110423

Pat Flynn

Shaw Environmental Inc.
Treasure Island
Bldg. 570 Avenue "M"
San Francisco, CA 94130

TESTAMERICA LABORATORIES, INC.

Ivan Vania
Project Manager

July 18, 2011

13715 Rider Trail North Earth City, MO 63045 **tel** 314.298.8566 **fax** 314.298.8757 **www.testamericainc.com**

Case Narrative
LOT NUMBER: **F1D110423 – Revision 2**

This report contains the analytical results for the 22 samples received under chain of custody by TestAmerica St. Louis on April 11, 2011. These samples are associated with your Treasure Island project.

The analytical results included in this report meet all applicable quality control procedure requirements.

The test results in this report meet all NELAP requirements for parameters in which accreditations are held by TestAmerica St. Louis. Any exceptions to NELAP requirements are noted in the case narrative. **TestAmerica St. Louis' Florida certification number is E87689.** The case narrative is an integral part of this report.

This report shall not be reproduced, except in full, without the written approval of the laboratory.

All chemical analysis results are based upon sample as received, wet weight, unless noted otherwise. All radiochemistry results are based upon sample as dried and ground with the exception of tritium, unless requested wet weight by the client.

This revision contains results for revision 1 and additional nuclides analyzed by gamma spectroscopy per client request.

Observations/Nonconformances
Reference the chain of custody and condition upon receipt report for any variations on receipt conditions and temperature of samples on receipt.

There were no other nonconformances or observations noted with any analysis on this lot.

METHODS SUMMARY

F1D110423

PARAMETER	ANALYTICAL METHOD	PREPARATION METHOD
Gamma Spectroscopy - Radium-226 & Hits	EML GA-01-R MOD	

References:

EML "ENVIRONMENTAL MEASUREMENTS LABORATORY PROCEDURES MANUAL"
HASL-300 28TH EDITION, VOLUME I and II DEPARTMENT OF ENERGY

SAMPLE SUMMARY

F1D110423

WO #	SAMPLE#	CLIENT SAMPLE ID	SAMPLED DATE	SAMP TIME
MGT7D	001	TIBKGRD-043-0311	03/29/11	15:45
MGT7F	002	TIBKGRD-044-0311	03/29/11	16:02
MGT7G	003	TIBKGRD-045-0311	03/29/11	15:02
MGT7H	004	TIBKGRD-046-0311	03/29/11	15:26
MGT7J	005	TIBKGRD-047-0311	03/30/11	08:15
MGT7K	006	TIBKGRD-048-0311	03/30/11	08:15
MGT7N	007	TIBKGRD-049-0311	03/30/11	08:37
MGT7Q	008	TIBKGRD-050-0311	03/30/11	08:55
MGT7T	009	TIBKGRD-051-0311	03/30/11	09:07
MGT7W	010	TIBKGRD-052-0311	03/30/11	09:21
MGT70	011	TIBKGRD-053-0311	03/30/11	11:02
MGT71	012	TIBKGRD-054-0311	03/30/11	11:27
MGT72	013	TIBKGRD-055-0311	03/30/11	13:04
MGT73	014	TIBKGRD-056-0311	03/30/11	13:04
MGT74	015	TIBKGRD-057-0311	03/30/11	14:15
MGT76	016	TIBKGRD-058-0311	03/31/11	08:08
MGT77	017	TIBKGRD-059-0311	03/31/11	08:38
MGT79	018	TIBKGRD-060-0311	03/31/11	08:55
MGT8A	019	TIBKGRD-061-0311	03/31/11	10:10
MGT8C	020	TIBKGRD-062-0311	03/31/11	13:15
MGT8E	021	TIBKGRD-063-0311	03/31/11	13:30
MGT8F	022	TIBKGRD-064-0311	03/31/11	14:50

NOTE(S):

- The analytical results of the samples listed above are presented on the following pages.
- All calculations are performed before rounding to avoid round-off errors in calculated results.
- Results noted as "ND" were not detected at or above the stated limit.
- This report must not be reproduced, except in full, without the written approval of the laboratory.
- Results for the following parameters are never reported on a dry weight basis: color, corrosivity, density, flashpoint, ignitability, layers, odor, paint filter test, pH, porosity pressure, reactivity, redox potential, specific gravity, spot tests, solids, solubility, temperature, viscosity, and weight.

Shaw E & I Inc

Client Sample ID: TIBKGRD-043-0311

Radiochemistry

Lab Sample ID: F1D110423-001
Work Order: MGT7D
Matrix: SOLID

Date Collected: 03/29/11 1545
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD			pCi/g		Batch # 1102232		Yld %
Actinium 227	-0.03	U	0.55		0.92	04/12/11	05/10/11
Actinium 228	**0.67**		**0.16**		**0.14**	**04/12/11**	**05/10/11**
Bismuth 212	0.21	U	0.27		0.44	04/12/11	05/10/11
Bismuth 214	**0.49**		**0.13**		**0.13**	**04/12/11**	**05/10/11**
Cesium 137	0.006	U	0.042		0.074	04/12/11	05/10/11
Lead 210	0.2	U	1.1		2.1	04/12/11	05/10/11
Lead 212	**0.51**		**0.11**		**0.11**	**04/12/11**	**05/10/11**
Lead 214	**0.60**		**0.12**		**0.11**	**04/12/11**	**05/10/11**
Potassium 40	**9.5**		**1.3**		**0.8**	**04/12/11**	**05/10/11**
Protactinium 231	-0.5	U	1.0		1.7	04/12/11	05/10/11
Radium (226)	**0.49**	J	**0.13**	0.50	**0.13**	**04/12/11**	**05/10/11**
Radium 228	**0.67**		**0.16**		**0.14**	**04/12/11**	**05/10/11**
Thallium 208	**0.209**		**0.068**		**0.066**	**04/12/11**	**05/10/11**
Thorium 234	0.7	U	1.1		1.5	04/12/11	05/10/11
Uranium 235	-0.03	U	0.76		0.34	04/12/11	05/10/11
Uranium 238	0.7	U	1.1		1.5	04/12/11	05/10/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

J Result is greater than sample detection limit but less than stated reporting limit.
U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-043-0311 DUP

Radiochemistry

Lab Sample ID: F1D110423-001X
Work Order: MGT7D
Matrix: SOLID

Date Collected: 03/29/11 1545
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				pCi/g		Batch # 1102232	Yld %
Actinium 227	-0.31	U	0.35		0.58	04/12/11	05/10/11
Actinium 228	**0.48**		**0.12**		**0.18**	**04/12/11**	**05/10/11**
Bismuth 212	0.24	U	0.28		0.45	04/12/11	05/10/11
Bismuth 214	**0.54**		**0.11**		**0.09**	**04/12/11**	**05/10/11**
Cesium 137	0.042	U	0.034		0.053	04/12/11	05/10/11
Lead 210	0.30	U	0.93		1.6	04/12/11	05/10/11
Lead 212	**0.529**		**0.098**		**0.083**	**04/12/11**	**05/10/11**
Lead 214	**0.52**		**0.11**		**0.10**	**04/12/11**	**05/10/11**
Potassium 40	**10.8**		**1.3**		**0.6**	**04/12/11**	**05/10/11**
Protactinium 231	0.05	U	0.67		1.2	04/12/11	05/10/11
Radium (226)	**0.54**		**0.11**	0.50	**0.09**	**04/12/11**	**05/10/11**
Radium 228	**0.48**		**0.12**		**0.18**	**04/12/11**	**05/10/11**
Thallium 208	**0.209**		**0.054**		**0.044**	**04/12/11**	**05/10/11**
Thorium 234	0.57	U	0.81		1.3	04/12/11	05/10/11
Uranium 235	0.12	U	0.17		0.29	04/12/11	05/10/11
Uranium 238	0.57	U	0.81		1.3	04/12/11	05/10/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-044-0311

Radiochemistry

Lab Sample ID: F1D110423-002
Work Order: MGT7F
Matrix: SOLID

Date Collected: 03/29/11 1602
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	-0.02	U	0.33		0.57	04/12/11	05/10/11
Actinium 228	**1.77**		**0.29**		**0.20**	**04/12/11**	**05/10/11**
Bismuth 212	0.70	U	0.57		0.89	04/12/11	05/10/11
Bismuth 214	**0.98**		**0.22**		**0.16**	**04/12/11**	**05/10/11**
Cesium 137	-0.003	U	0.072		0.12	04/12/11	05/10/11
Lead 210	0.8	U	1.4		2.4	04/12/11	05/10/11
Lead 212	**1.67**		**0.22**		**0.14**	**04/12/11**	**05/10/11**
Lead 214	**1.0**		**0.17**		**0.14**	**04/12/11**	**05/10/11**
Potassium 40	**8.8**		**1.6**		**0.7**	**04/12/11**	**05/10/11**
Protactinium 231	0.4	U	1.6		2.8	04/12/11	05/10/11
Radium (226)	**0.98**		**0.22**	0.50	**0.16**	**04/12/11**	**05/10/11**
Radium 228	**1.77**		**0.29**		**0.20**	**04/12/11**	**05/10/11**
Thallium 208	**0.63**		**0.13**		**0.1**	**04/12/11**	**05/10/11**
Thorium 234	1.0	U	1.3		2.3	04/12/11	05/10/11
Uranium 235	0.16	U	0.30		0.51	04/12/11	05/10/11
Uranium 238	1.0	U	1.3		2.3	04/12/11	05/10/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-045-0311

Radiochemistry

Lab Sample ID: F1D110423-003
Work Order: MGT7G
Matrix: SOLID

Date Collected: 03/29/11 1502
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	-0.02	U	0.88		1.5	04/12/11	05/10/11
Actinium 228	**0.88**		**0.21**		**0.22**	**04/12/11**	**05/10/11**
Bismuth 212	0.20	U	0.38		0.65	04/12/11	05/10/11
Bismuth 214	**0.83**		**0.22**		**0.19**	**04/12/11**	**05/10/11**
Cesium 137	0.034	U	0.067		0.12	04/12/11	05/10/11
Lead 210	1.3	U	1.4		2.2	04/12/11	05/10/11
Lead 212	**0.88**		**0.18**		**0.15**	**04/12/11**	**05/10/11**
Lead 214	**0.99**		**0.20**		**0.15**	**04/12/11**	**05/10/11**
Potassium 40	**14.1**		**2.2**		**0.8**	**04/12/11**	**05/10/11**
Protactinium 231	0.5	U	1.3		2.3	04/12/11	05/10/11
Radium (226)	**0.83**		**0.22**	0.50	**0.19**	**04/12/11**	**05/10/11**
Radium 228	**0.88**		**0.21**		**0.22**	**04/12/11**	**05/10/11**
Thallium 208	**0.307**		**0.095**		**0.090**	**04/12/11**	**05/10/11**
Thorium 234	0.4	U	1.2		2.1	04/12/11	05/10/11
Uranium 235	0.03	U	0.27		0.48	04/12/11	05/10/11
Uranium 238	0.4	U	1.2		2.1	04/12/11	05/10/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-046-0311

Radiochemistry

Lab Sample ID: F1D110423-004
Work Order: MGT7H
Matrix: SOLID

Date Collected: 03/29/11 1526
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	-0.28	U	0.33		0.54	04/12/11	05/10/11
Actinium 228	**0.38**		**0.13**		**0.18**	**04/12/11**	**05/10/11**
Bismuth 212	**0.48**		**0.24**		**0.23**	**04/12/11**	**05/10/11**
Bismuth 214	**0.54**		**0.11**		**0.08**	**04/12/11**	**05/10/11**
Cesium 137	0.014	U	0.029		0.051	04/12/11	05/10/11
Lead 210	0.70	U	0.78		1.3	04/12/11	05/10/11
Lead 212	**0.44**		**0.11**		**0.1**	**04/12/11**	**05/10/11**
Lead 214	**0.56**		**0.11**		**0.10**	**04/12/11**	**05/10/11**
Potassium 40	**8.4**		**1.2**		**0.6**	**04/12/11**	**05/10/11**
Protactinium 231	-0.27	U	0.83		1.4	04/12/11	05/10/11
Radium (226)	**0.54**		**0.11**	0.50	**0.08**	**04/12/11**	**05/10/11**
Radium 228	**0.38**		**0.13**		**0.18**	**04/12/11**	**05/10/11**
Thallium 208	**0.149**		**0.045**		**0.039**	**04/12/11**	**05/10/11**
Thorium 234	0.02	U	0.69		1.2	04/12/11	05/10/11
Uranium 235	0.06	U	0.17		0.30	04/12/11	05/10/11
Uranium 238	0.02	U	0.69		1.2	04/12/11	05/10/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-047-0311

Radiochemistry

Lab Sample ID: F1D110423-005
Work Order: MGT7J
Matrix: SOLID

Date Collected: 03/30/11 0815
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				pCi/g	Batch # 1102232		Yld %
Actinium 227	0.12	U	0.20		0.33	04/12/11	05/11/11
Actinium 228	**0.51**		**0.22**		**0.27**	**04/12/11**	**05/11/11**
Bismuth 212	**0.82**		**0.36**		**0.30**	**04/12/11**	**05/11/11**
Bismuth 214	**0.57**		**0.15**		**0.13**	**04/12/11**	**05/11/11**
Cesium 137	0.004	U	0.050		0.097	04/12/11	05/11/11
Lead 210	0.64	U	0.96		1.7	04/12/11	05/11/11
Lead 212	**0.46**		**0.11**		**0.10**	**04/12/11**	**05/11/11**
Lead 214	**0.60**		**0.13**		**0.12**	**04/12/11**	**05/11/11**
Potassium 40	**8.6**		**1.5**		**0.8**	**04/12/11**	**05/11/11**
Protactinium 231	0.05	U	0.91		1.6	04/12/11	05/11/11
Radium (226)	**0.57**		**0.15**	0.50	**0.13**	**04/12/11**	**05/11/11**
Radium 228	**0.51**		**0.22**		**0.27**	**04/12/11**	**05/11/11**
Thallium 208	**0.224**		**0.067**		**0.059**	**04/12/11**	**05/11/11**
Thorium 234	0.32	U	0.87		1.5	04/12/11	05/11/11
Uranium 235	0.06	U	0.17		0.30	04/12/11	05/11/11
Uranium 238	0.32	U	0.87		1.5	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-048-0311

Radiochemistry

Lab Sample ID: F1D110423-006
Work Order: MGT7K
Matrix: SOLID

Date Collected: 03/30/11 0815
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	-0.33	U	0.30		0.49	04/12/11	05/11/11
Actinium 228	**0.35**		**0.13**		**0.15**	**04/12/11**	**05/11/11**
Bismuth 212	**0.51**		**0.27**		**0.26**	**04/12/11**	**05/11/11**
Bismuth 214	**0.57**		**0.11**		**0.11**	**04/12/11**	**05/11/11**
Cesium 137	0.0008	U	0.034		0.062	04/12/11	05/11/11
Lead 210	0.31	U	0.86		1.5	04/12/11	05/11/11
Lead 212	**0.486**		**0.088**		**0.073**	**04/12/11**	**05/11/11**
Lead 214	**0.508**		**0.099**		**0.083**	**04/12/11**	**05/11/11**
Potassium 40	**9.1**		**1.1**		**0.4**	**04/12/11**	**05/11/11**
Protactinium 231	-0.17	U	0.75		1.3	04/12/11	05/11/11
Radium (226)	**0.57**		**0.11**	0.50	**0.11**	**04/12/11**	**05/11/11**
Radium 228	**0.35**		**0.13**		**0.15**	**04/12/11**	**05/11/11**
Thallium 208	**0.186**		**0.049**		**0.041**	**04/12/11**	**05/11/11**
Thorium 234	0.64	U	0.76		1.3	04/12/11	05/11/11
Uranium 235	-0.06	U	0.18		0.30	04/12/11	05/11/11
Uranium 238	0.64	U	0.76		1.3	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-049-0311

Radiochemistry

Lab Sample ID: F1D110423-007
Work Order: MGT7N
Matrix: SOLID

Date Collected: 03/30/11 0837
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	0.06	U	0.22		0.38	04/12/11	05/11/11
Actinium 228	**0.42**		**0.17**		**0.28**	**04/12/11**	**05/11/11**
Bismuth 212	0.35	U	0.38		0.61	04/12/11	05/11/11
Bismuth 214	**0.55**		**0.14**		**0.12**	**04/12/11**	**05/11/11**
Cesium 137	-0.02	U	0.21		0.11	04/12/11	05/11/11
Lead 210	0.5	U	1.0		1.8	04/12/11	05/11/11
Lead 212	**0.49**		**0.11**		**0.11**	**04/12/11**	**05/11/11**
Lead 214	**0.63**		**0.13**		**0.11**	**04/12/11**	**05/11/11**
Potassium 40	**10.7**		**1.7**		**0.6**	**04/12/11**	**05/11/11**
Protactinium 231	0.5	U	1.1		1.9	04/12/11	05/11/11
Radium (226)	**0.55**		**0.14**	0.50	**0.12**	**04/12/11**	**05/11/11**
Radium 228	**0.42**		**0.17**		**0.28**	**04/12/11**	**05/11/11**
Thallium 208	**0.212**		**0.079**		**0.070**	**04/12/11**	**05/11/11**
Thorium 234	0.74	U	0.80		1.4	04/12/11	05/11/11
Uranium 235	-0.1	U	0.51		0.37	04/12/11	05/11/11
Uranium 238	0.74	U	0.80		1.4	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-050-0311

Radiochemistry

Lab Sample ID: F1D110423-008
Work Order: MGT7Q
Matrix: SOLID

Date Collected: 03/30/11 0855
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	0.008	U	0.30		0.53	04/12/11	05/11/11
Actinium 228	**0.50**		**0.15**		**0.24**	**04/12/11**	**05/11/11**
Bismuth 212	0.14	U	0.30		0.52	04/12/11	05/11/11
Bismuth 214	**0.57**		**0.15**		**0.14**	**04/12/11**	**05/11/11**
Cesium 137	-0.02	U	1.8		0.08	04/12/11	05/11/11
Lead 210	0.7	U	1.0		1.7	04/12/11	05/11/11
Lead 212	**0.55**		**0.13**		**0.12**	**04/12/11**	**05/11/11**
Lead 214	**0.64**		**0.13**		**0.08**	**04/12/11**	**05/11/11**
Potassium 40	**8.9**		**1.5**		**0.7**	**04/12/11**	**05/11/11**
Protactinium 231	-0.01	U	0.80		1.4	04/12/11	05/11/11
Radium (226)	**0.57**		**0.15**	0.50	**0.14**	**04/12/11**	**05/11/11**
Radium 228	**0.50**		**0.15**		**0.24**	**04/12/11**	**05/11/11**
Thallium 208	**0.197**		**0.065**		**0.061**	**04/12/11**	**05/11/11**
Thorium 234	0.35	U	0.95		1.7	04/12/11	05/11/11
Uranium 235	-0.08	U	8.6		0.4	04/12/11	05/11/11
Uranium 238	0.35	U	0.95		1.7	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-051-0311

Radiochemistry

Lab Sample ID: F1D110423-009
Work Order: MGT7T
Matrix: SOLID

Date Collected: 03/30/11 0907
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	-0.28	U	0.30		0.49	04/12/11	05/11/11
Actinium 228	**0.44**		**0.12**		**0.08**	**04/12/11**	**05/11/11**
Bismuth 212	**0.68**		**0.21**		**0.11**	**04/12/11**	**05/11/11**
Bismuth 214	**0.46**		**0.12**		**0.11**	**04/12/11**	**05/11/11**
Cesium 137	-0.009	U	0.030		0.053	04/12/11	05/11/11
Lead 210	0.10	U	0.71		1.2	04/12/11	05/11/11
Lead 212	**0.457**		**0.0996**		**0.091**	**04/12/11**	**05/11/11**
Lead 214	**0.52**		**0.10**		**0.11**	**04/12/11**	**05/11/11**
Potassium 40	**9.4**		**1.2**		**0.6**	**04/12/11**	**05/11/11**
Protactinium 231	-0.12	U	0.77		1.3	04/12/11	05/11/11
Radium (226)	**0.46**	**J**	**0.12**	0.50	**0.11**	**04/12/11**	**05/11/11**
Radium 228	**0.44**		**0.12**		**0.08**	**04/12/11**	**05/11/11**
Thallium 208	**0.150**		**0.041**		**0.037**	**04/12/11**	**05/11/11**
Thorium 234	0.31	U	0.80		1.3	04/12/11	05/11/11
Uranium 235	0.06	U	0.17		0.29	04/12/11	05/11/11
Uranium 238	0.31	U	0.80		1.3	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

J Result is greater than sample detection limit but less than stated reporting limit.
U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-052-0311

Radiochemistry

Lab Sample ID: F1D110423-010
Work Order: MGT7W
Matrix: SOLID

Date Collected: 03/30/11 0921
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	-0.09	U	0.26		0.45	04/12/11	05/11/11
Actinium 228	**0.57**		**0.18**		**0.11**	**04/12/11**	**05/11/11**
Bismuth 212	0.14	U	0.33		0.59	04/12/11	05/11/11
Bismuth 214	**0.50**		**0.13**		**0.11**	**04/12/11**	**05/11/11**
Cesium 137	-0.01	U	0.12		0.10	04/12/11	05/11/11
Lead 210	0.4	U	1.1		1.9	04/12/11	05/11/11
Lead 212	**0.51**		**0.11**		**0.11**	**04/12/11**	**05/11/11**
Lead 214	**0.60**		**0.13**		**0.14**	**04/12/11**	**05/11/11**
Potassium 40	**10.1**		**1.8**		**0.9**	**04/12/11**	**05/11/11**
Protactinium 231	-0.5	U	1.1		1.9	04/12/11	05/11/11
Radium (226)	**0.50**	**J**	**0.13**	0.50	**0.11**	**04/12/11**	**05/11/11**
Radium 228	**0.57**		**0.18**		**0.11**	**04/12/11**	**05/11/11**
Thallium 208	**0.267**		**0.073**		**0.053**	**04/12/11**	**05/11/11**
Thorium 234	0.12	U	0.95		1.7	04/12/11	05/11/11
Uranium 235	0.08	U	0.18		0.32	04/12/11	05/11/11
Uranium 238	0.12	U	0.95		1.7	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

J Result is greater than sample detection limit but less than stated reporting limit.
U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-053-0311

Radiochemistry

Lab Sample ID: F1D110423-011
Work Order: MGT70
Matrix: SOLID

Date Collected: 03/30/11 1102
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	-0.49	U	0.42		0.68	04/12/11	05/11/11
Actinium 228	**0.55**		**0.23**		**0.28**	**04/12/11**	**05/11/11**
Bismuth 212	0.45	U	0.42		0.66	04/12/11	05/11/11
Bismuth 214	**0.66**		**0.14**		**0.10**	**04/12/11**	**05/11/11**
Cesium 137	0.031	U	0.056		0.10	04/12/11	05/11/11
Lead 210	0.5	U	1.2		2.1	04/12/11	05/11/11
Lead 212	**0.53**		**0.15**		**0.14**	**04/12/11**	**05/11/11**
Lead 214	**0.61**		**0.13**		**0.14**	**04/12/11**	**05/11/11**
Potassium 40	**11.2**		**1.7**		**0.7**	**04/12/11**	**05/11/11**
Protactinium 231	-0.3	U	1.3		2.2	04/12/11	05/11/11
Radium (226)	**0.66**		**0.14**	0.50	**0.10**	**04/12/11**	**05/11/11**
Radium 228	**0.55**		**0.23**		**0.28**	**04/12/11**	**05/11/11**
Thallium 208	**0.201**		**0.071**		**0.067**	**04/12/11**	**05/11/11**
Thorium 234	0.3	U	1.1		2.0	04/12/11	05/11/11
Uranium 235	0.04	U	0.22		0.39	04/12/11	05/11/11
Uranium 238	0.3	U	1.1		2.0	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-054-0311

Radiochemistry

Lab Sample ID: F1D110423-012
Work Order: MGT71
Matrix: SOLID

Date Collected: 03/30/11 1127
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	-0.60	U	0.38		0.60	04/12/11	05/11/11
Actinium 228	**0.96**		**0.16**		**0.05**	**04/12/11**	**05/11/11**
Bismuth 212	**0.66**		**0.23**		**0.16**	**04/12/11**	**05/11/11**
Bismuth 214	**0.75**		**0.12**		**0.08**	**04/12/11**	**05/11/11**
Cesium 137	0.004	U	0.033		0.059	04/12/11	05/11/11
Lead 210	1.07	U	0.94		1.5	04/12/11	05/11/11
Lead 212	**0.67**		**0.11**		**0.09**	**04/12/11**	**05/11/11**
Lead 214	**0.83**		**0.13**		**0.1**	**04/12/11**	**05/11/11**
Potassium 40	**11.8**		**1.4**		**0.5**	**04/12/11**	**05/11/11**
Protactinium 231	-0.3	U	1.0		1.7	04/12/11	05/11/11
Radium (226)	**0.75**		**0.12**	0.50	**0.08**	**04/12/11**	**05/11/11**
Radium 228	**0.96**		**0.16**		**0.05**	**04/12/11**	**05/11/11**
Thallium 208	**0.277**		**0.058**		**0.043**	**04/12/11**	**05/11/11**
Thorium 234	0.72	U	0.39		1.5	04/12/11	05/11/11
Uranium 235	0.03	U	0.22		0.37	04/12/11	05/11/11
Uranium 238	0.72	U	0.39		1.5	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-055-0311

Radiochemistry

Lab Sample ID: F1D110423-013
Work Order: MGT72
Matrix: SOLID

Date Collected: 03/30/11 1304
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	0.0	U	0.73		1.2	04/12/11	05/11/11
Actinium 228	**0.93**		**0.26**		**0.12**	**04/12/11**	**05/11/11**
Bismuth 212	0.33	U	0.45		0.74	04/12/11	05/11/11
Bismuth 214	**0.70**		**0.15**		**0.10**	**04/12/11**	**05/11/11**
Cesium 137	-0.03	U	0.74		0.12	04/12/11	05/11/11
Lead 210	0.8	U	1.1		1.8	04/12/11	05/11/11
Lead 212	**0.61**		**0.13**		**0.12**	**04/12/11**	**05/11/11**
Lead 214	**0.74**		**0.16**		**0.15**	**04/12/11**	**05/11/11**
Potassium 40	**13.2**		**2.1**		**0.8**	**04/12/11**	**05/11/11**
Protactinium 231	-0.07	U	1.0		1.9	04/12/11	05/11/11
Radium (226)	**0.70**		**0.15**	0.50	**0.10**	**04/12/11**	**05/11/11**
Radium 228	**0.93**		**0.26**		**0.12**	**04/12/11**	**05/11/11**
Thallium 208	**0.250**		**0.075**		**0.059**	**04/12/11**	**05/11/11**
Thorium 234	0.7	U	1.2		2.1	04/12/11	05/11/11
Uranium 235	0.15	U	0.21		0.35	04/12/11	05/11/11
Uranium 238	0.7	U	1.2		2.1	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-056-0311

Radiochemistry

Lab Sample ID: F1D110423-014
Work Order: MGT73
Matrix: SOLID

Date Collected: 03/30/11 1304
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	-0.24	U	0.40		0.67	04/12/11	05/11/11
Actinium 228	**0.56**		**0.22**		**0.25**	**04/12/11**	**05/11/11**
Bismuth 212	0.29	U	0.38		0.62	04/12/11	05/11/11
Bismuth 214	**0.62**		**0.18**		**0.15**	**04/12/11**	**05/11/11**
Cesium 137	-0.02	U	6.9		0.1	04/12/11	05/11/11
Lead 210	0.007	U	1.2		2.1	04/12/11	05/11/11
Lead 212	**0.59**		**0.15**		**0.14**	**04/12/11**	**05/11/11**
Lead 214	**0.75**		**0.17**		**0.13**	**04/12/11**	**05/11/11**
Potassium 40	**13.8**		**1.9**		**0.7**	**04/12/11**	**05/11/11**
Protactinium 231	0.2	U	1.0		1.8	04/12/11	05/11/11
Radium (226)	**0.62**		**0.18**	0.50	**0.15**	**04/12/11**	**05/11/11**
Radium 228	**0.56**		**0.22**		**0.25**	**04/12/11**	**05/11/11**
Thallium 208	**0.306**		**0.068**		**0.044**	**04/12/11**	**05/11/11**
Thorium 234	0.5	U	1.1		2.0	04/12/11	05/11/11
Uranium 235	0.06	U	0.20		0.35	04/12/11	05/11/11
Uranium 238	0.5	U	1.1		2.0	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-057-0311

Radiochemistry

Lab Sample ID: F1D110423-015
Work Order: MGT74
Matrix: SOLID

Date Collected: 03/30/11 1415
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	-0.30	U	0.36		0.59	04/12/11	05/11/11
Actinium 228	**0.84**		**0.20**		**0.18**	**04/12/11**	**05/11/11**
Bismuth 212	0.24	U	0.34		0.56	04/12/11	05/11/11
Bismuth 214	**0.86**		**0.19**		**0.15**	**04/12/11**	**05/11/11**
Cesium 137	0.043	U	0.045		0.073	04/12/11	05/11/11
Lead 210	0.5	U	1.0		1.7	04/12/11	05/11/11
Lead 212	**0.64**		**0.16**		**0.14**	**04/12/11**	**05/11/11**
Lead 214	**0.85**		**0.15**		**0.13**	**04/12/11**	**05/11/11**
Potassium 40	**14.1**		**1.6**		**0.5**	**04/12/11**	**05/11/11**
Protactinium 231	0.3	U	1.0		1.7	04/12/11	05/11/11
Radium (226)	**0.86**		**0.19**	0.50	**0.15**	**04/12/11**	**05/11/11**
Radium 228	**0.84**		**0.20**		**0.18**	**04/12/11**	**05/11/11**
Thallium 208	**0.273**		**0.061**		**0.044**	**04/12/11**	**05/11/11**
Thorium 234	1.1	U	1.0		1.7	04/12/11	05/11/11
Uranium 235	0.05	U	0.23		0.39	04/12/11	05/11/11
Uranium 238	1.1	U	1.0		1.7	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-058-0311

Radiochemistry

Lab Sample ID: F1D110423-016
Work Order: MGT76
Matrix: SOLID

Date Collected: 03/31/11 0808
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	-0.26	U	0.37		0.61	04/12/11	05/11/11
Actinium 228	**0.58**		**0.18**		**0.25**	**04/12/11**	**05/11/11**
Bismuth 212	0.22	U	0.36		0.61	04/12/11	05/11/11
Bismuth 214	**0.51**		**0.15**		**0.14**	**04/12/11**	**05/11/11**
Cesium 137	**0.104**		**0.057**		**0.076**	**04/12/11**	**05/11/11**
Lead 210	0.7	U	1.1		1.9	04/12/11	05/11/11
Lead 212	**0.60**		**0.13**		**0.11**	**04/12/11**	**05/11/11**
Lead 214	**0.56**		**0.13**		**0.14**	**04/12/11**	**05/11/11**
Potassium 40	**11.2**		**1.8**		**1.1**	**04/12/11**	**05/11/11**
Protactinium 231	-0.06	U	0.98		1.7	04/12/11	05/11/11
Radium (226)	**0.51**		**0.15**	0.50	**0.14**	**04/12/11**	**05/11/11**
Radium 228	**0.58**		**0.18**		**0.25**	**04/12/11**	**05/11/11**
Thallium 208	**0.183**		**0.079**		**0.080**	**04/12/11**	**05/11/11**
Thorium 234	0.72	U	0.96		1.7	04/12/11	05/11/11
Uranium 235	0.12	U	0.18		0.31	04/12/11	05/11/11
Uranium 238	0.72	U	0.96		1.7	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-059-0311

Radiochemistry

Lab Sample ID: F1D110423-017
Work Order: MGT77
Matrix: SOLID

Date Collected: 03/31/11 0838
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD			pCi/g		Batch # 1102232		Yld %
Actinium 227	-0.47	U	0.52		0.85	04/12/11	05/11/11
Actinium 228	**1.22**		**0.24**		**0.11**	**04/12/11**	**05/11/11**
Bismuth 212	0.32	U	0.45		0.76	04/12/11	05/11/11
Bismuth 214	**0.91**		**0.19**		**0.14**	**04/12/11**	**05/11/11**
Cesium 137	0.014	U	0.063		0.12	04/12/11	05/11/11
Lead 210	1.1	U	1.9		3.1	04/12/11	05/11/11
Lead 212	**0.91**		**0.20**		**0.18**	**04/12/11**	**05/11/11**
Lead 214	**1.08**		**0.19**		**0.16**	**04/12/11**	**05/11/11**
Potassium 40	**14.6**		**2.0**		**0.7**	**04/12/11**	**05/11/11**
Protactinium 231	-0.4	U	1.5		2.6	04/12/11	05/11/11
Radium (226)	**0.91**		**0.19**	0.50	**0.14**	**04/12/11**	**05/11/11**
Radium 228	**1.22**		**0.24**		**0.11**	**04/12/11**	**05/11/11**
Thallium 208	**0.216**		**0.077**		**0.099**	**04/12/11**	**05/11/11**
Thorium 234	0.7	U	1.4		2.4	04/12/11	05/11/11
Uranium 235	0.22	U	0.39		0.65	04/12/11	05/11/11
Uranium 238	0.7	U	1.4		2.4	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-060-0311

Radiochemistry

Lab Sample ID: F1D110423-018
Work Order: MGT79
Matrix: SOLID

Date Collected: 03/31/11 0855
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				pCi/g	Batch # 1102232		Yld %
Actinium 227	-0.36	U	0.38		0.62	04/12/11	05/11/11
Actinium 228	**1.10**		**0.19**		**0.11**	**04/12/11**	**05/11/11**
Bismuth 212	0.03	U	0.32		0.57	04/12/11	05/11/11
Bismuth 214	**0.83**		**0.14**		**0.11**	**04/12/11**	**05/11/11**
Cesium 137	0.0	U	0.049		0.087	04/12/11	05/11/11
Lead 210	0.6	U	1.1		1.8	04/12/11	05/11/11
Lead 212	**0.73**		**0.14**		**0.12**	**04/12/11**	**05/11/11**
Lead 214	**0.96**		**0.16**		**0.14**	**04/12/11**	**05/11/11**
Potassium 40	**16.1**		**1.8**		**0.7**	**04/12/11**	**05/11/11**
Protactinium 231	-0.29	U	0.99		1.7	04/12/11	05/11/11
Radium (226)	**0.83**		**0.14**	0.50	**0.11**	**04/12/11**	**05/11/11**
Radium 228	**1.10**		**0.19**		**0.11**	**04/12/11**	**05/11/11**
Thallium 208	**0.274**		**0.063**		**0.054**	**04/12/11**	**05/11/11**
Thorium 234	0.8	U	1.1		1.8	04/12/11	05/11/11
Uranium 235	0.03	U	0.20		0.34	04/12/11	05/11/11
Uranium 238	0.8	U	1.1		1.8	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-061-0311

Radiochemistry

Lab Sample ID: F1D110423-019
Work Order: MGT8A
Matrix: SOLID

Date Collected: 03/31/11 1010
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD			pCi/g		Batch # 1102232		Yld %
Actinium 227	0.20		0.13		0.17	04/12/11	05/11/11
Actinium 228	0.45		0.21		0.38	04/12/11	05/11/11
Bismuth 212	0.30	U	0.48		0.81	04/12/11	05/11/11
Bismuth 214	0.79		0.19		0.16	04/12/11	05/11/11
Cesium 137	0.005	U	0.068		0.13	04/12/11	05/11/11
Lead 210	0.8	U	1.1		1.9	04/12/11	05/11/11
Lead 212	0.68		0.15		0.14	04/12/11	05/11/11
Lead 214	0.80		0.16		0.20	04/12/11	05/11/11
Potassium 40	12.0		2.0		0.8	04/12/11	05/11/11
Protactinium 231	0.3	U	1.1		2.0	04/12/11	05/11/11
Radium (226)	0.79		0.19	0.50	0.16	04/12/11	05/11/11
Radium 228	0.45		0.21		0.38	04/12/11	05/11/11
Thallium 208	0.353		0.091		0.069	04/12/11	05/11/11
Thorium 234	1.37	U	0.68		1.7	04/12/11	05/11/11
Uranium 235	-0.06	U	2.8		0.5	04/12/11	05/11/11
Uranium 238	1.37	U	0.68		1.7	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-062-0311

Radiochemistry

Lab Sample ID: F1D110423-020
Work Order: MGT8C
Matrix: SOLID

Date Collected: 03/31/11 1315
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**Batch # 1102232**		**Yld %**
Actinium 227	0.07	U	0.46		0.78	04/12/11	05/11/11
Actinium 228	**0.57**		**0.24**		**0.30**	**04/12/11**	**05/11/11**
Bismuth 212	0.17	U	0.42		0.73	04/12/11	05/11/11
Bismuth 214	**0.90**		**0.17**		**0.10**	**04/12/11**	**05/11/11**
Cesium 137	-0.02	U	0.70		0.12	04/12/11	05/11/11
Lead 210	0.28	U	0.93		1.6	04/12/11	05/11/11
Lead 212	**0.71**		**0.15**		**0.14**	**04/12/11**	**05/11/11**
Lead 214	**0.89**		**0.15**		**0.11**	**04/12/11**	**05/11/11**
Potassium 40	**14.2**		**2.0**		**0.7**	**04/12/11**	**05/11/11**
Protactinium 231	-0.6	U	1.5		2.5	04/12/11	05/11/11
Radium (226)	**0.90**		**0.17**	0.50	**0.10**	**04/12/11**	**05/11/11**
Radium 228	**0.57**		**0.24**		**0.30**	**04/12/11**	**05/11/11**
Thallium 208	**0.304**		**0.086**		**0.074**	**04/12/11**	**05/11/11**
Thorium 234	0.3	U	1.1		2.0	04/12/11	05/11/11
Uranium 235	-0.04	U	0.74		0.46	04/12/11	05/11/11
Uranium 238	0.3	U	1.1		2.0	04/12/11	05/11/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-063-0311

Radiochemistry

Lab Sample ID: F1D110423-021
Work Order: MGT8E
Matrix: SOLID

Date Collected: 03/31/11 1330
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD			pCi/g		Batch # 1102233		Yld %
Actinium 227	0.22		0.15		0.22	04/12/11	05/09/11
Actinium 228	0.65		0.29		0.37	04/12/11	05/09/11
Bismuth 212	0.0	U	0.50		0.92	04/12/11	05/09/11
Bismuth 214	0.66		0.16		0.13	04/12/11	05/09/11
Cesium 137	0.029	U	0.058		0.11	04/12/11	05/09/11
Lead 210	1.1	U	1.1		1.8	04/12/11	05/09/11
Lead 212	0.54		0.13		0.13	04/12/11	05/09/11
Lead 214	0.74		0.18		0.17	04/12/11	05/09/11
Potassium 40	11.5		1.9		0.7	04/12/11	05/09/11
Protactinium 231	-0.4	U	1.3		2.3	04/12/11	05/09/11
Radium (226)	0.66		0.16	0.50	0.13	04/12/11	05/09/11
Radium 228	0.65		0.29		0.37	04/12/11	05/09/11
Thallium 208	0.226		0.075		0.066	04/12/11	05/09/11
Thorium 234	1.2	U	1.0		1.5	04/12/11	05/09/11
Uranium 235	0.15	U	0.24		0.40	04/12/11	05/09/11
Uranium 238	1.2	U	1.0		1.5	04/12/11	05/09/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-063-0311 DUP

Radiochemistry

Lab Sample ID: F1D110423-021X
Work Order: MGT8E
Matrix: SOLID

Date Collected: 03/31/11 1330
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				pCi/g	Batch # 1102233		Yld %
Actinium 227	0.0	U	0.45		0.77	04/12/11	05/09/11
Actinium 228	**0.85**		**0.20**		**0.11**	**04/12/11**	**05/09/11**
Bismuth 212	0.32	U	0.30		0.47	04/12/11	05/09/11
Bismuth 214	**0.72**		**0.14**		**0.11**	**04/12/11**	**05/09/11**
Cesium 137	0.046	U	0.046		0.073	04/12/11	05/09/11
Lead 210	0.61	U	0.98		1.6	04/12/11	05/09/11
Lead 212	**0.63**		**0.13**		**0.12**	**04/12/11**	**05/09/11**
Lead 214	**0.75**		**0.13**		**0.10**	**04/12/11**	**05/09/11**
Potassium 40	**12.9**		**1.6**		**0.7**	**04/12/11**	**05/09/11**
Protactinium 231	-0.02	U	0.96		1.7	04/12/11	05/09/11
Radium (226)	**0.72**		**0.14**	0.50	**0.11**	**04/12/11**	**05/09/11**
Radium 228	**0.85**		**0.20**		**0.11**	**04/12/11**	**05/09/11**
Thallium 208	**0.276**		**0.059**		**0.043**	**04/12/11**	**05/09/11**
Thorium 234	0.6	U	1.0		1.7	04/12/11	05/09/11
Uranium 235	0.22	U	0.22		0.37	04/12/11	05/09/11
Uranium 238	0.6	U	1.0		1.7	04/12/11	05/09/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Shaw E & I Inc

Client Sample ID: TIBKGRD-064-0311

Radiochemistry

Lab Sample ID: F1D110423-022
Work Order: MGT8F
Matrix: SOLID

Date Collected: 03/31/11 1450
Date Received: 04/11/11 0815

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	mdc	Prep Date	Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD				pCi/g		Batch # 1102233	Yld %
Actinium 227	0.09	U	0.12		0.20	04/12/11	05/09/11
Actinium 228	**0.51**		**0.14**		**0.13**	**04/12/11**	**05/09/11**
Bismuth 212	**0.51**		**0.24**		**0.23**	**04/12/11**	**05/09/11**
Bismuth 214	**0.69**		**0.12**		**0.09**	**04/12/11**	**05/09/11**
Cesium 137	**0.097**		**0.037**		**0.032**	**04/12/11**	**05/09/11**
Lead 210	8	U	11		18	04/12/11	05/09/11
Lead 212	**0.519**		**0.087**		**0.081**	**04/12/11**	**05/09/11**
Lead 214	**0.65**		**0.10**		**0.09**	**04/12/11**	**05/09/11**
Potassium 40	**11.6**		**1.3**		**0.4**	**04/12/11**	**05/09/11**
Protactinium 231	0.14	U	0.73		1.3	04/12/11	05/09/11
Radium (226)	**0.69**		**0.12**	0.50	**0.09**	**04/12/11**	**05/09/11**
Radium 228	**0.51**		**0.14**		**0.13**	**04/12/11**	**05/09/11**
Thallium 208	**0.184**		**0.047**		**0.043**	**04/12/11**	**05/09/11**
Thorium 234	0.02	U	1.9		3.4	04/12/11	05/09/11
Uranium 235	-0.03	U	0.19		0.32	04/12/11	05/09/11
Uranium 238	0.02	U	1.9		3.4	04/12/11	05/09/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined by instrument performance only.
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

METHOD BLANK REPORT

Radiochemistry

Client Lot ID: F1D110423
Matrix: SOLID

Parameter	Result	Qual	Total Uncert. (2 σ+/-)	RL	MDC	Prep Date	Lab Sample ID Analysis Date
Gamma Ra-226 & Hits By DOE GA-010R MOD			**pCi/g**	**Batch # 1102233**	**Yld %**		**F1D120000-233B**
Actinium 227	-0.04	U	0.12		0.21	04/12/11	05/26/11
Actinium 228	0.014	U	0.067		0.12	04/12/11	05/26/11
Bismuth 212	0.002	U	0.099		0.20	04/12/11	05/26/11
Bismuth 214	-0.02	U	0.11		0.1	04/12/11	05/26/11
Cesium 137	-0.0009	U	0.019		0.036	04/12/11	05/26/11
Lead 210	0.13	U	0.44		0.77	04/12/11	05/26/11
Lead 212	0.002	U	0.029		0.055	04/12/11	05/26/11
Lead 214	-0.02	U	0.17		0.07	04/12/11	05/26/11
Potassium 40	-0.11	U	0.84		0.62	04/12/11	05/26/11
Protactinium 231	0.01	U	0.45		0.82	04/12/11	05/26/11
Radium (226)	-0.02	U	0.11	0.50	0.1	04/12/11	05/26/11
Radium 228	0.014	U	0.067		0.12	04/12/11	05/26/11
Thallium 208	0.007	U	0.024		0.045	04/12/11	05/26/11
Thorium 234	0.08	U	0.35		0.61	04/12/11	05/26/11
Uranium 235	0.006	U	0.10		0.18	04/12/11	05/26/11
Uranium 238	0.08	U	0.35		0.61	04/12/11	05/26/11
Gamma Ra-226 & Hits By DOE GA-010R MOD			**pCi/g**	**Batch # 1102232**	**Yld %**		**F1D120000-232B**
Actinium 227	0.03	U	0.11		0.19	04/12/11	05/26/11
Actinium 228	-0.002	U	0.072		0.14	04/12/11	05/26/11
Bismuth 212	-0.04	U	0.17		0.30	04/12/11	05/26/11
Bismuth 214	0.009	U	0.046		0.092	04/12/11	05/26/11
Cesium 137	-0.008	U	0.023		0.042	04/12/11	05/26/11
Lead 210	0.16	U	0.44		0.78	04/12/11	05/26/11
Lead 212	-0.02	U	0.22		0.06	04/12/11	05/26/11
Lead 214	-0.008	U	0.087		0.093	04/12/11	05/26/11
Potassium 40	-0.3	U	11		0.5	04/12/11	05/26/11
Protactinium 231	0.12	U	0.37		0.67	04/12/11	05/26/11
Radium (226)	0.009	U	0.046	0.500	0.092	04/12/11	05/26/11
Radium 228	-0.002	U	0.072		0.14	04/12/11	05/26/11
Thallium 208	-0.003	U	0.037		0.039	04/12/11	05/26/11
Thorium 234	0.02	U	0.34		0.61	04/12/11	05/26/11
Uranium 235	-0.02	U	0.10		0.18	04/12/11	05/26/11
Uranium 238	0.02	U	0.34		0.61	04/12/11	05/26/11

NOTE(S)

Data are incomplete without the case narrative.

MDC is determined using instrument performance only
Bold results are greater than the MDC.

U Result is less than the sample detection limit.

Laboratory Control Sample Report

Radiochemistry

Client Lot ID: F1D110423
Matrix: SOLID

Parameter	Spike Amount	Result	Total Uncert. (2 σ+/-)	MDC	% Yld	% Rec	Lab Sample ID / QC Control Limits
Gamma Ra-226 & Hits By DOE GA-010R MOD		pCi/g		GA-01-R MOD			F1D120000-232C
Radium (226)	12.2	11.4	0.95	0.37		93	(81 - 103)
Thorium 232	9.50	10.1	0.91	0.48		106	(90 - 123)
	Batch #:	1102232		Analysis Date:	05/10/11		
Gamma Ra-226 & Hits By DOE GA-010R MOD		pCi/g		GA-01-R MOD			F1D120000-233C
Radium (226)	12.2	11.6	0.95	0.35		95	(81 - 103)
Thorium 232	9.50	10.2	0.97	0.61		108	(90 - 123)
	Batch #:	1102233		Analysis Date:	05/09/11		

NOTE(S)

MDC is determined by instrument performance only
Calculations are performed before rounding to avoid round-off error in calculated results

DUPLICATE EVALUATION REPORT

Radiochemistry

Client Lot ID: F1D110423
Matrix: SOLID

Date Sampled: 03/29/11
Date Received: 04/11/11

Parameter	SAMPLE Result		Total Uncert. (2σ+/-)	% Yld	DUPLICATE Result		Total Uncert. (2 σ+/-)	% Yld	QC Sample ID Precision	
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**GA-01-R MOD**				**F1D110423-001**	
Actinium 227	-0.03	U	0.55		-0.31	U	0.35		160	%RPD
Actinium 228	0.67		0.16		0.48		0.12		33	%RPD
Bismuth 212	0.21	U	0.27		0.24	U	0.28		12	%RPD
Bismuth 214	0.49		0.13		0.54		0.11		10	%RPD
Cesium 137	0.006	U	0.042		0.042	U	0.034		153	%RPD
Lead 210	0.2	U	1.1		0.30	U	0.93		31	%RPD
Lead 212	0.51		0.11		0.529		0.098		3	%RPD
Lead 214	0.60		0.12		0.52		0.11		15	%RPD
Potassium 40	9.5		1.3		10.8		1.3		13	%RPD
Protactinium 231	-0.5	U	1.0		0.05	U	0.67		251	%RPD
Radium (226)	0.49	J	0.13		0.54		0.11		10	%RPD
Radium 228	0.67		0.16		0.48		0.12		33	%RPD
Thallium 208	0.209		0.068		0.209		0.054		0.2	%RPD
Thorium 234	0.7	U	1.1		0.57	U	0.81		24	%RPD
Uranium 235	-0.03	U	0.76		0.12	U	0.17		364	%RPD
Uranium 238	0.7	U	1.1		0.57	U	0.81		24	%RPD
	Batch #:		1102232	(Sample)	1102232		(Duplicate)			
Gamma Ra-226 & Hits By DOE GA-010R MOD				**pCi/g**	**GA-01-R MOD**				**F1D110423-021**	
Actinium 227	0.22		0.15		0.0	U	0.45		200	%RPD
Actinium 228	0.65		0.29		0.85		0.20		26	%RPD
Bismuth 212	0.0	U	0.50		0.32	U	0.30		200	%RPD
Bismuth 214	0.66		0.16		0.72		0.14		9	%RPD
Cesium 137	0.029	U	0.058		0.046	U	0.046		45	%RPD
Lead 210	1.1	U	1.1		0.61	U	0.98		54	%RPD
Lead 212	0.54		0.13		0.63		0.13		16	%RPD
Lead 214	0.74		0.18		0.75		0.13		1	%RPD
Potassium 40	11.5		1.9		12.9		1.6		11	%RPD
Protactinium 231	-0.4	U	1.3		-0.02	U	0.96		183	%RPD
Radium (226)	0.66		0.16		0.72		0.14		9	%RPD
Radium 228	0.65		0.29		0.85		0.20		26	%RPD
Thallium 208	0.226		0.075		0.276		0.059		20	%RPD
Thorium 234	1.2	U	1.0		0.6	U	1.0		71	%RPD
Uranium 235	0.15	U	0.24		0.22	U	0.22		39	%RPD
Uranium 238	1.2	U	1.0		0.6	U	1.0		71	%RPD
	Batch #:		1102233	(Sample)	1102233		(Duplicate)			

NOTE(S)

Data are incomplete without the case narrative.
Calculations are performed before rounding to avoid round-off error in calculated results

J Result is greater than sample detection limit but less than stated reporting limit.
U Result is less than the sample detection limit.

F1D110423 CLIENT ANALYSIS SUMMARY

Storage Loc: RAD

Project Manager: IV | Quote #: 70379 | SDG:

Project: 122412-048.02 | Treasure Island

PO#: 382409 OP | Report to: Pat Flynn

Client: 1352452 Shaw E & I Inc

#SMPS in LOT: 0

Date Received: 2011-04-11
Analytical Due Date: 2011-05-06
Report Due Date: 2011-05-09
Report Type: W
EDD Code: 99

Receipt Confirmation Requested - patricia.flynn@shawgrp.com Follow DODQSM - Client Memorandum #4

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
1	TIBKGRD-043-0311			2011-03-29 / 1545	MGT7D	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day In-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
2	TIBKGRD-044-0311			2011-03-29 / 1602	MGT7F	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day In-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
3	TIBKGRD-045-0311			2011-03-29 / 1502	MGT7G	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day In-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
4	TIBKGRD-046-0311			2011-03-29 / 1526	MGT7H	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day In-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
5	TIBKGRD-047-0311			2011-03-30 / 815	MGT7J	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day In-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
6	TIBKGRD-048-0311			2011-03-30 / 815	MGT7K	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day In-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
7	TIBKGRD-049-0311			2011-03-30 / 837	MGT7N	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day In-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

F1D110423

CLIENT ANALYSIS SUMMARY

Storage Loc: RAD

Project Manager: IV | Quote #: 70379 | SDG:

Project: 122412-048.02 | Treasure Island

PO#: 382409 OP | Report to: Pat Flynn

Client: 1352452 Shaw E & I Inc

#SMPS In LOT: 0

Date Received: 2011-04-11
Analytical Due Date: 2011-05-06
Report Due Date: 2011-05-09
Report Type: W
EDD Code: 99

Receipt Confirmation Requested - patricia.flynn@shawgrp.com Follow DODQSM - Client Memorandum #4

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
8	TIBKGRD-050-0311			2011-03-30 / 855	MGT7Q	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
9	TIBKGRD-051-0311			2011-03-30 / 907	MGT7T	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
10	TIBKGRD-052-0311			2011-03-30 / 921	MGT7W	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
11	TIBKGRD-053-0311			2011-03-30 / 1102	MGT70	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
12	TIBKGRD-054-0311			2011-03-30 / 1127	MGT71	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
13	TIBKGRD-055-0311			2011-03-30 / 1304	MGT72	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
14	TIBKGRD-056-0311			2011-03-30 / 1304 14 DXB 4-12-11	MGT73	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A

F1D110423

CLIENT ANALYSIS SUMMARY

Storage Loc: RAD

Project Manager: IV | Quote #: 70379 | SDG:

Project: 122412-048.02 | Treasure Island

PO#: 382409 OP | Report to: Pat Flynn

Client: 1352452 Shaw E & I Inc

#SMPS In LOT: 0

Date Received: 2011-04-11
Analytical Due Date: 2011-05-06
Report Due Date: 2011-05-09
Report Type: W
EDD Code: 99

Receipt Confirmation Requested - patricia.flynn@shawgrp.com Follow DODQSM - Client Memorandum #4

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
15	TIBKGRD-057-0311			2011-03-30 / 1315	MGT74	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
16	TIBKGRD-058-0311			2011-03-31 / 808	MGT76	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
17	TIBKGRD-059-0311			2011-03-31 / 838	MGT77	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
18	TIBKGRD-060-0311			2011-03-31 / 855	MGT79	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
19	TIBKGRD-061-0311			2011-03-31 / 1010	MGT8A	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
20	TIBKGRD-062-0311			2011-03-31 / 1315	MGT8C	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A
21	TIBKGRD-063-0311			2011-03-31 / 1330	MGT8E	SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

SAMPLE #	CLIENT SAMPLE ID	Site ID	Client Matrix	DATE/TIME SAMPLED	WORKORDER	A

F1D110423

CLIENT ANALYSIS SUMMARY

Storage Loc: RAD

Date Received: 2011-04-11

Analytical Due Date: 2011-05-06

Report Due Date: 2011-05-09

Report Type: W

EDD Code: 99

Project Manager: IV

Quote #: 70379

SDG:

Project: 122412-048.02

Treasure Island

PO#: 382409 OP

Report to: Pat Flynn

Client: 1352452 Shaw E & I Inc

#SMPS In LOT: 0

Receipt Confirmation Requested - patricia.flynn@shawgrp.com Follow DODQSM - Client Memorandum #4

22 TIBKGRD-064-0311 2011-03-31 / 1450 MGT8F SOLID

SAMPLE COMMENTS:

XX	ZV		RAD SCREEN	SOLID, RAD SCREEN	RA	IN-HOUSE RAD SCREEN	01	STANDARD TEST SET	PROT: B	WRK LOC	06
XX	0B	EML	GA-01-R MOD	SOLID, GA-01-R MOD, Gamma Ra-226 & Hits	J9	Dry, Grind, and Fill Geometry -> 21 day in-growth	DQ	DOD QSM V3	PROT: B	WRK LOC	06

Shaw

CUL 160

Shaw Environmental and Infrastructure Inc.

4005 Port Chicago Hwy
Concord, CA 94520

CHAIN OF CUSTODY

Ref. Document # CTO10-BACKGROUND TI

Page 1 of 3

Project Number: 122412
Project Name / Location: TI -Background Samples
Purchase Order #: 297537

Project Manager: Pete Bourgeois (Name & phone #)

Shipment Date: 4/4/11
Waybill Number: UPS
Lab Destination: TestAmerica St loius
Lab Contact Name / ph. #: Ivan Vania

Send Report To: Patricia Flynn
Phone/Fax Number: 925-288-2037
Address: 4005 Port Chicago Hwy
City: Concord, CA, 94520

Sampler's Name(s): LT, UMC, RG, KM, RA

Sample ID Number	Sample Description	Collection Information: Date	Time	Method	Matrix	# of containers	Preservative (water) / Preservative (soil) / Container Type	Gamma Spec-Radium 226
TIBKGRD-043-0311	SOIL	3/29/11	1548	G	S	1	16oz glass jar	X
TIBKGRD-044-0311	SOIL	3/29/11	1602	G	S	1	16oz glass jar	X
TIBKGRD-045-0311	SOIL	3/29/11	1502	G	S	1	16oz glass jar	X
TIBKGRD-046-0311	SOIL	3/29/11	1526	G	S	1	16oz glass jar	X
TIBKGRD-047-0311	SOIL	3/30/11	0815	G	S	1	16oz glass jar	X
TIBKGRD-048-0311	SOIL	3/30/11	0815	G	S	1	16oz glass jar	X
TIBKGRD-049-0311	SOIL	3/30/11	0837	G	S	1	16oz glass jar	X
TIBKGRD-050-0311	SOIL	3/30/11	0855	G	S	1	16oz glass jar	X
TIBKGRD-051-0311	SOIL	3/30/11	0907	G	S	1	16oz glass jar	X

Special Instructions:

Turnaround Time: ☐ 24-hr ☐ 48-hr
Standard TAT X ☐ 3-day ☐ 5-day

Level Of QC Required: I II III
Project Specific:

Relinquished By: [signature] Date: 4/4/11 Time: 1350
Received By: [signature] Date: 4/5/11 Time: 0815
Relinquished By: Date: Time:
Received By: Date: Time:

Method Codes
C = Composite G = Grab

Matrix Codes
DW = Drinking Water SO = Soil
GW = Ground Water SL = Sludge
WW = Waste Water CP = Chip Samples
A = Air

Shaw

Shaw Environmental and Infrastructure Inc.

4005 Port Chicago Hwy
Concord, CA 94520

CHAIN OF CUSTODY

Ref. Document # CTO10-BACKGROUND TI

Page 2 of 3

Project Number: 122412
Project Name / Location: TI -Background Samples
Purchase Order #: 297537

Project Manager: Pete Bourgeois (Name & phone #)

Shipment Date: 4/4/11
Waybill Number: UPS
Lab Destination: TestAmerica St loius
Lab Contact Name / ph. #: Ivan Vania

Send Report To: Patricia Flynn
Phone/Fax Number: 925-288-2037
Address: 4005 Port Chicago Hwy
City: Concord, CA, 94520

Sampler's Name(s): LT, CML, RG, RM, ZP, RA

Sample ID Number	Sample Description	Collection Information: Date	Time	Method	Matrix	# of containers	Preservative (water) / Preservative (soil) / Container Type	Analyses Requested: Gamma Spec-Radium 226
TIBKGRD-052-0311	SOIL	3/30/11	0921	G	S	1	16oz glass jar	X
TIBKGRD-053-0311	SOIL	3/30/11	1102	G	S	1	16oz glass jar	X
TIBKGRD-054-0311	SOIL	3/30/11	1127	G	S	1	16oz glass jar	X
TIBKGRD-055-0311	SOIL	3/30/11	1304	G	S	2	8oz plastic jar	X
TIBKGRD-056-0311	SOIL	3/30/11	1304	G	S	2	8oz plastic jar	X
TIBKGRD-057-0311	SOIL	3/30/11	1415	G	S	2	8oz plastic jar	X
TIBKGRD-058-0311	SOIL	3/31/11	0808	G	S	1	16oz plastic jar	X
TIBKGRD-059-0311	SOIL	3/31/11	0838	G	S	1	16oz plastic jar	X
TIBKGRD-060-0311	SOIL	3/31/11	0855	G	S	1	16oz plastic jar	X

Special Instructions:

Turnaround Time: ☐ 24-hr ☐ 48-hr
Standard TAT X ☐ 3-day ☐ 5-day

Level Of QC Required: I II III
Project Specific:

Relinquished By: Rick Dy Date: 4/4/11 Time: 1350
Received By: B-1 Date: 4/4/11 Time: 1815
Relinquished By: Date: Time:
Received By: Date: Time:

Method Codes
C = Composite G = Grab

Matrix Codes
DW = Drinking Water SO = Soil
GW = Ground Water SL = Sludge
WW = Waste Water CP = Chip Samples
A = Air

Shaw

Shaw Environmental and Infrastructure Inc.

4005 Port Chicago Hwy
Concord, CA 94520

CHAIN OF CUSTODY

Ref. Document # CTO10-BACKGROUND TI

Page 3 of 3

Project Number: 122412
Project Name / Location: TI -Background Samples
Purchase Order #: 297537

Project Manager: Pete Bourgeois (Name & phone #)

Shipment Date: 4/4/11
Waybill Number: UPS
Lab Destination: TestAmerica St loius
Lab Contact Name / ph. #: Ivan Vania

Send Report To: Patricia Flynn
Phone/Fax Number: 925-288-2037
Address: 4005 Port Chicago Hwy
City: Concord, CA, 94520

Sampler's Name(s): CT, CMc, RG, KM, ZP, RA

Sample ID Number	Sample Description	Collection Information Date	Time	Method	Matrix	# of containers	Preservative (water) / Preservative (soil) / Container Type	Gamma Spec-Radium 226
TIBKGRD-061-0311	SOIL	3/31/11	1010	G	S	1	16oz plastic jar	X
TIBKGRD-062-0311	SOIL	3/31/11	1315	G	S	1	16oz plastic jar	X
TIBKGRD-063-0311	SOIL	3/31/11	1330	G	S	1	16oz plastic jar	X
TIBKGRD-064-0311	SOIL	3/31/11	1450	G	S	1	16oz plastic jar	X

Special Instructions:

Turnaround Time: ☐ 24-hr ☐ 48-hr
Standard TAT X ☐ 3-day ☐ 5-day

Level Of QC Required: I II III Project Specific:

Relinquished By: Rick Dr Date: 4/4/11 Time: 1350
Received By: Date: 4/6/11 Time: 0915
Relinquished By: Date: Time:
Received By: Date: Time:

Method Codes
C = Composite G = Grab

Matrix Codes
DW = Drinking Water SO = Soil
GW = Ground Water SL = Sludge
WW = Waste Water CP = Chip Samples
A = Air

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

Lot #(s): F1D110423

CONDITION UPON RECEIPT FORM

Client: Shaw
Quote No: 70379
COC/RFA No: CT010-Background T1

160

Initiated By: BO Date: 4/11/11 Time: 0815

Shipping Information

Shipper: FedEx (UPS) DHL Courier Client Other: _____ Multiple Packages: Y (N)

Shipping # (s):*		Sample Temperature (s):**	
1. 1Z6uV 545 03 9743 8151	6.	1. Ambient	6.
2.	7.	2.	7.
3.	8.	3.	8.
4.	9.	4.	9.
5.	10.	5.	10.

*Numbered shipping lines correspond to Numbered Sample Temp lines

**Sample must be received at 4°C ± 2°C- If not, note contents below. Temperature variance does NOT affect the following: Metals-Liquid or Rad tests- Liquid or Solids

Condition (Circle "Y" for yes, "N" for no and "N/A" for not applicable):

1.	(Y) N	Are there custody seals present on the cooler?	8.	(Y) N	Are there custody seals present on bottles?
2.	Y (N) N/A	Do custody seals on cooler appear to be tampered with?	9.	Y (N) N/A	Do custody seals on bottles appear to be tampered with?
3.	(Y) N	Were contents of cooler frisked after opening, but before unpacking?	10.	Y N (N/A)	Was sample received with proper pH[1]? (If not, make note below)
4.	(Y) N	Sample received with Chain of Custody?	11.	(Y) N	Sample received in proper containers?
5.	(Y) N N/A	Does the Chain of Custody match sample ID's on the container(s)?	12.	Y N (N/A)	Headspace in VOA or TOX liquid samples? (If Yes, note sample ID's below)
6.	Y (N)	Was sample received broken?	13.	Y N (N/A)	Was Internal COC/Workshare received?
7.	(Y) N	Is sample volume sufficient for analysis?	14.	Y N (N/A)	Was pH taken by original TestAmerica lab?

[1] For DOE-AL (Pantex, LANL, Sandia) sites, pH of ALL containers received must be verified, EXCEPT VOA, TOX and soils.

Notes:

Corrective Action:
- ☐ Client Contact Name: _____ Informed by: _____
- ☐ Sample(s) processed "as is"
- ☐ Sample(s) on hold until: _____ If released, notify: _____

Project Management Review: [signature] Date: 4-12-11

THIS FORM MUST BE COMPLETED AT THE TIME THE ITEMS ARE BEING CHECKED IN. IF ANY ITEM IS COMPLETED BY SOMEONE OTHER THAN THE INITIATOR, THEN THAT PERSON IS REQUIRED TO APPLY THEIR INITIAL AND THE DATE NEXT TO THAT ITEM.

ADMIN-0004, REVISED 10/21/08 \\Slsvr01\QA\FORMS\ST-LOUIS\ADMIN\Admin004 rev11.doc

Appendix D
Instrument Calibration and Quality Control Data

85051

Designer and Manufacturer of Scientific and Industrial Instruments

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.
501 Oak Street, 325-235-5494, Sweetwater, TX 79556, U.S.A.
☐ 10744 Dutchtown Road, 865-392-4601, Knoxville, TN 37932, U.S.A.

CUSTOMER CB&I ORDER NO. 20260978/416518

Mfg. Ludlum Measurements, Inc. Model 19 Serial No. 138426

Mfg. Model Serial No.

Cal. Date 27-Jan-15 Cal Due Date 27-Jan-16 Cal. Interval 1 Year Meterface 202-016

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 74 °F RH 20 % Alt 703.8 mm Hg

☐ New Instrument Instrument Received ☑ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Meter Zeroed ☐ Background Subtract ☐ Input Sens. Linearity
☑ F/S Resp. ck ☑ Reset ck. ☐ Window Operation ☑ Geotropism
☑ Audio ck. ☐ Alarm Setting ck. ☑ Batt. ck. (Min. Volt) 2.2 VDC

☐ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89. ☑ Calibrated in accordance with LMI SOP 14.9 rev 02/07/97.

Instrument Volt Set 556 V Input Sens. 32 mV Det. Oper. V at mV Threshold Dial Ratio = mV

☐ HV Readout (2 points) Ref./Inst. 500 / V Ref./Inst. 1500 / V

COMMENTS:

Calibration performed with front of can facing calibration source.
Cs137≈3mCi(s/n:2171CP)

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER		REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
5000	52.7 cm	4000μR/hr	3900	4000
5000	106.2	1000μR/hr	1000	1000
500	169.9	400μR/hr= 72300 cpm	400	400
500	361.6	100μR/hr	100	100
250	245.1	200μR/hr= 38000 cpm	200	200
250	361.6	100μR/hr	100	100
50		7230 cpm	40	40
50		1800 cpm	10	10
25		3800 cpm	20	20
25		950 cpm	5	5

*Uncertainty within ± 10% C.F. within ± 20% 50,25 Range(s) Calibrated Electronically

	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*		REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout				Log Scale			

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978 State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources: Cs-137 S/N: ☐ 059 ☑ 2171CP ☐ 2261CP ☐ 720 ☐ 734 ☐ 781 ☐ 1131 ☐ 1616 ☐ 1696 ☐ 1909 ☐ 1916CP ☐ 5105 ☐ 5717CO ☐ 5719CO ☐ 60546 ☐ 70897 ☐ 73410 ☐ E552 ☐ G112 ☐ M565 ☐ S-394 ☐ S-1054 ☐ T10081 ☐ T10082 Neutron Am-241 Be S/N: ☐ T-304 Ra-226 S/N: ☐ Y982

☐ Alpha S/N ☐ Beta S/N ☐ Other

☑ m 500 S/N 289158 ☐ Oscilloscope S/N ☑ Multimeter S/N 93870637

Calibrated By: Jeremy Thompson Date 27-Jan-15

Reviewed By: [illegible] Date 27 Jan 15

This certificate shall not be reproduced except in full, without the written approval of Ludlum Measurements, Inc.
FORM C22A 05/19/2014 Page 1 of 1

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed:

CB&I Federal Services

Source ID #	Source Nuclide
1405-22-1	Cs-137

Instrument Model	Instrument Serial #	Calibration Date	Calibration Due Date
19	138426	1/27/2015	1/27/2016
		Calibration	OK

*Any dates not represented indicates instrument not used.

Date	Background (µR/hr)	Source (µR/hr)	Pass or Fail Background	Pass or Fail Source	Instrument not used
5/5/2015	5	2600	PASS	PASS	
5/7/2015	5	2600	PASS	PASS	
5/8/2015	5	2600	PASS	PASS	
5/11/2015	5	2600	PASS	PASS	
5/12/2015	5	2500	PASS	PASS	
5/13/2015	5	2700	PASS	PASS	
5/14/2015	5	2500	PASS	PASS	
5/15/2015	5	2700	PASS	PASS	
5/18/2015	5	2600	PASS	PASS	
5/19/2015	5	2500	PASS	PASS	
5/20/2015	5	2600	PASS	PASS	
5/21/2015	5	2500	PASS	PASS	
5/22/2015	5	2600	PASS	PASS	
5/26/2015	5	2700	PASS	PASS	
5/27/2015	5	2600	PASS	PASS	
5/28/2015	5	2500	PASS	PASS	
5/29/2015	5	2600	PASS	PASS	
6/1/2015	5	2600	PASS	PASS	
6/2/2015	5	2600	PASS	PASS	
6/3/2015	5	2700	PASS	PASS	
6/4/2015	5	2700	PASS	PASS	
6/5/2015	5	2700	PASS	PASS	
6/8/2015	5	2400	PASS	PASS	
6/9/2015	5	2600	PASS	PASS	
6/10/2015	5	2400	PASS	PASS	
6/11/2015	5	2400	PASS	PASS	
6/12/2015	5	2600	PASS	PASS	
6/15/2015	5	2400	PASS	PASS	
6/16/2015	5	2600	PASS	PASS	
6/17/2015	5	2400	PASS	PASS	
6/18/2015	5	2600	PASS	PASS	
6/19/2015	5	2500	PASS	PASS	
6/20/2015	5	2600	PASS	PASS	
6/21/2015	5	2600	PASS	PASS	
6/22/2015	5	2600	PASS	PASS	

CB&I Federal Services

Source ID #	Source Nuclide
1405-22-1	Cs-137

Instrument Model	Instrument Serial #	Calibration Date	Calibration Due Date
19	95511	1/27/2015	1/27/2016
		Calibration	OK

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
6/23/2015	5	2400	PASS	PASS	
6/24/2015	5	2400	PASS	PASS	
6/25/2015	5	2400	PASS	PASS	
6/26/2015	5	2600	PASS	PASS	
6/29/2015	4	2600	PASS	PASS	
6/30/2015	4	2600	PASS	PASS	
7/1/2015	4	2600	PASS	PASS	
7/2/2015	4	2500	PASS	PASS	
7/6/2015	5	2600	PASS	PASS	
7/7/2015	4	2250	PASS	PASS	
7/8/2015	4	2500	PASS	PASS	
7/9/2015	4	2300	PASS	PASS	
7/10/2015	4	2600	PASS	PASS	
7/13/2015	4	2600	PASS	PASS	
7/14/2015	5	2600	PASS	PASS	
7/15/2015	4	2700	PASS	PASS	
7/16/2015	4	2600	PASS	PASS	
7/17/2015	4	2700	PASS	PASS	
7/20/2015	4	2600	PASS	PASS	
7/21/2015	4	2400	PASS	PASS	
7/22/2015	4	2400	PASS	PASS	
7/23/2015	5	2600	PASS	PASS	
7/24/2015	4	2600	PASS	PASS	
7/27/2015	4	2600	PASS	PASS	
7/28/2015	4	2600	PASS	PASS	
7/29/2015	4	2600	PASS	PASS	
7/30/2015	4	2400	PASS	PASS	
7/31/2015	4	2600	PASS	PASS	
8/3/2015	4	2600	PASS	PASS	
8/4/2015	4	2600	PASS	PASS	
8/5/2015	4	2600	PASS	PASS	
8/6/2015	4	2600	PASS	PASS	
8/7/2015	4	2400	PASS	PASS	
8/10/2015	4	2600	PASS	PASS	
8/11/2015	4	2600	PASS	PASS	
8/12/2015	4	2600	PASS	PASS	

CB&I Federal Services

Source ID #	Source Nuclide
1405-22-1	Cs-137

Instrument Model	Instrument Serial #	Calibration Date	Calibration Due Date
19	138426	1/27/2015	1/27/2016
		Calibration	OK

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used	
8/13/2015	4	2600	PASS	PASS		
8/14/2015	4	2800	PASS	PASS		
8/17/2015	4	2200	PASS	PASS		
8/18/2015	4	2500	PASS	PASS		
8/19/2015	4	2800	PASS	PASS		
8/20/2015	4	2600	PASS	PASS		
8/21/2015	4	2800	PASS	PASS		
8/24/2015	5	2200	PASS	PASS		
8/25/2015	5	2200	PASS	PASS		
8/26/2015	4	2600	PASS	PASS		
8/27/2015	4	2400	PASS	PASS		
8/28/2015	4	2400	PASS	PASS		
8/31/2015	4	2600	PASS	PASS		
9/1/2015	4	2600	PASS	PASS		
9/2/2015	4	2600	PASS	PASS		
9/3/2015	4	2800	PASS	PASS		
9/4/2015	4	2600	PASS	PASS		
9/8/2015	4	2600	PASS	PASS		
9/9/2015	4	2600	PASS	PASS		
9/10/2015	4	2400	PASS	PASS		
9/11/2015	4	2600	PASS	PASS		
9/14/2015	4	2400	PASS	PASS		
9/15/2015	4	2600	PASS	PASS		
9/16/2015	4	2200	PASS	PASS		
9/17/2015	4	2400	PASS	PASS		
9/18/2015					X	*9/18/15 Needle malfunctioned
9/21/2015					X	
9/22/2015					X	
9/23/2015					X	
9/24/2015					X	*9/24/15 Sent to Findley for repai
10/2/2015	4	2200	PASS	PASS		*10/1/2015 returned from repairs
10/5/2015	4	2200	PASS	PASS		
10/6/2015	4	2200	PASS	PASS		
10/7/2015	4	2200	PASS	PASS		
10/8/2015	4	2600	PASS	PASS		
10/9/2015	4	2200	PASS	PASS		

CB&I Federal Services

Source ID #	Source Nuclide
1405-22-1	Cs-137

Instrument Model	Instrument Serial #	Calibration Date	Calibration Due Date
19	138426	1/27/2015	1/27/2016
		Calibration	OK

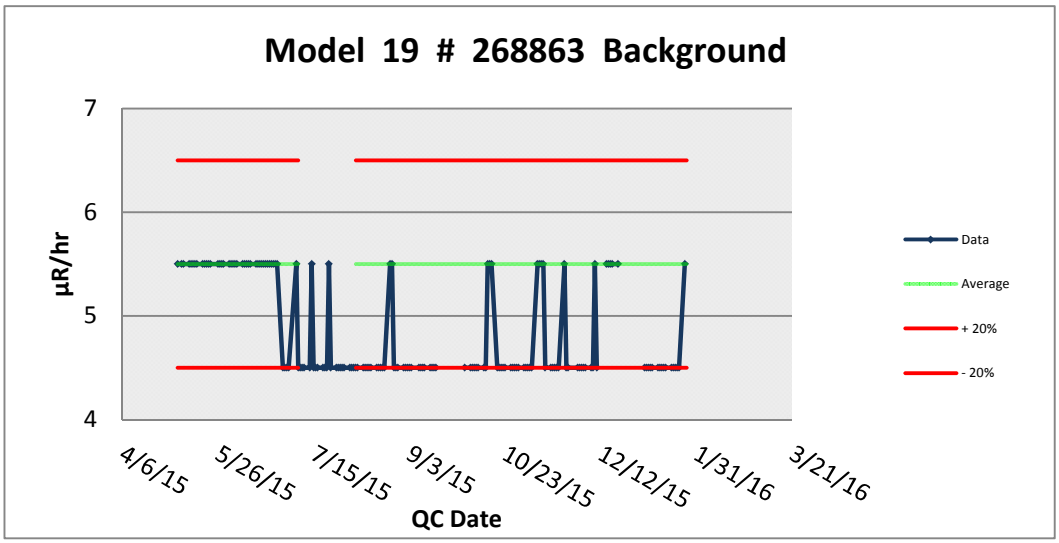
Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
10/12/2015	4	2600	PASS	PASS	
10/13/2015	4	2600	PASS	PASS	
10/14/2015	5	2600	PASS	PASS	
10/15/2015	5	2200	PASS	PASS	
10/16/2015	5	2200	PASS	PASS	
10/19/2015	4	2400	PASS	PASS	
10/20/2015	4	2400	PASS	PASS	
10/21/2015	4	2400	PASS	PASS	
10/22/2015	4	2400	PASS	PASS	
10/23/2015	4	2400	PASS	PASS	
10/26/2015	4	2200	PASS	PASS	
10/27/2015	4	2200	PASS	PASS	
10/28/2015	4	2200	PASS	PASS	
10/29/2015	4	2200	PASS	PASS	
10/30/2015	4	2200	PASS	PASS	
11/2/2015	4	2400	PASS	PASS	
11/3/2015	4	2200	PASS	PASS	
11/4/2015	4	2200	PASS	PASS	
11/5/2015	4	2200	PASS	PASS	
11/6/2015	4	2200	PASS	PASS	
11/9/2015	5	2200	PASS	PASS	
11/10/2015	5	2300	PASS	PASS	
11/11/2015	5	2200	PASS	PASS	
11/12/2015	5	2200	PASS	PASS	
11/13/2015	4	2300	PASS	PASS	
11/16/2015	4	2200	PASS	PASS	
11/17/2015	4	2200	PASS	PASS	
11/18/2015	4	2200	PASS	PASS	
11/19/2015	4	2200	PASS	PASS	
11/20/2015	4	2200	PASS	PASS	
11/23/2015	5	2200	PASS	PASS	
11/24/2015	4	2200	PASS	PASS	
11/25/2015	4	2200	PASS	PASS	
11/30/2015	4	2200	PASS	PASS	
12/1/2015	4	2200	PASS	PASS	
12/2/2015	4	2200	PASS	PASS	

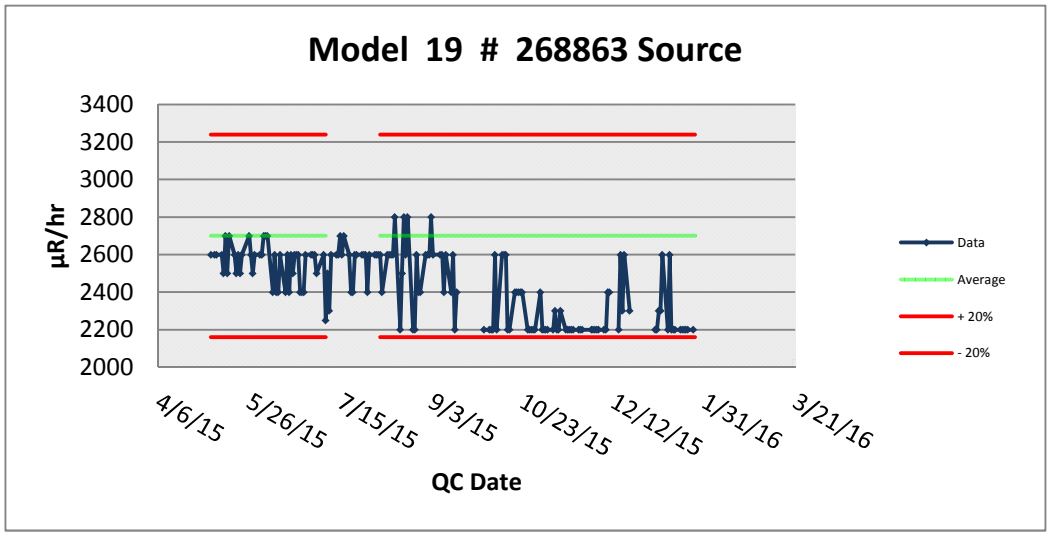
CB&I Federal Services

Source ID #	Source Nuclide
1405-22-1	Cs-137

Instrument Model	Instrument Serial #	Calibration Date	Calibration Due Date
19	138426	1/27/2015	1/27/2016
		Calibration	OK

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
12/3/2015	4	2200	PASS	PASS	
12/4/2015	4	2200	PASS	PASS	
12/7/2015	4	2200	PASS	PASS	
12/8/2015	4	2200	PASS	PASS	
12/9/2015	5	2400	PASS	PASS	
12/10/2015	4	2400	PASS	PASS	
12/11/2015					X
12/14/2015					X
12/15/2015	5	2200	PASS	PASS	
12/16/2015	5	2600	PASS	PASS	
12/17/2015	5	2300	PASS	PASS	
12/18/2015	5	2600	PASS	PASS	
12/21/2015	5	2300	PASS	PASS	
12/22/2015					X
1/4/2016	4	2200	PASS	PASS	
1/5/2016	4	2200	PASS	PASS	
1/6/2016	4	2300	PASS	PASS	
1/7/2016	4	2300	PASS	PASS	
1/8/2016	4	2600	PASS	PASS	
1/11/2016	4	2200	PASS	PASS	
1/12/2016	4	2600	PASS	PASS	
1/13/2016	4	2200	PASS	PASS	
1/14/2016	4	2200	PASS	PASS	
1/15/2016	4	2200	PASS	PASS	
1/18/2016	4	2200	PASS	PASS	
1/19/2016	4	2200	PASS	PASS	
1/20/2016	4	2200	PASS	PASS	
1/21/2016	4	2200	PASS	PASS	
1/22/2016	4	2200	PASS	PASS	
1/25/2016	5	2200	PASS	PASS	
1/26/2016					1/26/2016 sent off


Model 19 # 268863 Background
7
6
5
4
µR/hr
4/6/15
5/26/15
7/15/15
9/3/15
10/23/15
12/12/15
1/31/16
3/21/16
QC Date
Data
Average
+ 20%
- 20%


Model 19 # 268863 Source
3400
3200
3000
2800
2600
2400
2200
2000
µR/hr
4/6/15
5/26/15
7/15/15
9/3/15
10/23/15
12/12/15
1/31/16
3/21/16
QC Date
Data
Average
+ 20%
- 20%

Background Determination

Instument Model	Instrument Serial #	Calibration Due Date
19	138426	1/27/2016

Surface Type :	Table Top (570 Trailer Lab)
Date Collected :	2/19/2015
Collected By :	D. Morrison

Background Dose Rate	5

CPM -20% Value
4

CPM +20% Value
6

Completed By :	**Dennis Morrison**	**Date :**	**2/19/2015**
Reviewed By :	**Takeshi Ibuki**	**Date :**	**2/19/2015**

Source Determination

Instrument Model	Instrument Serial #	Calibration Due Date	Source Nuclide	Source ID #
19	138426	1/27/2016	Cs-137	1405-22-1

Surface Type :	Table Top (570 Trailer Lab)
Date Collected :	2/19/2015
Collected By :	D. Morrison

Source Response	2700

CPM -20% Value
2160

CPM +20% Value
3240

Completed By :	**Dennis Morrison**	**Date :**	**2/19/2015**
Reviewed By :	**Takeshi Ibuki**	**Date :**	**2/19/2015**

Designer and Manufacturer of Scientific and Industrial Instruments

67003

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.
501 Oak Street
325-235-5494
Sweetwater, TX 79556, U.S.A.

☐ 10744 Dutchtown Road
865-392-4601
Knoxville, TN 37932, U.S.A.

CUSTOMER CB&I ORDER NO. 20278330/427996

Mfg. Ludlum Measurements, Inc. Model 19 Serial No. 267085

Mfg. Model Serial No.

Cal. Date 4-Nov-15 Cal Due Date 4-Nov-16 Cal. Interval 1 Year Meterface 202-1070

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 75 °F RH 42 % Alt 704.0 mm Hg

☐ New Instrument Instrument Received ☐ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☑ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Meter Zeroed ☐ Background Subtract ☐ Input Sens. Linearity
☑ F/S Resp. ck ☑ Reset ck. ☐ Window Operation ☑ Geotropism
☑ Audio ck. ☐ Alarm Setting ck. ☑ Batt. ck. (Min. Volt) 2.2 VDC
☐ Calibrated in accordance with LMI SOP 14.8 ☑ Calibrated in accordance with LMI SOP 14.9

Instrument Volt Set 575 V Input Sens. 26 mV Det. Oper. V at mV Threshold Dial Ratio = mV

☑ HV Readout (2 points) Ref./Inst. 500 / 516 V Ref./Inst. 1000 / 1000 V

COMMENTS:
4000uR/hr=52.6cm
1000uR/hr=106.0cm
400uR/hr=169.5cm
100uR/hr=372.0cm
200uR/hr=286.2cm
100uR/hr=372.0cm

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
5000	4000µR/hr	N/A	4000
5000	1000µR/hr		1000
500	400µR/hr= 73600cpm		400
500	100µR/hr		100
250	200µR/hr= 36200cpm		200
250	100µR/hr		100
50	7360 cpm		40
50	1840 cpm		10
25	3620 cpm		20
25	905 cpm		5

*Uncertainty within ± 10% C.F. within ± 20%

50, 25 **Range(s) Calibrated Electronically**

	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*		REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout				Log Scale			

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques.
The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978 State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources: Cs-137 S/N: ☐ 059 ☑ 2171CP ☐ 2261CP ☐ 720 ☐ 734 ☐ 781 ☐ 1131 ☐ 1616 ☐ 1696 ☐ 1909 ☐ 1916CP ☐ 5105 ☐ 5717CO
☐ 5719CO ☐ 60646 ☐ 70897 ☐ 73410 ☐ E552 ☐ G112 ☐ M565 ☐ S-394 ☐ S-1054 ☐ T10081 ☐ T10082 Neutron Am-241 Be S/N: ☐ T-304 Ra-226 S/N: ☐ Y982

☐ Alpha S/N ☐ Beta S/N ☐ Other

☑ m 500 S/N 125489 ☐ Oscilloscope S/N ☑ Multimeter S/N 68260348

Calibrated By: V. Lee Alvarado Date 4 Nov 15

Reviewed By: Dean Nelson Date 4-Nov-15

This certificate shall not be reproduced except in full without the written approval of Ludlum Measurements, Inc.
FORM C22A 09/28/2015 Page 1 of 1

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test
☐ Failed:

CB&I Federal Services

Source ID #	Source Nuclide
1405-22-1	Cs-137

Instrument Model	Instrument Serial #	Calibration Date	Calibration Due Date
19	267085	11/4/2015	11/4/2016
		Calibration	OK

*Any dates not represented indicates instrument not used.

Date	Background (µR/hr)	Source (µR/hr)	Pass or Fail Background	Pass or Fail Source	Instrument not used
11/12/2015	5	2300	PASS	PASS	
11/13/2015	4	2800	PASS	PASS	
11/16/2015	4	2200	PASS	PASS	
11/17/2015	4	2100	PASS	PASS	
11/18/2015	4	2200	PASS	PASS	
11/19/2015	4	2200	PASS	PASS	
11/20/2015	4	2200	PASS	PASS	
11/23/2015	5	2200	PASS	PASS	
11/24/2015	4	2200	PASS	PASS	
11/25/2015	4	2100	PASS	PASS	
11/30/2015	4	2200	PASS	PASS	
12/1/2015	4	2200	PASS	PASS	
12/2/2015	4	2200	PASS	PASS	
12/3/2015	4	2200	PASS	PASS	
12/4/2015	4	2100	PASS	PASS	
12/7/2015	4	2100	PASS	PASS	
12/8/2015	4	2200	PASS	PASS	
12/9/2015	5	2400	PASS	PASS	
12/10/2015	4	2200	PASS	PASS	
12/11/2015					X
12/14/2015					X
12/15/2015	5	2600	PASS	PASS	
12/16/2015	5	2200	PASS	PASS	
12/17/2015	5	2600	PASS	PASS	
12/18/2015	5	2200	PASS	PASS	
12/21/2015	5	2400	PASS	PASS	
12/22/2015					X
1/4/2016	4	2100	PASS	PASS	
1/5/2016	4	2200	PASS	PASS	
1/6/2016	4	2200	PASS	PASS	
1/7/2016	4	2100	PASS	PASS	
1/8/2016	4	2200	PASS	PASS	
1/11/2016	4	2200	PASS	PASS	
1/12/2016	4	2400	PASS	PASS	
1/13/2016	4	2200	PASS	PASS	

CB&I Federal Services

Source ID #	Source Nuclide
1405-22-1	Cs-137

Instrument Model	Instrument Serial #	Calibration Date	Calibration Due Date
19	267085	11/4/2015	11/4/2016
		Calibration	OK

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
1/14/2016	5	2400	PASS	PASS	
1/15/2016	5	2100	PASS	PASS	
1/18/2016	4	2100	PASS	PASS	
1/19/2016	5	2100	PASS	PASS	
1/20/2016	4	2200	PASS	PASS	
1/21/2016	4	2200	PASS	PASS	
1/22/2016	5	2200	PASS	PASS	
1/25/2016	5	2100	PASS	PASS	
1/26/2016	4	2200	PASS	PASS	
1/27/2016	5	2100	PASS	PASS	
1/28/2016	5	2200	PASS	PASS	
1/29/2016	4	2200	PASS	PASS	
2/1/2016	5	2200	PASS	PASS	
2/2/2016	4	2000	PASS	PASS	
2/3/2016	4	2100	PASS	PASS	
2/4/2016	4	2100	PASS	PASS	
2/5/2016	4	2200	PASS	PASS	
2/8/2016	4	2100	PASS	PASS	
2/9/2016	4	2200	PASS	PASS	
2/10/2016	4	2000	PASS	PASS	
2/11/2016	5	2000	PASS	PASS	
2/12/2016	4	2200	PASS	PASS	
2/15/2016	4	2200	PASS	PASS	
2/16/2016	4	2100	PASS	PASS	
2/17/2016	4	2100	PASS	PASS	
2/18/2016	4	2200	PASS	PASS	
2/19/2016	4	2100	PASS	PASS	
2/22/2016	4	2100	PASS	PASS	
2/23/2016	4	2100	PASS	PASS	
2/24/2016	4	2200	PASS	PASS	
2/25/2016	4	2200	PASS	PASS	
2/26/2016	5	2200	PASS	PASS	
2/29/2016	4	2100	PASS	PASS	
3/1/2016	4	2000	PASS	PASS	
3/2/2016	4	2000	PASS	PASS	
3/3/2016	4	2100	PASS	PASS	

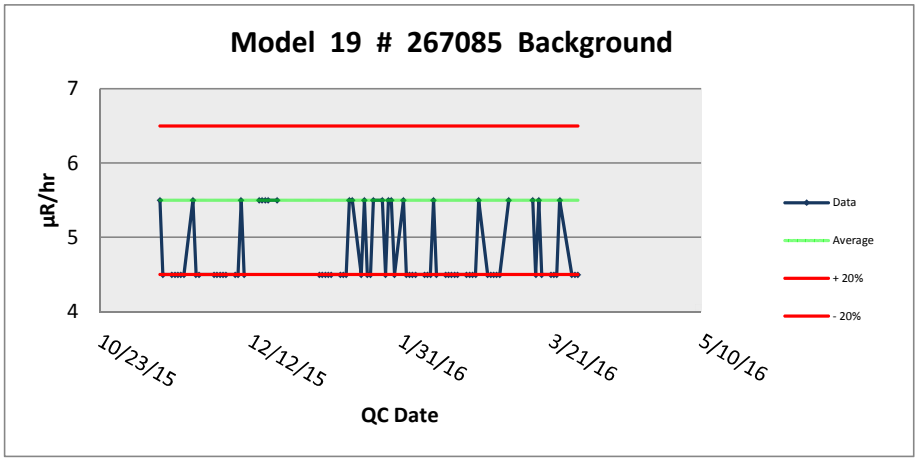
CB&I Federal Services

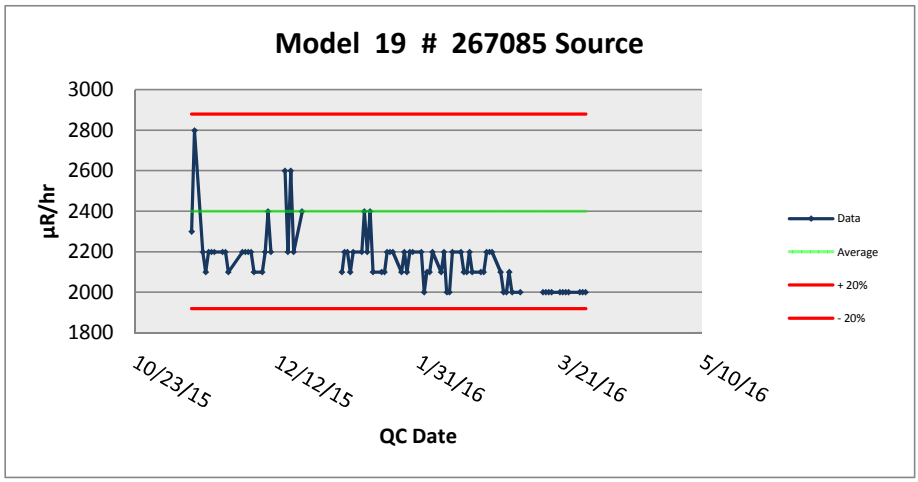
Source ID #	Source Nuclide
1405-22-1	Cs-137

Instrument Model	Instrument Serial #	Calibration Date	Calibration Due Date
19	267085	11/4/2015	11/4/2016
		Calibration	OK

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
3/4/2016	4	2000	PASS	PASS	
3/7/2016	5	2000	PASS	PASS	
3/8/2016					X
3/9/2016					X
3/10/2016					X
3/11/2016					X
3/14/2016					X
3/15/2016	5	2000	PASS	PASS	
3/16/2016	4	2000	PASS	PASS	
3/17/2016	5	2000	PASS	PASS	
3/18/2016	4	2000	PASS	PASS	
3/21/2016	4	2000	PASS	PASS	
3/22/2016	4	2000	PASS	PASS	
3/23/2016	4	2000	PASS	PASS	
3/24/2016	5	2000	PASS	PASS	
3/28/2016	4	2000	PASS	PASS	
3/29/2016	4	2000	PASS	PASS	
3/30/2016	4	2000	PASS	PASS	

Control Graphs





Background Determination

Instument Model	Instrument Serial #	Calibration Due Date
19	267085	11/4/2016

Surface Type :	Table Top (570 Trailer Lab)
Date Collected :	11/10/2015
Collected By :	M. Chi

Background Dose Rate	5

CPM +20% Value
6

CPM -20% Value
4

Completed By :	**Minhsec Chi**	**Date :**	**11/11/2015**

Reviewed By :	**Takeshi Ibuki**	**Date :**	**11/11/2015**

Source Determination

Instrument Model	Instrument Serial #	Calibration Due Date	Source Nuclide	Source ID #
19	267085	11/4/2016	Cs-137	1405-22-1

Surface Type :	Table Top (570 Trailer Lab)
Date Collected :	11/10/2015
Collected By :	M. Chi

Source Response	2400

CPM +20% Value
2880

CPM -20% Value
1920

Completed By :	**Minhsec Chi**	**Date :**	**11/11/2015**
Reviewed By :	**Takeshi Ibuki**	**Date :**	**11/11/2015**

Designer and Manufacturer of Scientific and Industrial Instruments

67001

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.
501 Oak Street
325-235-5494
Sweetwater, TX 79556, U.S.A.
☐ 10744 Dutchtown Road
865-392-4601
Knoxville, TN 37932, U.S.A.

CUSTOMER CB&I ORDER NO. 20271710/423565

Mfg. Ludlum Measurements, Inc. Model 19 Serial No. 267096

Mfg. Model Serial No.

Cal. Date 16-Jul-15 Cal Due Date 16-Jul-16 Cal. Interval 1 Year Meterface 202-1070

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 75 °F RH 47 % Alt 704.8 mm Hg

☐ New Instrument Instrument Received ☑ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Meter Zeroed ☐ Background Subtract ☐ Input Sens. Linearity
☑ F/S Resp. ck ☑ Reset ck. ☐ Window Operation ☑ Geotropism
☑ Audio ck. ☐ Alarm Setting ck. ☑ Batt. ck. (Min. Volt) 2.2 VDC

☐ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89. ☑ Calibrated in accordance with LMI SOP 14.9 rev 05/15/2015.

Instrument Volt Set 550 V Input Sens. 28 mV Det. Oper. V at mV Threshold Dial Ratio = mV

☑ HV Readout (2 points) Ref./Inst. 500 / 502 V Ref./Inst. ~~1200~~ 1100 / 1112 V

COMMENTS:
Cs137 1.9mci (M565)

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
5000 30.9 cm	4000µR/hr	4000	4000
5000 61.7 cm	1000µR/hr	1000	1000
500 98.9 cm	400µR/hr = 72600 cpm	400	400
500 205.8 cm	100µR/hr	100	100
250 141.6 cm	200µR/hr = 35200 cpm	190	200
250 205.8 cm	100µR/hr	95	100
50	7260 cpm	40	40
50	1815 cpm	10	10
25	3520 cpm	19	20
25	880 cpm	4.8	5

*Uncertainty within ± 10% C.F. within ± 20%

Range(s) Calibrated Electronically

	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout			

	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Log Scale			

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other international Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978

State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources: Cs-137 S/N: ☐ 059 ☐ 2171CP ☐ 2261CP ☐ 720 ☐ 734 ☐ 781 ☐ 1131 ☐ 1616 ☐ 1696 ☐ 1909 ☐ 1916CP ☐ 5105 ☐ 5717CO ☐ 5719CO ☐ 60646 ☐ 70897 ☐ 73410 ☐ E552 ☐ G112 ☑ M565 ☐ S-394 ☐ S-1054 ☐ T10081 ☐ T10082 Neutron Am-241 Be S/N: ☐ T-304 Ra-226 S/N: ☐ Y982

☐ Alpha S/N ☐ Beta S/N ☐ Other

☑ m 500 S/N 189509 ☐ Oscilloscope S/N ☑ Multimeter S/N 71300492

Calibrated By: Wendell Williams Date 16 Jul 15

Reviewed By: [illegible] Date 16 Jul 15

This certificate shall not be reproduced except in full, without the written approval of Ludlum Measurements, Inc.

FORM C22A 07/09/2015 Page 1 of 1

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed:

CB&I Federal Services

Source ID #	Source Nuclide
1405-22-1	Cs-137

Instrument Model	Instrument Serial #	Calibration Date	Calibration Due Date
19	267096	7/16/2015	7/16/2016
		Calibration	OK

*Any dates not represented indicates instrument not used.

Date	Background (µR/hr)	Source (µR/hr)	Pass or Fail Background	Pass or Fail Source	Instrument not used
7/27/2015	4	2400	PASS	PASS	
7/28/2015	4	2400	PASS	PASS	
7/29/2015	4	2400	PASS	PASS	
7/30/2015	4	2200	PASS	PASS	
7/31/2015	4	2400	PASS	PASS	
8/3/2015	4	2200	PASS	PASS	
8/4/2015	4	2300	PASS	PASS	
8/5/2015	4	2300	PASS	PASS	
8/6/2015	4	2300	PASS	PASS	
8/7/2015	4	2200	PASS	PASS	
8/10/2015	4	2400	PASS	PASS	
8/11/2015	4	2200	PASS	PASS	
8/12/2015	4	2200	PASS	PASS	
8/13/2015	4	2400	PASS	PASS	
8/14/2015	4	2400	PASS	PASS	
8/17/2015	4	2300	PASS	PASS	
8/18/2015	4	2400	PASS	PASS	
8/19/2015	4	2400	PASS	PASS	
8/20/2015	4	2400	PASS	PASS	
8/21/2015	4	2400	PASS	PASS	
8/24/2015	4	2200	PASS	PASS	
8/25/2015	4	2200	PASS	PASS	
8/26/2015	4	2400	PASS	PASS	
8/27/2015	4	2400	PASS	PASS	
8/28/2015	4	2200	PASS	PASS	
8/31/2015	4	2400	PASS	PASS	
9/1/2015	4	2400	PASS	PASS	
9/2/2015	4	2400	PASS	PASS	
9/3/2015	4	2400	PASS	PASS	
9/4/2015	4	2300	PASS	PASS	
9/8/2015	4	2200	PASS	PASS	
9/9/2015	4	2400	PASS	PASS	
9/10/2015	4	2200	PASS	PASS	
9/11/2015	4	2400	PASS	PASS	
9/14/2015	4	2200	PASS	PASS	

CB&I Federal Services

Source ID #	Source Nuclide
1405-22-1	Cs-137

Instrument Model	Instrument Serial #	Calibration Date	Calibration Due Date
19	267096	7/16/2015	7/16/2016
		Calibration	OK

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
9/15/2015	4	2200	PASS	PASS	
9/16/2015	4	2200	PASS	PASS	
9/17/2015	4	2400	PASS	PASS	
9/18/2015	4	2400	PASS	PASS	
9/21/2015	4	2400	PASS	PASS	
9/22/2015	4	2400	PASS	PASS	
9/23/2015	4	2400	PASS	PASS	
9/24/2015	4	2400	PASS	PASS	
9/25/2015	4	2400	PASS	PASS	
9/28/2015	4	2400	PASS	PASS	
9/29/2015	4	2200	PASS	PASS	
9/30/2015	4	2200	PASS	PASS	
10/1/2015	4	2200	PASS	PASS	
10/2/2015	4	2200	PASS	PASS	
10/5/2015	4	2200	PASS	PASS	
10/6/2015	4	2200	PASS	PASS	
10/7/2015	4	2200	PASS	PASS	
10/8/2015	4	2400	PASS	PASS	
10/9/2015	4	2200	PASS	PASS	
10/12/2015	4	2200	PASS	PASS	
10/13/2015	4	2200	PASS	PASS	
10/14/2015	4	2200	PASS	PASS	
10/15/2015	4	2200	PASS	PASS	
10/16/2015	4	2400	PASS	PASS	
10/19/2015	4	2200	PASS	PASS	
10/20/2015	4	2200	PASS	PASS	
10/21/2015	4	2200	PASS	PASS	
10/22/2015	4	2200	PASS	PASS	
10/23/2015	4	2200	PASS	PASS	
10/26/2015	4	2200	PASS	PASS	
10/27/2015	4	2100	PASS	PASS	
10/28/2015	4	2200	PASS	PASS	
10/29/2015	4	2100	PASS	PASS	
10/30/2015	4	2200	PASS	PASS	
11/2/2015	4	2400	PASS	PASS	
11/3/2015	4	2200	PASS	PASS	

CB&I Federal Services

Source ID #	Source Nuclide
1405-22-1	Cs-137

Instrument Model	Instrument Serial #	Calibration Date	Calibration Due Date
19	267096	7/16/2015	7/16/2016
		Calibration	OK

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
11/4/2015	4	2200	PASS	PASS	
11/5/2015	4	2100	PASS	PASS	
11/6/2015	4	2100	PASS	PASS	
11/9/2015	4	2200	PASS	PASS	
11/10/2015	4	2600	PASS	PASS	
11/11/2015	4	2100	PASS	PASS	
11/12/2015	4	1900	PASS	PASS	
11/13/2015	4	2200	PASS	PASS	
11/16/2015	4	2100	PASS	PASS	
11/17/2015	4	2200	PASS	PASS	
11/18/2015	4	2100	PASS	PASS	
11/19/2015	4	2100	PASS	PASS	
11/20/2015	4	2200	PASS	PASS	
11/23/2015	4	2200	PASS	PASS	
11/24/2015	4	2100	PASS	PASS	
11/25/2015	4	2100	PASS	PASS	
11/30/2015	4	2100	PASS	PASS	
12/1/2015	4	2100	PASS	PASS	
12/2/2015	4	2100	PASS	PASS	
12/3/2015	4	2100	PASS	PASS	
12/4/2015	4	2200	PASS	PASS	
12/7/2015	4	2100	PASS	PASS	
12/8/2015	4	2200	PASS	PASS	
12/9/2015	4	2200	PASS	PASS	
12/10/2015	4	2000	PASS	PASS	
12/11/2015					X
12/14/2015					X
12/15/2015	5	2000	PASS	PASS	
12/16/2015	5	2300	PASS	PASS	
12/17/2015	5	2200	PASS	PASS	
12/18/2015	5	2200	PASS	PASS	
12/21/2015	5	2200	PASS	PASS	
12/22/2015	5	2200	PASS	PASS	
1/4/2016	4	2000	PASS	PASS	
1/5/2016	4	2100	PASS	PASS	
1/6/2016	4	2000	PASS	PASS	

CB&I Federal Services

Source ID #	Source Nuclide
1405-22-1	Cs-137

Instrument Model	Instrument Serial #	Calibration Date	Calibration Due Date
19	267096	7/16/2015	7/16/2016
		Calibration	OK

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
1/7/2016	4	2100	PASS	PASS	
1/8/2016	4	2190	PASS	PASS	
1/11/2016	4	2200	PASS	PASS	
1/12/2016	4	2200	PASS	PASS	
1/13/2016	4	2000	PASS	PASS	
1/14/2016	4	2200	PASS	PASS	
1/15/2016	4	2100	PASS	PASS	
1/18/2016	4	2000	PASS	PASS	
1/19/2016	4	2000	PASS	PASS	
1/20/2016	4	2000	PASS	PASS	
1/21/2016	4	2000	PASS	PASS	
1/22/2016	4	2000	PASS	PASS	
1/25/2016	5	2000	PASS	PASS	
1/26/2016	4	2100	PASS	PASS	
1/27/2016	5	2200	PASS	PASS	
1/28/2016	5	2100	PASS	PASS	
1/29/2016	4	2300	PASS	PASS	
2/1/2016	4	2000	PASS	PASS	
2/2/2016	4	2100	PASS	PASS	
2/3/2016	4	1900	PASS	PASS	
2/4/2016	4	2000	PASS	PASS	
2/5/2016	4	2000	PASS	PASS	
2/8/2016	4	2000	PASS	PASS	
2/9/2016	4	2000	PASS	PASS	
2/10/2016	4	2000	PASS	PASS	
2/11/2016	5	2200	PASS	PASS	
2/12/2016	5	2000	PASS	PASS	
2/15/2016	4	2000	PASS	PASS	
2/16/2016	4	2000	PASS	PASS	
2/17/2016	4	2000	PASS	PASS	
2/18/2016	4	2000	PASS	PASS	
2/19/2016	4	2100	PASS	PASS	
2/22/2016	4	2000	PASS	PASS	
2/23/2016	4	2100	PASS	PASS	
2/24/2016	4	2000	PASS	PASS	
2/25/2016	4	2000	PASS	PASS	

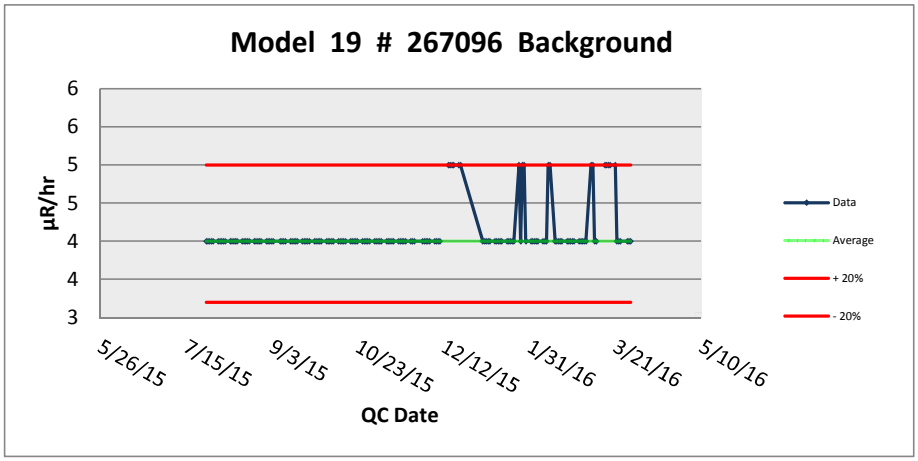
CB&I Federal Services

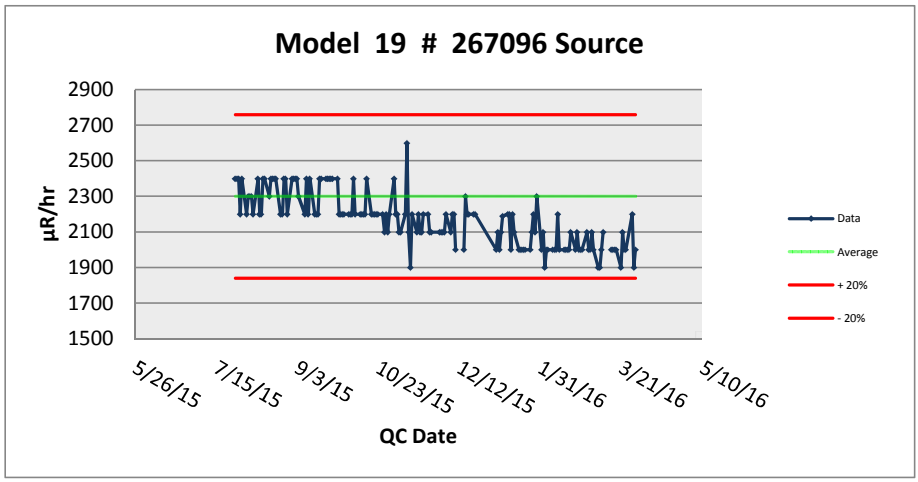
Source ID #	Source Nuclide
1405-22-1	Cs-137

Instrument Model	Instrument Serial #	Calibration Date	Calibration Due Date
19	267096	7/16/2015	7/16/2016
		Calibration	OK

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
2/26/2016	4	2000	PASS	PASS	
2/29/2016	4	2100	PASS	PASS	
3/1/2016	4	2000	PASS	PASS	
3/2/2016	4	2000	PASS	PASS	
3/3/2016	4	2100	PASS	PASS	
3/4/2016	4	2000	PASS	PASS	
3/7/2016	5	1900	PASS	PASS	
3/8/2016	5	1900	PASS	PASS	
3/9/2016	4	2000	PASS	PASS	
3/10/2016	4	2100	PASS	PASS	
3/11/2016					X
3/14/2016					X
3/15/2016	5	2000	PASS	PASS	
3/16/2016	5	2000	PASS	PASS	
3/17/2016	5	2000	PASS	PASS	
3/18/2016	5	2000	PASS	PASS	
3/21/2016	5	1900	PASS	PASS	
3/22/2016	4	2100	PASS	PASS	
3/23/2016	4	2000	PASS	PASS	
3/24/2016	4	2000	PASS	PASS	
3/28/2016	4	2200	PASS	PASS	
3/29/2016	4	1900	PASS	PASS	
3/30/2016	4	2000	PASS	PASS	

Control Graphs





Background Determination

Instument Model	Instrument Serial #	Calibration Due Date
19	267096	7/16/2016

Surface Type :	Table Top (570 Lab)
Date Collected :	7/23/2015
Collected By :	M. Chi

Background Dose Rate	4

CPM +20% Value
5

CPM -20% Value
3

Completed By :	**Minhsec Chi**	**Date :**	**7/23/2015**
Reviewed By :	**Takeshi Ibuki**	**Date :**	**7/23/2015**

Source Determination

Instrument Model	Instrument Serial #	Calibration Due Date	Source Nuclide	Source ID #
19	267096	7/16/2016	Cs-137	1405-22-1

Surface Type :	Table Top (570 Lab)
Date Collected :	7/23/2015
Collected By :	M. Chi

Source Response	2300

CPM +20% Value
2760

CPM -20% Value
1840

Completed By :	**Minhsec Chi**	**Date :**	**7/23/2015**
Reviewed By :	**Takeshi Ibuki**	**Date :**	**7/23/2015**

Designer and Manufacturer of Scientific and Industrial Instruments

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.
501 Oak Street
325-235-5494
Sweetwater, TX 79556, U.S.A.
☐ 10744 Dutchtown Road
865-392-4601
Knoxville, TN 37932, U.S.A.

CUSTOMER CB & I ORDER NO. 20266706/420297

Mf Ludlum Measurements, Inc. Model 2221 Serial No. 97290

Mf Ludlum Measurements, Inc. Model 44-20 Serial No. PR295572

Cal. Date 28-Apr-15 Cal Due Date 28-Apr-16 Cal. Interval 1 Year Meterface 202-159

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 73 °F RH 25 % Alt 700.8 mm Hg

☐ New Instrument Instrument Received ☐ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☑ Other-See comments

☑ Mechanical ck. ☑ Meter Zeroed ☐ Background Subtract ☑ Input Sens. Linearity
☑ F/S Resp. ck ☑ Reset ck. ☑ Window Operation ☑ Geotropism
☑ Audio ck. ☑ Alarm Setting ck. ☑ Batt. ck. (Min. Volt) 4.4 VDC
☐ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89. ☐ Calibrated in accordance with LMI SOP 14.9 rev 02/07/97.

nstrument Volt Set Comments V Input Sens. Comments mV Det. Oper. Comments V at Comments mV Threshold Dial Ratio 100 = 10 mV

☑ HV Readout (2 points) Ref./Inst. 500 / 497 V Ref./Inst. 2000 / 1993 V

COMMENTS:

	Peak settings	Gross Counts	Model 2221 currently set
High Voltage:	670 V	1000 V	for gross counts.
Threshold dial:	642	100(10mv)	High voltage set with detector
Window dial:	40	n/a	connected.
Window Position:	"IN"	"OUT"	
Resolution for Cs137:	≈8.91%	n/a	Firmware: 261027

OL checked but not set. Calibrated with 5' cable.Ra226≈189.9µCi(S/N:Y982)
Count at 100µR/hr(205.8 C/m) for Cs137≈1.9mCi(S/N:M565)is: 206,589cpm
No as found readings for Ra226 conversion chart due to new 44-20.

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
x1K	400kcpm	400	400
x1K	100kcpm	100	100
x100	40kcpm	400	400
x100	10kcpm	100	100
x10	4kcpm	400	400
x10	1kcpm	100	100
x1	400cpm	400	400
x1	100cpm	100	100

*Uncertainty within ± 10% C.F. within ± 20% ALL Range(s) Calibrated Electronically

	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*		REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout	400kcpm	40043 100	40043 100	Log Scale	500kcpm	500K cpm	500K cpm
	40kcpm	4004	4004		50kcpm	50	50
	4kcpm	400	400		5kcpm	5	5
	400cpm	40	40		500cpm	500	500
	40cpm	4	4		50cpm	50	50

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques.
The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978 State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources: Cs-137 S/N: ☐ 059 ☐ 2171CP ☐ 2261CP ☐ 720 ☐ 734 ☐ 781 ☐ 1131 ☐ 1616 ☐ 1696 ☐ 1909 ☐ 1916CP ☐ 5105 ☐ 5717CO ☐ 5719CO ☐ 60646 ☐ 70897 ☐ 73410 ☐ E552 ☐ G112 ☐ M565 ☐ S-394 ☐ S-1054 ☐ T10081 ☐ T10082 Neutron Am-241 Be S/N: ☐ T-304 Ra-226 S/N: ☐ Y982

☐ Alpha S/N ☐ Beta S/N ☐ Other

☐ 500 S/N 289158 ☐ Oscilloscope S/N ☑ Multimeter S/N 93870637

Calibrated By: Jeremy Thompson Date 28-Apr-15

Reviewed By: [illegible] Date 28 Apr 15

This certificate shall not be reproduced except in full, without the written approval of Ludlum Measurements, Inc.
FORM C22A 05/19/2014 Page 1 of 3

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed:

Designer and Manufacturer
of
Scientific and Industrial
Instruments

LUDLUM MEASUREMENTS, INC.
501 Oak Street
325-235-5494
Sweetwater, TX 79556, U.S.A.

☐ 10744 Dutchtown Road
865-392-4601
Knoxville, TN 37932, U.S.A.

Bench Test Data For Detector

Detector 44-20 Serial No. PR255 572

Customer CB & I Order #. 20266706/420297

Counter 2221 Serial No. 97290 Counter Input Sensitivity 10 mV

Count Time 6 Seconds Distance Source to Detector surface

Other

High Voltage	Background	Isotope Am241 Size 20.77 μCi	Isotope Size	Isotope Size	Isotope Size
850	1335	18215			
900	1347	18554			
950	1341	18593			
*1000	1343	18509			
1050	1316	18530			
1100	1350	18742			
1150	1357	18928			
1200	2834	20116			

Signature Jeremy Thompson Date 28 Apr 15

• *Serving The Nuclear Industry Since 1962* •

Designer and Manufacturer
of
Scientific and Industrial
Instruments

LUDLUM MEASUREMENTS, INC.
501 Oak Street
325-235-5494
Sweetwater, TX 79556, U.S.A.

☐ 10744 Dutchtown Road
865-392-4601
Knoxville, TN 37932, U.S.A.

CONVERSION CHART

Customer: CB & I Date: 28-Apr-15 Order #: 20266706/420297

Model: 2221 Serial No.: 97290 Detector Model: 44-20 Serial No.: PR 295 572

Source: Ra226 = 185.9 μCi High Voltage: 1000 V

Input Sensitivity: 10 mV

Reference Point	"As Found" Readings (CPM): Analog	Range/Scale	After Adjustment Readings (CPM): Analog	Range/Scale
200 μR/hr 97.4 cm	NA	NA	430	X1K
150 113.5 cm			320	
100 141.6 cm			21	

Reference Point	"As Found" Readings: Digital	Count Time	After Adjustment Readings: Digital	Count Time
200 μR/hr 97.4 cm	NA	NA	42348	6 Seconds
150 113.5 cm			32180	
100 141.6 cm			21078	

Signature: Jeremy Thompson Date: 28-Apr-15

• *Serving The Nuclear Industry Since 1962* •

CB&I Federal Services

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.778
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	97290	PR295572	4/28/2015	4/28/2016
				Calibration	**OK**

*Any dates not represented indicates instrument not used.

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
4/5/2015	9779	404517	PASS	PASS	
5/5/2015	10669	379791	PASS	PASS	
5/6/2015	11347	364953	PASS	PASS	
5/7/2015	11965	369438	PASS	PASS	
5/8/2015	11691	349260	PASS	PASS	
5/11/2015	10902	274077	PASS	PASS	
5/12/2015	10827	333592	PASS	PASS	
5/13/2015	10821	329497	PASS	PASS	
5/14/2015	10884	336278	PASS	PASS	
5/15/2015	10574	325641	PASS	PASS	
5/18/2015	10500	360926	PASS	PASS	
5/19/2015	10686	344854	PASS	PASS	
5/20/2015	10502	341700	PASS	PASS	
5/21/2015	11308	379655	PASS	PASS	
5/22/2015	10879	368145	PASS	PASS	
5/26/2015	10168	343041	PASS	PASS	
5/27/2015	10063	352360	PASS	PASS	
5/28/2015	10603	369383	PASS	PASS	
5/29/2015	10210	369244	PASS	PASS	
6/1/2015	10425	354546	PASS	PASS	
6/2/2015	9996	343475	PASS	PASS	
6/3/2015	10568	369977	PASS	PASS	
6/4/2015	10165	382798	PASS	PASS	
6/5/2015	10229	346119	PASS	PASS	
6/8/2015	9202	351271	PASS	PASS	
6/9/2015	9370	340894	PASS	PASS	
6/10/2015	9503	344690	PASS	PASS	
6/11/2015	9546	335137	PASS	PASS	
6/12/2015	9857	329352	PASS	PASS	
6/15/2015	10216	340753	PASS	PASS	
6/16/2015	10291	396694	PASS	PASS	
6/17/2015	10315	355018	PASS	PASS	
6/18/2015	10116	365006	PASS	PASS	
6/19/2015	9638	334509	PASS	PASS	
6/20/2015	10552	337266	PASS	PASS	

CB&I Federal Services

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.78
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	97290	PR295572	4/28/2015	4/28/2016
				Calibration	**OK**

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used	
6/21/2015	9855	352215	PASS	PASS		
6/22/2015	11182	323441	PASS	PASS		
6/23/2015	10544	318210	PASS	PASS		
6/24/2015	10273	331240	PASS	PASS		
6/25/2015	9730	356835	PASS	PASS		
6/26/2015	10229	335565	PASS	PASS		
6/29/2015	9341	324714	PASS	PASS		
6/30/2015	9250	335629	PASS	PASS		
7/1/2015	9300	343671	PASS	PASS		
7/2/2015	10698	352524	PASS	PASS		
7/6/2015	13588	332302	PASS	PASS		
7/7/2015	10676	331335	PASS	PASS		
7/8/2015	10941	331088	PASS	PASS		
7/9/2015	10924	325955	PASS	PASS		
7/10/2015	10201	326633	PASS	PASS		
7/13/2015	10200	337677	PASS	PASS		
7/14/2015	10461	330567	PASS	PASS		
7/15/2015	13565	326832	PASS	PASS		
7/16/2015	11156	337993	PASS	PASS		
7/17/2015					X	
7/20/2015	9721	333330	PASS	PASS		
7/21/2015	11862	329345	PASS	PASS		
7/22/2015	10886	347779	PASS	PASS		
7/23/2015	11229	326839	PASS	PASS		
7/24/2015					X	
7/27/2015					X	7/27/2015 Sent for repair
7/30/2015	11093	326356	PASS	PASS		7/30/2015 Returned from Finley
7/31/2015	11555	326722	PASS	PASS		
8/3/2015	9937	328234	PASS	PASS		
8/4/2015	11496	342185	PASS	PASS		
8/5/2015	11629	325175	PASS	PASS		
8/6/2015	10278	336262	PASS	PASS		
8/7/2015	10001	326178	PASS	PASS		
8/10/2015	10609	326959	PASS	PASS		
8/11/2015	10729	345882	PASS	PASS		
8/12/2015	10943	339044	PASS	PASS		

CB&I Federal Services

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.78
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	97290	PR295572	4/28/2015	4/28/2016
				Calibration	**OK**

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used	
8/13/2015	11740	330118	PASS	PASS		
8/14/2015	10297	326455	PASS	PASS		
8/17/2015	11645	325734	PASS	PASS		
8/18/2015	10366	377723	PASS	PASS		
8/19/2015	9662	341100	PASS	PASS		
8/20/2015	10315	347147	PASS	PASS		
8/21/2015	10519	345831	PASS	PASS		
8/24/2015	12432	355001	PASS	PASS		
8/25/2015	10693	389638	PASS	PASS		
8/26/2015	11565	364379	PASS	PASS		
8/27/2015					X	*Instrument sent to San Diego 8/27/2015
10/2/2015	10741	329832	PASS	PASS		*10/1/2015 returned
10/5/2015	10044	330298	PASS	PASS		
10/6/2015	11516	327247	PASS	PASS		
10/7/2015	10392	331312	PASS	PASS		
10/8/2015	10252	332149	PASS	PASS		
10/9/2015	10629	332021	PASS	PASS		
10/12/2015	13467	330730	PASS	PASS		
10/13/2015	11484	333598	PASS	PASS		
10/14/2015	10264	331342	PASS	PASS		
10/15/2015	9256	336099	PASS	PASS		
10/16/2015	11444	326753	PASS	PASS		
10/19/2015	10552	331309	PASS	PASS		
10/20/2015	10234	332447	PASS	PASS		
10/21/2015	12016	335188	PASS	PASS		
10/22/2015	10364	335643	PASS	PASS		
10/23/2015	11316	335924	PASS	PASS		
10/26/2015	10739	332989	PASS	PASS		
10/27/2015	10444	333965	PASS	PASS		
10/28/2015	10904	332762	PASS	PASS		
10/29/2015	11076	334411	PASS	PASS		
10/30/2015	10314	334448	PASS	PASS		
11/2/2015	12824	334837	PASS	PASS		
11/3/2015	10463	333344	PASS	PASS		
11/4/2015	10732	335220	PASS	PASS		
11/5/2015	11547	334369	PASS	PASS		

CB&I Federal Services

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.78
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	97290	PR295572	4/28/2015	4/28/2016
				Calibration	**OK**

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
11/6/2015	11726	334090	PASS	PASS	
11/9/2015	10758	334290	PASS	PASS	
11/10/2015	10345	336287	PASS	PASS	
11/11/2015	11758	333097	PASS	PASS	
11/12/2015	10661	336665	PASS	PASS	
11/13/2015	10320	334535	PASS	PASS	
11/16/2015	10528	333702	PASS	PASS	
11/17/2015	10508	332150	PASS	PASS	
11/18/2015	10842	335043	PASS	PASS	
11/19/2015	10670	329436	PASS	PASS	
11/20/2015	10207	338165	PASS	PASS	
11/23/2015	11483	344995	PASS	PASS	
11/24/2015	9662	334944	PASS	PASS	
11/25/2015	10307	334561	PASS	PASS	
11/30/2015	11592	331237	PASS	PASS	
12/1/2015	11162	332526	PASS	PASS	
12/2/2015	11057	332602	PASS	PASS	
12/3/2015	11526	332381	PASS	PASS	
12/4/2015	10057	332520	PASS	PASS	
12/7/2015	9602	332220	PASS	PASS	
12/8/2015	10789	333383	PASS	PASS	
12/9/2015	10447	330348	PASS	PASS	
12/10/2015	9703	332541	PASS	PASS	
12/11/2015					X
12/14/2015					X
12/15/2015	10303	334042	PASS	PASS	
12/16/2015	10842	333587	PASS	PASS	
12/17/2015	10115	330373	PASS	PASS	
12/18/2015	11130	332781	PASS	PASS	
12/21/2015	11352	332701	PASS	PASS	
12/22/2015					X
1/4/2016	10972	332384	PASS	PASS	
1/5/2016	13515	336483	PASS	PASS	
1/6/2016	10870	336483	PASS	PASS	
1/7/2016	9928	331189	PASS	PASS	
1/8/2016	10253	331098	PASS	PASS	

CB&I Federal Services

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.78
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	97290	PR295572	4/28/2015	4/28/2016
				Calibration	**OK**

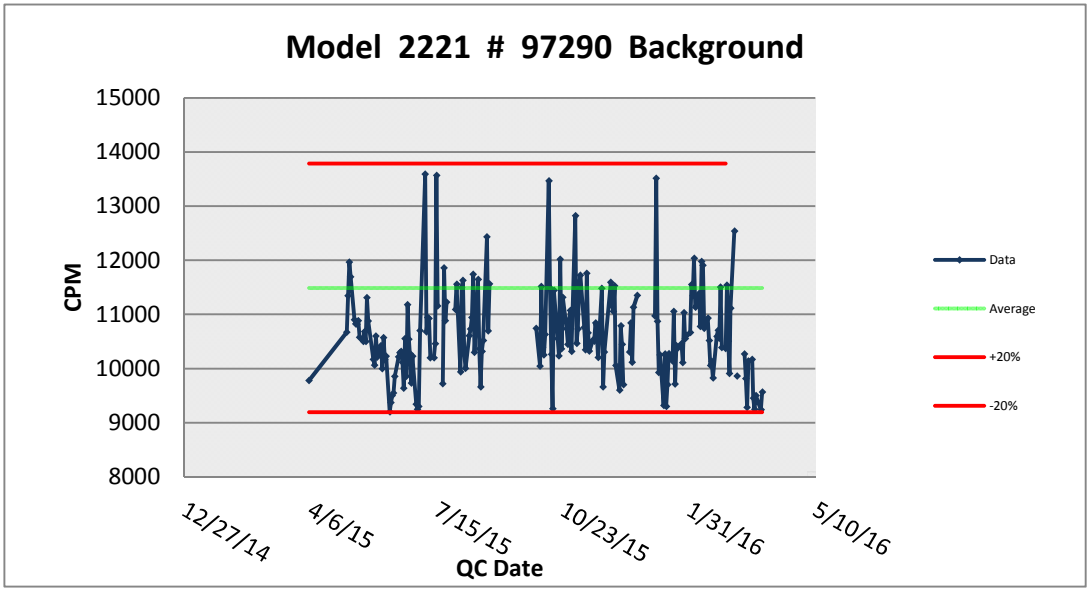
Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
1/11/2016	9318	330406	PASS	PASS	
1/12/2016	10267	331412	PASS	PASS	
1/13/2016	9298	335504	PASS	PASS	
1/14/2016	9700	326216	PASS	PASS	
1/15/2016	10276	331423	PASS	PASS	
1/18/2016	10141	332655	PASS	PASS	
1/19/2016	11055	330901	PASS	PASS	
1/20/2016	9716	332520	PASS	PASS	
1/21/2016	10423	333444	PASS	PASS	
1/22/2016	10376	333880	PASS	PASS	
1/25/2016	10461	329503	PASS	PASS	
1/26/2016	10109	330263	PASS	PASS	
1/27/2016	11029	333361	PASS	PASS	
1/28/2016	10551	326860	PASS	PASS	
1/29/2016	10610	327616	PASS	PASS	
2/1/2016	10666	325906	PASS	PASS	
2/2/2016	11550	327497	PASS	PASS	
2/3/2016	11344	329097	PASS	PASS	
2/4/2016	12037	328018	PASS	PASS	
2/5/2016	11132	327261	PASS	PASS	
2/8/2016	11387	329003	PASS	PASS	
2/9/2016	10775	331882	PASS	PASS	
2/10/2016	11980	328709	PASS	PASS	
2/11/2016	11909	330109	PASS	PASS	
2/12/2016	10743	328697	PASS	PASS	
2/15/2016	10931	329169	PASS	PASS	
2/16/2016	10516	326985	PASS	PASS	
2/17/2016	10055	330158	PASS	PASS	
2/18/2016	10133	326469	PASS	PASS	
2/19/2016	9827	328508	PASS	PASS	
2/22/2016	10597	326842	PASS	PASS	
2/23/2016	10709	327170	PASS	PASS	
2/24/2016	10561	324404	PASS	PASS	
2/25/2016	11504	323944	PASS	PASS	
2/26/2016	10385	325508	PASS	PASS	
2/29/2016	10371	322963	PASS	PASS	

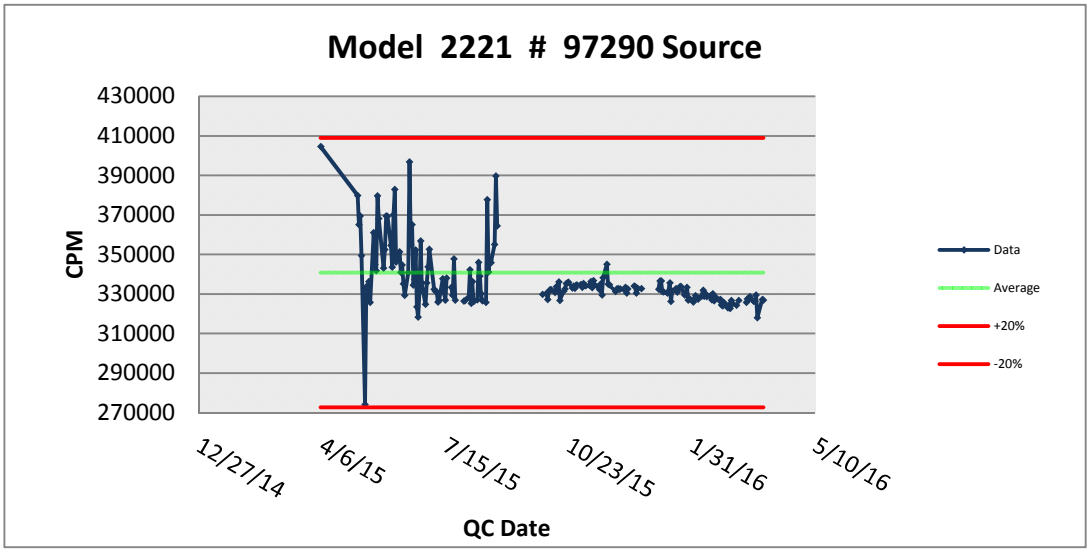
CB&I Federal Services

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.78
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	97290	PR295572	4/28/2015	4/28/2016
				Calibration	**OK**

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
3/1/2016	11542	324392	**PASS**	**PASS**	
3/2/2016	10508	322684	**PASS**	**PASS**	
3/3/2016	9910	326614	**PASS**	**PASS**	
3/4/2016	11116	325137	**PASS**	**PASS**	
3/7/2016	12536	324323	**PASS**	**PASS**	
3/8/2016					X
3/9/2016	9863	326762	**PASS**	**PASS**	
3/10/2016					X
3/11/2016					X
3/14/2016					X
3/15/2016	10272	325794	**PASS**	**PASS**	
3/16/2016	9815	327565	**PASS**	**PASS**	
3/17/2016	9282	327150	**PASS**	**PASS**	
3/18/2016	10137	328593	**PASS**	**PASS**	
3/21/2016	10171	326130	**PASS**	**PASS**	
3/22/2016	9452	326359	**PASS**	**PASS**	
3/23/2016	9245	329513	**PASS**	**PASS**	
3/24/2016	9503	318018	**PASS**	**PASS**	
3/28/2016	9239	327250	**PASS**	**PASS**	
3/29/2016	9568	326852	**PASS**	**PASS**	

Control Graphs





Background Determination

Instrument Model	Instrument Serial #	Probe Model	Probe Serial #	Calibration Due Date
2221	97290	44-20	PR295572	4/28/2016

Surface Type :	Push cart table assembly (Bldg 570 Lab)
Date Collected :	4/28/2015
Collected By :	J. Massey
Count Time	1

#	Counts	cpm
1	11164	11164
2	11835	11835
3	11518	11518
4	11215	11215
5	11292	11292
6	11194	11194
7	11660	11660
8	11679	11679
9	11906	11906
10	11414	11414
Mean	11487.7	
Std dev	273.2378085	
20%	2297.54	

Bkgd -3σ Value
10667.99
Bkgd - 20%
9191

Bkgd +3σ Value
12307.41
Bkgd + 20%
13785

Completed By :	**John Massey**	**Date :**	**4/28/2015**

Reviewed By :	**Takeshi Ibuki**	**Date :**	**4/28/2015**

Source Determination

Instrument Model	Instrument Serial #	Probe Model	Probe Serial #	Calibration Due Date
2221	97290	44-20	PR295572	4/28/2016

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.78

Surface Type :	Push cart table assembly (Bldg 570 Lab)
Date Collected :	4/28/2015
Collected By :	J. Massey
Count Time	1

#	Counts	cpm
1	338917	338917
2	342870	342870
3	343081	343081
4	341648	341648
5	338516	338516
6	341067	341067
7	337245	337245
8	340833	340833
9	342799	342799
10	341585	341585
Mean	340856.1	
Std dev	2007.222152	
20%	68171.22	

Source -3σ Value
334834
Bkgd - 20%
272685

Source +3σ Value
346878
Bkgd + 20%
409027

Completed By :	**John Massey**	**Date :**	**4/28/2015**

Reviewed By :	**Takeshi Ibuki**	**Date :**	**4/28/2015**

Designer and Manufacturer of Scientific and Industrial Instruments

66998

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.
501 Oak Street, 325-235-5494, Sweetwater, TX 79556, U.S.A.
☐ 10744 Dutchtown Road, 865-392-4601, Knoxville, TN 37932, U.S.A.

CUSTOMER CB&I ORDER NO. 20260980/416519

Mfg. Ludlum Measurements, Inc. Model 2221 Serial No. 262337

Mfg. Ludlum Measurements, Inc. Model 44-20 Serial No. PR337255

Cal. Date 27-Jan-15 Cal Due Date 27-Jan-16 Cal. Interval 1 Year Meterface 202-159

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 74 °F RH 20 % Alt 703.8 mm Hg

☐ New Instrument Instrument Received ☑ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Meter Zeroed ☐ Background Subtract ☑ Input Sens. Linearity
☑ F/S Resp. ck ☑ Reset ck. ☑ Window Operation ☑ Geotropism
☑ Audio ck. ☑ Alarm Setting ck. ☑ Batt. ck. (Min. Volt) 4.4 VDC

☑ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89. ☐ Calibrated in accordance with LMI SOP 14.9 rev 02/07/97.

Instrument Volt Set Comments V Input Sens. Comments mV Det. Oper. Comments V at Comments mV Threshold Dial Ratio 100 = 10 mV

☑ HV Readout (2 points) Ref./Inst. 500 / 500 V Ref./Inst. 2000 / 1996 V

COMMENTS:

	Peak settings	Gross Counts	Model 2221 currently set
High Voltage:	593 V	900 V	for gross counts.
Threshold dial:	642	100(10mv)	High voltage set with detector
Window dial:	40	n/a	connected.
Window Position:	"IN"	"OUT"	OL checked but not set.
Resolution for Cs137:	≈11.01%	n/a	Firmware: 261028

Cs137≈3mCi(S/N:2171CP) count at 100µR/hr is:219,395cpm Distance is 361.6 cm
Count taken with crystal end facing source. Calibrated with 5' cable.

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
x1K	400kcpm	400	400
x1K	100kcpm	100	100
x100	40kcpm	400	400
x100	10kcpm	100	100
x10	4kcpm	400	400
x10	1kcpm	100	100
x1	400cpm	400	400
x1	100cpm	100	100

*Uncertainty within ± 10% C.F. within ± 20% ALL Range(s) Calibrated Electronically

	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*		REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout	400kcpm	40019 101	40019 101	Log Scale	500kcpm	500K cpm	500K cpm
	40kcpm	4002	4002		50kcpm	50	50
	4kcpm	400	400		5kcpm	5	5
	400cpm	40	40		500cpm	500	500
	40cpm	4	4		50cpm	50	50

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978 State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources: Cs-137 S/N: ☐ 059 ☐ 2171CP ☐ 2261CP ☐ 720 ☐ 734 ☐ 781 ☐ 1131 ☐ 1616 ☐ 1696 ☐ 1909 ☐ 1916CP ☐ 5105 ☐ 5717CO ☐ 5719CO ☐ 60646 ☐ 70897 ☐ 73410 ☐ E552 ☐ G112 ☐ M565 ☐ S-394 ☐ S-1054 ☐ T10081 ☐ T10082 Neutron Am-241 Be S/N: ☐ T-304 Ra-226 S/N: ☐ Y982

☐ Alpha S/N ☐ Beta S/N ☐ Other

☑ m 500 S/N 289158 ☐ Oscilloscope S/N ☑ Multimeter S/N 93870637

Calibrated By: Jeremy Thompson Date 27-Jan-15

Reviewed By: Thad [illegible] Date 28 Jan 15

This certificate shall not be reproduced except in full, without the written approval of Ludlum Measurements, Inc.

FORM C22A 05/19/2014 Page 1 of 3

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed:

Designer and Manufacturer
of
Scientific and Industrial
Instruments

LUDLUM MEASUREMENTS, INC.
501 Oak Street
325-235-5494
Sweetwater, TX 79556, U.S.A.

☐ 10744 Dutchtown Road
865-392-4601
Knoxville, TN 37932, U.S.A.

Bench Test Data For Detector

Detector 44-20 Serial No. PR337255

Customer CB&I Order #. 20260980/416519

Counter 2221 Serial No. 262337 Counter Input Sensitivity 10 mV

Count Time 6 Seconds Distance Source to Detector Surface

Other

High Voltage	Background	Isotope Am241 Size 20 mpki	Isotope Size	Isotope Size	Isotope Size
800	1290	18367			
850	1304	18644			
*900	1234	18729			
950	1337	18756			
1000	1543	18720			
1050	1692	19903			
1100	1977	19243			
1150	3274	20624			

Signature Jeremy Thompson Date 27-Jan-15

• *Serving The Nuclear Industry Since 1962* •

Designer and Manufacturer
of
Scientific and Industrial
Instruments

LUDLUM MEASUREMENTS, INC.
501 Oak Street
325-235-5494
Sweetwater, TX 79556, U.S.A.

☐ 10744 Dutchtown Road
865-392-4601
Knoxville, TN 37932, U.S.A.

CONVERSION CHART

Customer CB&I Date 27-Jan-15 Order #. 20260980/416519

Model 2221 Serial No. 262357 Detector Model 44-20 Serial No. PR337255

Source Ra226: 149.9 pCi High Voltage 900 V

Input Sensitivity 10 mV

Reference Point		"As Found" Readings (CPM): Analog	Range/Scale	After Adjustment Readings (CPM): Analog	Range/Scale
200 μR/hr	97.4 cm	4440	X1K	4440	X1K
150	113.5	330		330	
100	141.6	220		220	

Reference Point		"As Found" Readings: Digital	Count Time	After Adjustment Readings: Digital	Count Time
200 μR/hr	97.4 cm	44546	6 Seconds	44546	6 Seconds
150	113.5	33267		33267	
100	141.6	22114		22114	

Signature: Jeremy Thompson Date 27-Jan-15

• *Serving The Nuclear Industry Since 1962* •

ORDER#: 20260980

PACKING LIST FROM:
LUDLUM MEASUREMENTS, INC.
501 OAK ST PO BOX 810
SWEETWATER TEXAS USA 79556
TEL: 325-235-5494

SHIP VIA:
UPS WAYBILL
SHIP DATE:
1/28/2015
LMI CUST. #:
11362

20260980

CUST PO #: MC HINDALL

SHIP TO:
CB&I
BAY DOOR #5
16406 US ROUTE 224 EAST
FINDLAY, OH 45840
USA

3/3

Ordered By: MIKE HINGALL PHONE NUMBER: (419) 424-4960

BOX# / # OF BOXES:

BOX LN	ORD QTY	SHIP QTY	PART NO.	DESCRIPTION	ADDITIONAL INFO
15	1.00 EA	1.00 EA	2221	M 2221 FOR REPAIR/CAL	SN262337
16	1.00 EA	1.00 EA	44-20	M 44-20 FOR REPAIR/CAL	PR337255
17	1.00 EA	1.00 EA	12/12/3		SN092413E
18	1.00 EA	1.00 EA	LNG CABLE		✓
19	1.00 EA	1.00 EA	M	MANUAL	✓
20	1.00 EA	1.00 EA	MPEL	PELICAN CASE MEDIUM	✓
21	1.00 EA	1.00 EA	UPS WAY BILL		✓
24	12.00 EA	4.00 EA	21-9313	BATTERY-DURACELL "D	✓
25	3.00 EA	1.00 EA	223	EXTENDED CALIBRATION	✓

COMMENTS:
UPS
FAIR/ BAD DENTS 44-20
1 YR/ SPEC INST.

(D) Product is export controlled for AT reasons under ECCN 1A 999. As such, these commodities, technology or software are eligible for export from the United States only in accordance with Export Administration regulations. Diversion contrary to U.S. law is prohibited.

CB&I Federal Services

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.816
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	262337	PR337255	1/27/2015	1/27/2016
				Calibration	**OK**

*Any dates not represented indicates instrument not used.

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
4/15/2015	9846	328284	PASS	PASS	
4/16/2015					X
4/17/2015					X
4/20/2015					X
4/21/2015					X
4/22/2015					X
4/23/2015	10012	328849	PASS	PASS	
4/24/2015	9747	326905	PASS	PASS	
4/27/2015					X
4/28/2015	9224	326548	PASS	PASS	
					X
5/13/2015	10272	329578	PASS	PASS	
5/14/2015	10440	330399	PASS	PASS	
5/15/2015	10196	325419	PASS	PASS	
5/18/2015	10387	327482	PASS	PASS	
5/19/2015	10115	328467	PASS	PASS	
5/20/2015	10450	328337	PASS	PASS	
5/21/2015	11100	326991	PASS	PASS	
5/22/2015	10544	327246	PASS	PASS	
5/26/2015	10738	326396	PASS	PASS	
5/27/2015	10489	325892	PASS	PASS	
5/28/2015	10092	326747	PASS	PASS	
5/29/2015	9899	330377	PASS	PASS	
6/1/2015	10888	331185	PASS	PASS	
6/2/2015	10672	328637	PASS	PASS	
6/3/2015	9445	330818	PASS	PASS	
6/4/2015	10350	328888	PASS	PASS	
6/11/2015	9408	326359	PASS	PASS	
6/12/2015	9174	327912	PASS	PASS	
6/15/2015	10539	327744	PASS	PASS	
6/17/2015	9638	328422	PASS	PASS	
6/18/2015	10296	332488	PASS	PASS	
6/19/2015	10455	328031	PASS	PASS	
6/20/2015	9781	332914	PASS	PASS	
6/21/2015	10095	324860	PASS	PASS	

CB&I Federal Services

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.82
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	262337	PR337255	1/27/2015	1/27/2016
				Calibration	**OK**

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
6/22/2015	10182	326481	PASS	PASS	
6/23/2015	10380	330686	PASS	PASS	
6/24/2015	10295	329511	PASS	PASS	
6/25/2015	9963	328644	PASS	PASS	
6/26/2015	9982	327399	PASS	PASS	
6/29/2015	9298	324167	PASS	PASS	
6/30/2015	9215	324705	PASS	PASS	
7/1/2015	9557	322677	PASS	PASS	
7/2/2015	8872	331484	PASS	PASS	
7/6/2015	10822	326624	PASS	PASS	
7/7/2015	10147	326791	PASS	PASS	
7/8/2015	10098	328221	PASS	PASS	
7/9/2015	10401	326589	PASS	PASS	
7/10/2015	10471	325867	PASS	PASS	
7/13/2015	9760	325532	PASS	PASS	
7/14/2015	9590	331994	PASS	PASS	
7/15/2015	10294	327701	PASS	PASS	
7/16/2015	12709	328150	PASS	PASS	
7/17/2015	10282	326299	PASS	PASS	
7/20/2015	9941	327540	PASS	PASS	
7/21/2015	11043	326116	PASS	PASS	
7/22/2015	9933	328996	PASS	PASS	
7/23/2015	10798	325422	PASS	PASS	
7/24/2015	9996	326480	PASS	PASS	
7/27/2015	11241	327289	PASS	PASS	
7/28/2015	10971	324321	PASS	PASS	
7/29/2015	10815	313642	PASS	PASS	
7/30/2015	9851	331860	PASS	PASS	
7/31/2015	10483	326612	PASS	PASS	
8/3/2015	10642	330453	PASS	PASS	
8/4/2015	9426	317594	PASS	PASS	
8/5/2015	10865	325174	PASS	PASS	
8/6/2015	10988	309135	PASS	PASS	
8/7/2015	9988	322269	PASS	PASS	
8/10/2015	9353	324630	PASS	PASS	
8/11/2015	9341	327336	PASS	PASS	

CB&I Federal Services

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.82
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	262337	PR337255	1/27/2015	1/27/2016
				Calibration	**OK**

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
8/12/2015	10576	327787	PASS	PASS	
8/13/2015	10598	328643	PASS	PASS	
8/14/2015	11897	327011	PASS	PASS	
8/17/2015	10565	326163	PASS	PASS	
8/18/2015	10062	325981	PASS	PASS	
8/19/2015	10105	326446	PASS	PASS	
8/20/2015	10714	327427	PASS	PASS	
8/21/2015	9921	327513	PASS	PASS	
8/24/2015	12142	327960	PASS	PASS	
8/25/2015	10336	332606	PASS	PASS	
8/26/2015	9881	327264	PASS	PASS	
8/27/2015	9614	328859	PASS	PASS	
8/28/2015	10828	326241	PASS	PASS	
8/31/2015	9882	325728	PASS	PASS	
9/1/2015	9719	324740	PASS	PASS	
9/2/2015	9595	325796	PASS	PASS	
9/3/2015	9606	327702	PASS	PASS	
9/4/2015	10178	327101	PASS	PASS	
9/8/2015	10586	328278	PASS	PASS	
9/9/2015	10380	333597	PASS	PASS	
9/10/2015	10515	332864	PASS	PASS	
9/11/2015	9930	332461	PASS	PASS	
9/14/2015	9882	334165	PASS	PASS	
9/15/2015	9789	333690	PASS	PASS	
9/16/2015	10323	332190	PASS	PASS	
9/17/2015	9442	332161	PASS	PASS	
9/18/2015	9824	331498	PASS	PASS	
9/21/2015	10756	332969	PASS	PASS	
9/22/2015	9434	330930	PASS	PASS	
9/23/2015	10045	330635	PASS	PASS	
9/24/2015	9987	331473	PASS	PASS	
9/25/2015	10060	331040	PASS	PASS	
9/28/2015	9714	328173	PASS	PASS	
9/29/2015	9963	328837	PASS	PASS	
9/30/2015	9621	330650	PASS	PASS	
10/1/2015	11921	330170	PASS	PASS	

CB&I Federal Services

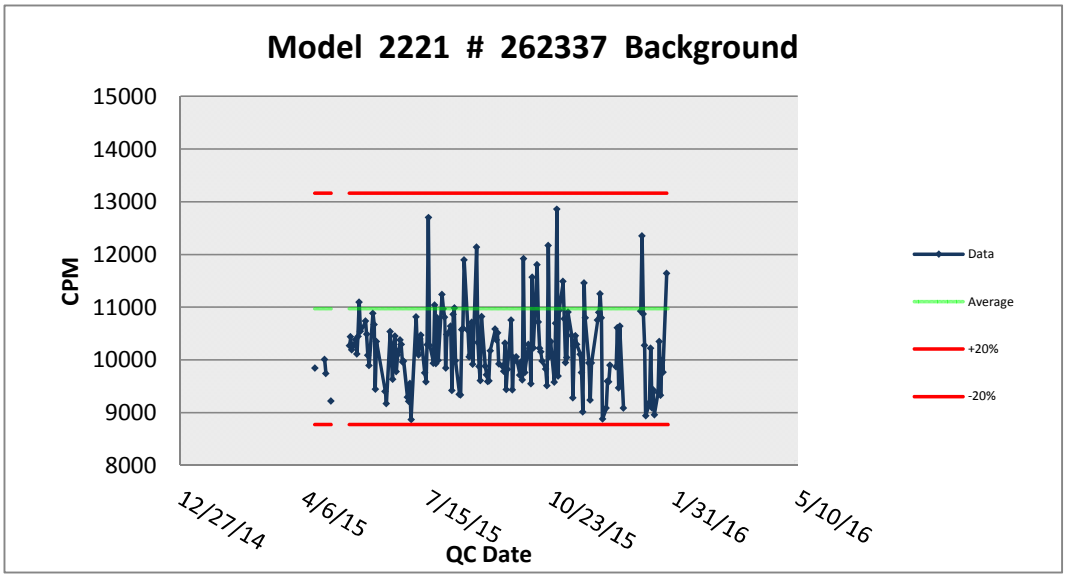
Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.82
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	262337	PR337255	1/27/2015	1/27/2016
				Calibration	**OK**

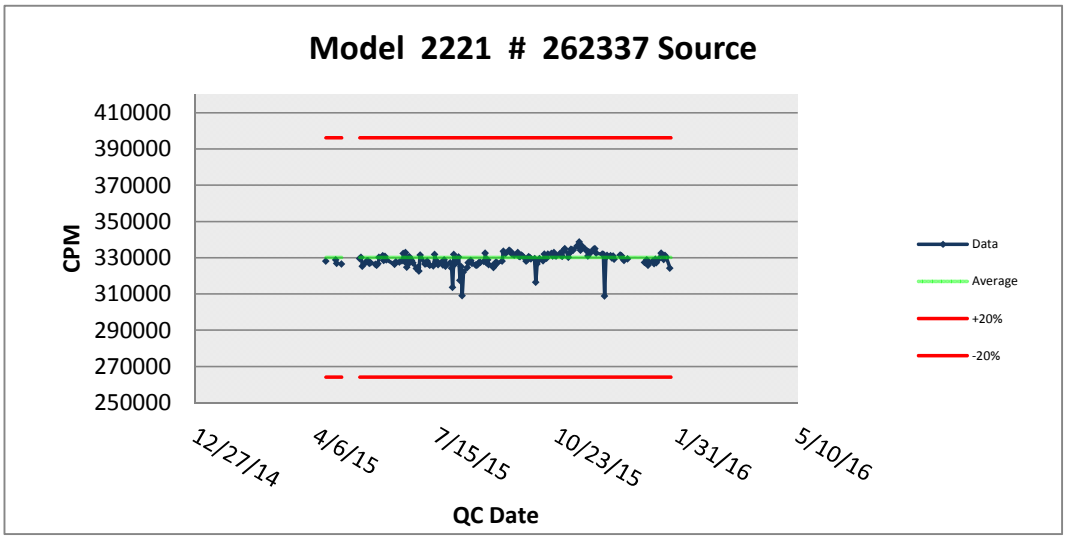
Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
10/2/2015	9764	329423	PASS	PASS	
10/5/2015	10295	329593	PASS	PASS	
10/6/2015	10226	316589	PASS	PASS	
10/7/2015	9549	326671	PASS	PASS	
10/8/2015	11573	328330	PASS	PASS	
10/9/2015	10230	329655	PASS	PASS	
10/12/2015	11807	328438	PASS	PASS	
10/13/2015	10720	332034	PASS	PASS	
10/14/2015	10227	330350	PASS	PASS	
10/15/2015	10156	329706	PASS	PASS	
10/16/2015	9984	332108	PASS	PASS	
10/19/2015	9833	332366	PASS	PASS	
10/20/2015	9513	330979	PASS	PASS	
10/21/2015	12175	333006	PASS	PASS	
10/22/2015	10065	331126	PASS	PASS	
10/23/2015	10353	330956	PASS	PASS	
10/26/2015	9581	332363	PASS	PASS	
10/27/2015	10698	331213	PASS	PASS	
10/28/2015	12861	330847	PASS	PASS	
10/29/2015	9698	334263	PASS	PASS	
10/30/2015	10947	335064	PASS	PASS	
11/2/2015	11490	330350	PASS	PASS	
11/3/2015	10782	332559	PASS	PASS	
11/4/2015	9953	334674	PASS	PASS	
11/5/2015	10048	334480	PASS	PASS	
11/6/2015	10913	334192	PASS	PASS	
11/9/2015	10469	336427	PASS	PASS	
11/10/2015	9287	336533	PASS	PASS	
11/11/2015	10265	338868	PASS	PASS	
11/12/2015	10461	334240	PASS	PASS	
11/13/2015	10296	336743	PASS	PASS	
11/16/2015	10108	334794	PASS	PASS	
11/17/2015	9764	333949	PASS	PASS	
11/18/2015	9020	330944	PASS	PASS	
11/19/2015	11464	333387	PASS	PASS	
11/20/2015	10798	332529	PASS	PASS	

CB&I Federal Services

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.82
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	262337	PR337255	1/27/2015	1/27/2016
				Calibration	**OK**

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
11/23/2015	9944	334748	PASS	PASS	
11/24/2015	9241	335066	PASS	PASS	
11/25/2015	9943	332655	PASS	PASS	
11/30/2015	10757	332003	PASS	PASS	
12/1/2015	10902	331895	PASS	PASS	
12/2/2015	11253	309023	PASS	PASS	
12/3/2015	10800	330195	PASS	PASS	
12/4/2015	8886	331394	PASS	PASS	
12/7/2015	9088	331180	PASS	PASS	
12/8/2015	9598	329983	PASS	PASS	
12/9/2015	9587	330942	PASS	PASS	
12/10/2015	9903	329296	PASS	PASS	
12/11/2015					X
12/14/2015					X
12/15/2015	9872	331561	PASS	PASS	
12/16/2015	10612	331165	PASS	PASS	
12/17/2015	9470	329541	PASS	PASS	
12/18/2015	10646	328578	PASS	PASS	
12/21/2015	9092	329398	PASS	PASS	
12/22/2015					X
1/4/2016	10931	327426	PASS	PASS	
1/5/2016	12356	327376	PASS	PASS	
1/6/2016	10874	328912	PASS	PASS	
1/7/2016	10282	325923	PASS	PASS	
1/8/2016	8943	327434	PASS	PASS	
1/11/2016	9192	328167	PASS	PASS	
1/12/2016	10224	326788	PASS	PASS	
1/13/2016	9097	329192	PASS	PASS	
1/14/2016	9437	327327	PASS	PASS	
1/15/2016	8961	328698	PASS	PASS	
1/18/2016	9386	332655	PASS	PASS	
1/19/2016	10351	331716	PASS	PASS	
1/20/2016	9334	329031	PASS	PASS	
1/21/2016	9994	331463	PASS	PASS	
1/22/2016	9767	330289	PASS	PASS	
1/25/2016	11642	324244	PASS	PASS	


Model 2221 # 262337 Background
15000
14000
13000
12000
11000
10000
9000
8000
CPM
12/27/14
4/6/15
7/15/15
10/23/15
1/31/16
5/10/16
QC Date
Data
Average
+20%
-20%


Model 2221 # 262337 Source
410000
390000
370000
350000
330000
310000
290000
270000
250000
CPM
12/27/14
4/6/15
7/15/15
10/23/15
1/31/16
5/10/16
QC Date
Data
Average
+20%
-20%

Background Determination

Instrument Model	Instrument Serial #	Probe Model	Probe Serial #	Calibration Due Date
2221	262337	44-20	PR337255	1/27/2016

Surface Type :	Push cart table assembly (Bldg 570 Lab)
Date Collected :	2/19/2015
Collected By :	D. Morrison
Count Time	1

#	Counts	cpm
1	10653	10653
2	10714	10714
3	10790	10790
4	11195	11195
5	11176	11176
6	10929	10929
7	11164	11164
8	11087	11087
9	11179	11179
10	10809	10809
Mean	10969.6	
Std dev	214.5000389	
20%	2193.92	

Bkgd -3σ Value	Bkgd +3σ Value
10326.10	11613.10
Bkgd - 20%	**Bkgd + 20%**
8776	13163

Completed By :	**Dennis Morrison**	**Date :**	**2/19/2015**

Reviewed By :	**Takeshi Ibuki**	**Date :**	**2/19/2015**

Source Determination

Instrument Model	Instrument Serial #	Probe Model	Probe Serial #	Calibration Due Date
2221	262337	44-20	PR337255	1/27/2016

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.82

Surface Type :	Push cart table assembly (Bldg 570 Lab)
Date Collected :	2/19/2015
Collected By :	D. Morrison
Count Time	1

#	Counts	cpm
1	329976	329976
2	329889	329889
3	330319	330319
4	330913	330913
5	329374	329374
6	331411	331411
7	329705	329705
8	330886	330886
9	330005	330005
10	328986	328986
Mean	330146.4	
Std dev	746.61729	
20%	66029.28	

Source -3σ Value
327907
Bkgd - 20%
264118

Source +3σ Value
332386
Bkgd + 20%
396175

Completed By :	**Dennis Morrison**	**Date :**	**2/19/2015**

Reviewed By :	**Takeshi Ibuki**	**Date :**	**2/19/2015**

Certificate of Calibration

Calibration and Voltage Plateau

Environmental Restoration Group, Inc.
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

Meter:	Manufacturer:	Ludlum	Model Number:	2221r	Serial Number:	282966
Detector:	Manufacturer:	Ludlum	Model Number:	44-20	Serial Number:	PR262403

- [x] Mechanical Check
- [x] F/S Response Check
- [x] Geotropism
- [x] Meter Zeroed
- [x] THR/WIN Operation
- [x] Reset Check
- [x] Audio Check
- [x] Battery Check (Min 4.4 VDC)

HV Check (+/- 2.5%): [x] 500 V [x] 1000 V [ ] 1500 V

Cable Length: [x] 39-inch [ ] 72-inch [ ] Other:

Source Distance: [ ] Contact [x] 6 inches [ ] Other:

Source Geometry [x] Side [ ] Below [ ] Other:

Threshold: 10 mV

Window:

Barometric Pressure: 24.66 inches Hg

Temperature: 72 °F

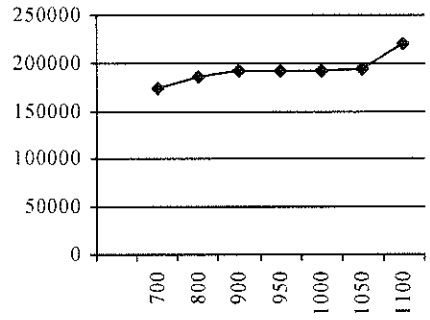
Relative Humidity: 20 %

Instrument found within tolerance: [x] Yes [ ] No

Range/Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400	400	400	396761	400
x 1000	100	100	100		100
x 100	400	400	400	39681	400
x 100	100	100	100		100
x 10	400	400	400	3968	400
x 10	100	100	100		100
x 1	400	400	400	397	400
x 1	100	100	100		100

High Voltage	Source Counts	Background
700	173228	
800	186214	
900	190584	
950	190704	26124
1000	191222	
1050	194055	
1100	219393	

Voltage Plateau



Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 950

Reference Instruments and/or Sources:

Ludlum pulser serial number: [ ] 97743 [x] 201932

Fluke multimeter serial number: [ ] 8749012

[ ] Alpha Source: Th-230 @ 12,800 dpm (1/4/12) sn: 4098-03

[x] Gamma Source Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03

[ ] Beta Source: Tc-99 @ 17,700 dpm (1/4/12) sn: 4099-03

[ ] Other Source:

Calibrated By: [signature]

Calibration Date: 9-29-15

Calibration Due 9-29-16

Reviewed By: [signature]

Date: 9/29/15

ERG Form ITC. 101.A

This calibration conforms to the requirements and acceptable calibration conditions of ANSI N323A - 1997

Environmental Restoration Group, Inc.
8809 Washington NE, Ste. 150
Albuquerque, NM 87113

ph: 505.298.4224
fax: 505.797-1404
web: www.ERGOffice.com

EQUIPMENT PACKING SLIP

Company Name: CB & I - CA
Contact Name: Oscar Gonzales
Contact Telephone: 415-398-6547

Order Number: 3005
P.O. or Reference Number: 500060

Date Ordered: 09/29/2015
Date Shipped: 09/29/2015
Date of Delivery: 09/30/2015

Shipping Method:
Shipping Number: ERG FedEx Number

Ship To Information:

CB & I - CA

Billing Address:

CB & I - CA
Accounts Payable
650 Ave M
San Francisco, CA 94130

Equipment Enclosed:

Instrument Tested	*Instrument*	*Serial Number*
☐	Ludlum 2221r	282966
☐	Ludlum 44-20	PR262403

Special Instructions:

None

Chi, Minhsec

From: Scott Heronimus <ScottHeronimus@ERGOFFICE.COM>
Sent: Wednesday, September 30, 2015 11:51 AM
To: Chi, Minhsec
Subject: RE: ERG 2221 rental received 09302015

We were aware of the "dents" and they had no effect on the instruments when calibrated they were calibrated yesterday.

Scott Heronimus

Environmental Restoration Group, Inc.
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
phone: (505) 298-4224
fax: (505) 797-1404

check us out at: http://www.ERGoffice.com

**** NOTICE : This communication may contain confidential and/or privileged information for use only by the individual to which it is addressed. If you have received this communication in error, please immediately notify the sender and delete this e-mail and any attachments. Thank you.****

From: Chi, Minhsec [mailto:Minhsec.Chi@Cbifederalservices.com]
Sent: Wednesday, September 30, 2015 12:44 PM
To: Scott Heronimus <ScottHeronimus@ERGOFFICE.COM>
Cc: Morrison, Dennis <Dennis.Morrison@Cbifederalservices.com>; Coffey, Lisa M <lisa.coffey@CBIFederalServices.com>
Subject: ERG 2221 rental received 09302015

Scott,

The Ludlum 2221/44-20 S/N: 282966/PR262403 that we received from ERG has some dents on both the meter and probe, photos attached for your reference. Was wondering if you were aware of this since there is no documentation stating the damage. It could be possible the instrument was damaged during shipping. The meter and probe does function properly.

Minhsec Chi
Radiological Control Technician 4
Federal Services
Environmental & Infrastructure
minhsec.chi@cbifederalservices.com

CB&I
950 Avenue M
Treasure Island
San Francisco, CA 94130
United States of America
www.CBI.com

From: Coffey, Lisa M
Sent: Wednesday, September 30, 2015 11:15 AM
To: Morrison, Dennis

Cc: Chi, Minhsec
Subject: ERG 2221 rental received 09302015

Dennis,
Attached are photos of the 2221 rented from ERG. I received the box and took inventory, noticing the side of the 2221 itself as well as the probe had a few dents. Informed Min and handed over to perform his checks and documentation for set up. Just FYI.

Thanks,
Lisa

Lisa Coffey
Scientist III
Radiation Safety
Federal Services
Tel: +1 925.288.2180
Cell: +1 717.250.7723
lisa.coffey@cbifederalservices.com

CB&I
4005 Port Chicago Highway
Suite 200
Concord, CA 94520
United States of America
www.CBI.com

This e-mail and any attached files may contain CB&I Federal Services LLC (or its affiliates) confidential and privileged information. This information is protected by law and/or agreements between CB&I Federal Services LLC (or its affiliates) and either you, your employer or any contract provider with which you or your employer are associated. If you are not an intended recipient, please contact the sender by reply e-mail and delete all copies of this e-mail; further, you are notified that disclosing, copying, distributing or taking any action in reliance on the contents of this information is strictly prohibited.

CB&I Federal Services

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.692
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	282966	PR262403	9/29/2015	9/29/2016
				Calibration	**OK**

*Any dates not represented indicates instrument not used.

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
10/15/2015	9806	331894	PASS	PASS	
10/16/2015	8567	309207	PASS	PASS	
10/19/2015	9356	331775	PASS	PASS	
10/20/2015	10082	331913	PASS	PASS	
10/21/2015	10715	334213	PASS	PASS	
10/22/2015	9990	332151	PASS	PASS	
10/23/2015	9540	331617	PASS	PASS	
10/26/2015	9834	332428	PASS	PASS	
10/27/2015	9886	331826	PASS	PASS	
10/28/2015	10162	331297	PASS	PASS	
10/29/2015	10817	333084	PASS	PASS	
10/30/2015	10452	333324	PASS	PASS	
11/2/2015	10394	333499	PASS	PASS	
11/3/2015	10513	332303	PASS	PASS	
11/4/2015	9882	331198	PASS	PASS	
11/5/2015	10366	333367	PASS	PASS	
11/6/2015	10797	334277	PASS	PASS	
11/9/2015	10211	332271	PASS	PASS	
11/10/2015	10820	335692	PASS	PASS	
11/11/2015	10824	335894	PASS	PASS	
11/12/2015	10126	334429	PASS	PASS	
11/13/2015	10245	335322	PASS	PASS	
11/16/2015	9520	332524	PASS	PASS	
11/17/2015	9771	330804	PASS	PASS	
11/18/2015	10738	331948	PASS	PASS	
11/19/2015	10057	333404	PASS	PASS	
11/20/2015	10631	332278	PASS	PASS	
11/23/2015	10845	333116	PASS	PASS	
11/24/2015	9170	332364	PASS	PASS	
11/25/2015	10445	335320	PASS	PASS	
11/30/2015	9999	331067	PASS	PASS	
12/1/2015	10461	330354	PASS	PASS	
12/2/2015	10500	331010	PASS	PASS	
12/3/2015	10638	330021	PASS	PASS	
12/4/2015	9772	329206	PASS	PASS	

CB&I Federal Services

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.69
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	282966	PR262403	9/29/2015	9/29/2016
				Calibration	**OK**

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
12/7/2015	9622	329217	PASS	PASS	
12/8/2015	9833	330300	PASS	PASS	
12/9/2015	9747	329219	PASS	PASS	
12/10/2015	10337	330882	PASS	PASS	
12/11/2015	8444	330605	PASS	PASS	
12/14/2015					X
12/15/2015	8467	331105	PASS	PASS	
12/16/2015	10492	329771	PASS	PASS	
12/17/2015	9854	331948	PASS	PASS	
12/18/2015	9663	331912	PASS	PASS	
12/21/2015	10352	331967	PASS	PASS	
12/22/2015	8626	328765	PASS	PASS	
1/4/2016	10788	332373	PASS	PASS	
1/5/2016	10756	330115	PASS	PASS	
1/6/2016	10348	331482	PASS	PASS	
1/7/2016	9708	330082	PASS	PASS	
1/8/2016	10911	328104	PASS	PASS	
1/11/2016	9546	330012	PASS	PASS	
1/12/2016	9476	330545	PASS	PASS	
1/13/2016	9075	329383	PASS	PASS	
1/14/2016	9110	331489	PASS	PASS	
1/15/2016	9225	329995	PASS	PASS	
1/18/2016	9628	330394	PASS	PASS	
1/19/2016	10017	332137	PASS	PASS	
1/20/2016	10055	330424	PASS	PASS	
1/21/2016	8848	330848	PASS	PASS	
1/22/2016	10637	332660	PASS	PASS	
1/25/2016	10048	325091	PASS	PASS	
1/26/2016	10070	328085	PASS	PASS	
1/27/2016	10350	329461	PASS	PASS	
1/28/2016	10689	327414	PASS	PASS	
1/29/2016	10295	325623	PASS	PASS	
2/1/2016	9910	324144	PASS	PASS	
2/2/2016	10810	325528	PASS	PASS	
2/3/2016	10636	325841	PASS	PASS	
2/4/2016	9769	326709	PASS	PASS	

CB&I Federal Services

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.69
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	282966	PR262403	9/29/2015	9/29/2016
				Calibration	**OK**

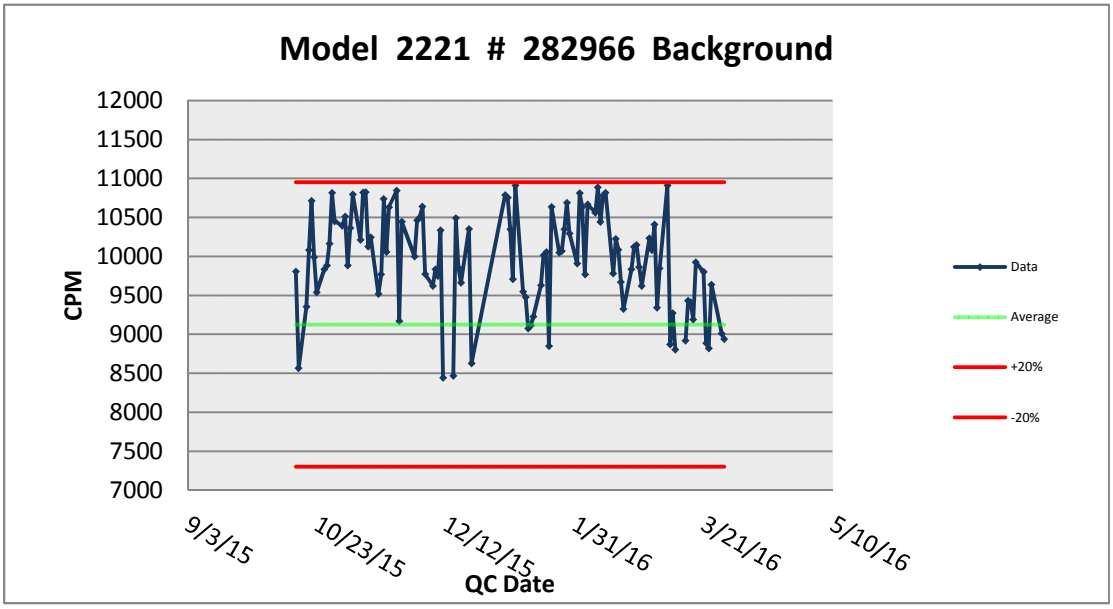
Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
2/5/2016	10667	328299	PASS	PASS	
2/8/2016	10561	327519	PASS	PASS	
2/9/2016	10887	327464	PASS	PASS	
2/10/2016	10444	326889	PASS	PASS	
2/11/2016	10781	328770	PASS	PASS	
2/12/2016	10815	327718	PASS	PASS	
2/15/2016	9780	327058	PASS	PASS	
2/16/2016	10225	326985	PASS	PASS	
2/17/2016	10084	323042	PASS	PASS	
2/18/2016	9672	323475	PASS	PASS	
2/19/2016	9324	323181	PASS	PASS	
2/22/2016	9834	322623	PASS	PASS	
2/23/2016	10122	321222	PASS	PASS	
2/24/2016	10146	324186	PASS	PASS	
2/25/2016	9865	325361	PASS	PASS	
2/26/2016	9623	324458	PASS	PASS	
2/29/2016	10232	320775	PASS	PASS	
3/1/2016	10082	321997	PASS	PASS	
3/2/2016	10411	321624	PASS	PASS	
3/3/2016	9341	324830	PASS	PASS	
3/4/2016	9849	323506	PASS	PASS	
3/7/2016	10909	324770	PASS	PASS	
3/8/2016	8869	326565	PASS	PASS	
3/9/2016	9273	325350	PASS	PASS	
3/10/2016	8805	326033	PASS	PASS	
3/11/2016					X
3/14/2016	8918	322683	PASS	PASS	
3/15/2016	9433	324692	PASS	PASS	
3/16/2016	9412	323010	PASS	PASS	
3/17/2016	9192	322714	PASS	PASS	
3/18/2016	9926	324168	PASS	PASS	
3/21/2016	9800	323036	PASS	PASS	
3/22/2016	8888	323587	PASS	PASS	
3/23/2016	8819	323737	PASS	PASS	
3/24/2016	9639	323315	PASS	PASS	
3/28/2016	9010	324218	PASS	PASS	

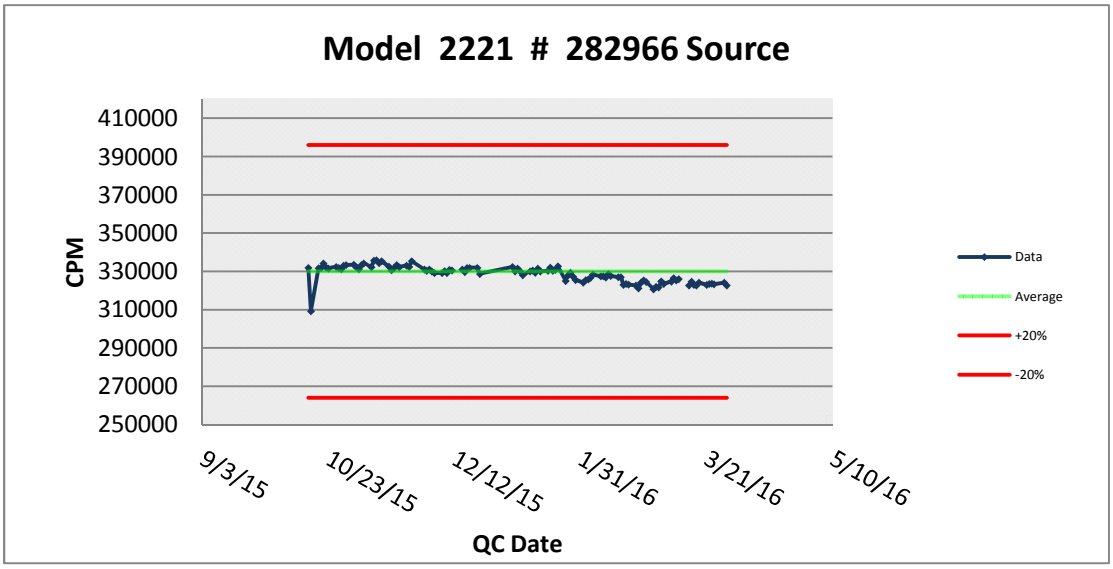
CB&I Federal Services

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life (yrs)	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.69
Instrument Model	**Probe Model**	**Instrument Serial #**	**Probe Serial #**	**Calibration Date**	**Calibration Due Date**
2221	44-20	282966	PR262403	9/29/2015	9/29/2016
				Calibration	**OK**

Date	Background (CPM)	Source (CPM)	Pass or Fail Background	Pass or Fail Source	Instrument not used
3/29/2016	8938	322704	PASS	PASS	

Control Graphs





Background Determination

Instrument Model	Instrument Serial #	Probe Model	Probe Serial #	Calibration Due Date
2221	282966	44-20	PR262403	9/29/2016

Surface Type :	Push cart table assembly (Bldg 570 Lab)
Date Collected :	10/2/2015
Collected By :	M.Chi
Count Time	1

#	Counts	cpm
1	9242	9242
2	9165	9165
3	9174	9174
4	9044	9044
5	9335	9335
6	8987	8987
7	9048	9048
8	9077	9077
9	9259	9259
10	8929	8929
Mean	9126	
Std dev	129.952983	
20%	1825.2	

Bkgd -3σ Value
8736.14
Bkgd - 20%
7301

Bkgd +3σ Value
9515.86
Bkgd + 20%
10951

Completed By :	**M.Chi**	**Date :**	**10/2/2015**
Reviewed By :	**Takeshi Ibuki**	**Date :**	**10/2/2015**

Source Determination

Instrument Model	Instrument Serial #	Probe Model	Probe Serial #	Calibration Due Date
2221	282966	44-20	PR262403	9/29/2016

Source ID #	Source Nuclide	Initial Source Activity (µCi)	Creation Date	Half Life	Decayed Source Activity (µCi)
1405-22-1	Cs-137	9.958	11/1/2009	30.17	8.69

Surface Type :	Push cart table assembly (Bldg 570 Lab)
Date Collected :	10/2/2015
Collected By :	M.Chi
Count Time	1

#	Counts	cpm
1	329279	329279
2	329149	329149
3	331367	331367
4	332016	332016
5	332621	332621
6	328831	328831
7	329765	329765
8	329784	329784
9	328709	328709
10	328212	328212
Mean	329973.3	
Std dev	1504.495711	
20%	65994.66	

Source -3σ Value
325460
Bkgd - 20%
263979

Source +3σ Value
334487
Bkgd + 20%
395967

Completed By :	**M.Chi**	**Date :**	**10/2/2015**

Reviewed By :	**Takeshi Ibuki**	**Date :**	**10/2/2015**

67931

Designer and Manufacturer of Scientific and Industrial Instruments

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.
501 Oak Street, 325-235-5494, Sweetwater, TX 79556, U.S.A.
☐ 10744 Dutchtown Road, 865-392-4601, Knoxville, TN 37932, U.S.A.

CUSTOMER CB&I ORDER NO. 20275894/426388

Ludlum Measurements, Inc. Model 2360 Serial No. 268506

Mfg. Ludlum Measurements, Inc. Model 43-93 Serial No. PR 286559

Cal. Date 28-Sep-15 Cal Due Date 28-Sep-16 Cal. Interval 1 Year Meterface 202-855

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 73 °F RH 32 % Alt 698.0 mm Hg

☐ New Instrument Instrument Received ☑ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Meter Zeroed ☐ Background Subtract ☐ Input Sens. Linearity
☐ F/S Resp. ck ☑ Reset ck. ☑ Window Operation ☑ Geotropism
☑ Audio ck. ☑ Alarm Setting ck. ☑ Batt. ck. (Min. Volt) 2.2 VDC ☑ RS-232 Port OK

☑ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89. ☐ Calibrated in accordance with LMI SOP 14.9 rev 05/15/2015.

Instrument Volt Set 700 V

☑ HV Readout (2 points) Ref./Inst. 500 / 501 V Ref./Inst. 2000 / 2001 V

Firmware Version: 39010v24
Alpha Threshold: 120mv
Beta Threshold: 3.5mv
Beta Window: 30mv
Overload set to simulate light leak
Instrument calibrated with a 39" cable.
High voltage set with detector not connected.

(EEPROM Settings)
User Time: 1.0
Alpha Alarm: 999999
Beta Alarm: 999999
A/B Alarm: 999999
Model 2360 Date: 9/28/2015
Calibration Date Due: 9/28/2016

COMMENTS:
See attachment for efficiencies

Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
x1000	400k cpm	400	400
x1000	100k cpm	100	100
x100	40k cpm	400	400
x100	10k cpm	100	100
x10	4k cpm	400	400
x10	1k cpm	100	100
x1	400 cpm	400	400
x1	100 cpm	100	100

*Uncertainty within ± 10% C.F. within ± 20% ALL Range(s) Calibrated Electronically

	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*		REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout	400kcpm	3960(0)	3960(0)	Log Scale			
	40kcpm	3996	3996				
	4kcpm	399	399				
	400cpm	40	40				
	40cpm	4	4				

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques.
The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978 State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources: Cs-137 S/N: ☐ 059 ☐ 2171CP ☐ 2261CP ☐ 720 ☐ 734 ☐ 781 ☐ 1131 ☐ 1616 ☐ 1696 ☐ 1909 ☐ 1916CP ☐ 5105 ☐ 5717CO ☐ 5719CO ☐ 60646 ☐ 70897 ☐ 73410 ☐ E552 ☐ G112 ☐ M565 ☐ S-394 ☐ S-1054 ☐ T10081 ☐ T10082 Neutron Am-241 Be S/N: ☐ T-304 Ra-226 S/N: ☐ Y982

☑ Alpha S/N Pu239 SN:7053 ☑ Beta S/N Tc99SN:5280,SrY90SN:5281 ☐ Other

m 500 S/N 190566 ☐ Oscilloscope S/N ☑ Multimeter S/N 86250390

Calibrated By: Date 28-Sept-15

Reviewed By: Date 28 Sep 15

This certificate shall not be reproduced except in full, without the written approval of Ludlum Measurements, Inc.
FORM C22S 07/09/2015 Page 1 of 3

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed:

CB&I Federal Services

alpha scan probability for detecting a single count	Time interval for probability to detect another alpha count (in seconds)
70.8%	13

Instrument Model :	2360	**Instrument Serial # :**	268506	**Calibration Date :**	9/28/2015	**Recommended Static MDA**		**Scan MDA dpm/100cm²**	
Probe Model :	43-93	**Probe Serial # :**	PR286559	**Calibration Due Date:**	9/28/2016	**Alpha**	95	**Alpha**	**N/A**
		Active Detector Area:	100	**Calibration :**	OK	**Beta**	950	**Beta**	**407**

T_{scan} =width of probe / scan speed. (6.93/1.00 for 43-93)

C_{scan}= avg bkgd count rate / T_{scan}

Prob Width (cm)	6.93
Scan Speed (cm/s)	1.00
Release Limit (dpm/100cm²) α	100
β	5,000

	MDC (DPM/ 100cm²)	Bkgd. Count Time	Source Count Time	2 π Instrument Efficiency	Surface Efficiency
Alpha	28	2	2	42.60%	0.25
Beta	243	2	2	30.77%	0.50

*Any dates not represented indicates instrument not used.

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
10/20/2015	1	230	15847	10584	0.5	115	15846	10354	PASS	PASS	PASS	PASS	
10/21/2015	0	246	15198	10475	0	123	15198	10229	PASS	PASS	PASS	PASS	
10/22/2015	0	263	16045	10000	0	131.5	16045	9737	PASS	PASS	PASS	PASS	
10/23/2015	0	219	15803	10329	0	109.5	15803	10110	PASS	PASS	PASS	PASS	
10/26/2015	0	199	15872	10563	0	99.5	15872	10364	PASS	PASS	PASS	PASS	
10/27/2015	0	212	15886	10464	0	106	15886	10252	PASS	PASS	PASS	PASS	
10/28/2015	0	214	15998	10536	0	107	15998	10322	PASS	PASS	PASS	PASS	
10/29/2015	0	258	15720	10756	0	129	15720	10498	PASS	PASS	PASS	PASS	
10/30/2015	1	214	15380	10478	0.5	107	15379	10264	PASS	PASS	PASS	PASS	
11/2/2015	0	222	15366	10332	0	111	15366	10110	PASS	PASS	PASS	PASS	
11/3/2015	0	227	16155	10360	0	113.5	16155	10133	PASS	PASS	PASS	PASS	
11/4/2015	1	203	15542	10646	0.5	101.5	15541	10443	PASS	PASS	PASS	PASS	
11/5/2015	1	211	16198	10551	0.5	105.5	16197	10340	PASS	PASS	PASS	PASS	
11/6/2015	0	199	15358	10168	0	99.5	15358	9969	PASS	PASS	PASS	PASS	
11/9/2015	0	269	15333	10814	0	134.5	15333	10545	PASS	PASS	PASS	PASS	
11/10/2015	1	254	15602	10883	0.5	127	15601	10629	PASS	PASS	PASS	PASS	
11/11/2015	1	238	15591	10558	0.5	119	15590	10320	PASS	PASS	PASS	PASS	
11/12/2015	1	242	16085	10504	0.5	121	16084	10262	PASS	PASS	PASS	PASS	
11/13/2015	1	260	15634	10648	0.5	130	15633	10388	PASS	PASS	PASS	PASS	
11/16/2015	0	208	15129	10340	0	104	15129	10132	PASS	PASS	PASS	PASS	
11/17/2015	1	222	15881	10479	0.5	111	15880	10257	PASS	PASS	PASS	PASS	
11/18/2015	1	218	16025	10625	0.5	109	16024	10407	PASS	PASS	PASS	PASS	
11/19/2015	1	213	15808	10798	0.5	106.5	15807	10585	PASS	PASS	PASS	PASS	

CB&I Federal Services

alpha scan probability for detecting a single count	Time interval for probability to detect another alpha count (in seconds)
70.8%	13

Instrument Model :	2360	**Instrument Serial # :**	268506	**Calibration Date :**	9/28/2015	**Recommended Static MDA**		**Scan MDA dpm/100cm²**	
Probe Model :	43-93	**Probe Serial # :**	PR286559	**Calibration Due Date:**	9/27/2016	**Alpha**	95	**Alpha**	**N/A**
		Active Detector Area:	100	**Calibration :**	**OK**	**Beta**	950	**Beta**	**407**

T_{scan} =width of probe / scan speed. (6.93/1.00 for 43-93)

C_{scan}= avg bkgd count rate / T_{scan}

Prob Width (cm)	6.93
Scan Speed (cm/s)	1.00
Release Limit (dpm/100cm²) α	100
β	5,000

	MDC (DPM/ 100cm²)	Bkgd. Count Time	Source Count Time	2 π Instrument Efficiency	Surface Efficiency
Alpha	28	2	2	42.60%	0.25
Beta	243	2	2	30.77%	0.50

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
11/20/2015	0	214	15460	10392	0	107	15460	10178	PASS	PASS	PASS	PASS	
11/23/2015	1	246	16272	10064	0.5	123	16271	9818	PASS	PASS	PASS	PASS	
11/24/2015	0	222	15555	10825	0	111	15555	10603	PASS	PASS	PASS	PASS	
11/25/2015	0	253	15997	10321	0	126.5	15997	10068	PASS	PASS	PASS	PASS	
11/30/2015	0	271	16367	10432	0	135.5	16367	10161	PASS	PASS	PASS	PASS	
12/1/2015	0	214	15901	10654	0	107	15901	10440	PASS	PASS	PASS	PASS	
12/2/2015	1	240	16094	10400	0.5	120	16093	10160	PASS	PASS	PASS	PASS	
12/3/2015	0	243	15650	10308	0	121.5	15650	10065	PASS	PASS	PASS	PASS	
12/4/2015	0	256	15598	10573	0	128	15598	10317	PASS	PASS	PASS	PASS	
12/7/2015	0	234	15602	10258	0	117	15602	10024	PASS	PASS	PASS	PASS	
12/8/2015	0	228	15584	10471	0	114	15584	10243	PASS	PASS	PASS	PASS	
12/9/2015	1	225	15499	10277	0.5	112.5	15498	10052	PASS	PASS	PASS	PASS	
12/10/2015	0	207	15561	10344	0	103.5	15561	10137	PASS	PASS	PASS	PASS	
12/11/2015													X
12/14/2015													X
12/15/2015	1	238	15673	10191	0.5	119	15672	9953	PASS	PASS	PASS	PASS	
12/16/2015	0	234	15978	10406	0	117	15978	10172	PASS	PASS	PASS	PASS	
12/17/2015	1	209	15719	10672	0.5	104.5	15718	10463	PASS	PASS	PASS	PASS	
12/18/2015													X
12/21/2015	0	205	15941	10347	0	102.5	15941	10142	PASS	PASS	PASS	PASS	
12/22/2015													X
1/4/2016	0	264	15695	10508	0	132	15695	10244	PASS	PASS	PASS	PASS	
1/5/2016	0	237	16116	10407	0	118.5	16116	10170	PASS	PASS	PASS	PASS	
1/6/2016	0	272	16220	10584	0	136	16220	10312	PASS	PASS	PASS	PASS	
1/7/2016	0	236	15534	10570	0	118	15534	10334	PASS	PASS	PASS	PASS	
1/8/2016	1	224	15457	10539	0.5	112	15456	10315	PASS	PASS	PASS	PASS	

CB&I Federal Services

alpha scan probability for detecting a single count	Time interval for probability to detect another alpha count (in seconds)
70.8%	13

Instrument Model :	2360	**Instrument Serial # :**	268506	**Calibration Date :**	9/28/2015	**Recommended Static MDA**		**Scan MDA dpm/100cm^2**	
Probe Model :	43-93	**Probe Serial # :**	PR286559	**Calibration Due Date:**	9/27/2016	**Alpha**	95	**Alpha**	**N/A**
		Active Detector Area:	100	**Calibration :**	OK	**Beta**	950	**Beta**	**407**

T_{scan} =width of probe / scan speed. (6.93/1.00 for 43-93)

C_{scan}= avg bkgd count rate / T_{scan}

Prob Width (cm)	6.93
Scan Speed (cm/s)	1.00
Release Limit (dpm/100cm²) α	100
β	5,000

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	2 π Instrument Efficiency	Surface Efficiency
Alpha	28	2	2	42.60%	0.25
Beta	243	2	2	30.77%	0.50

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
1/11/2016	0	268	15541	10467	0	134	15541	10199	PASS	PASS	PASS	PASS	
1/12/2016	1	260	15861	10536	0.5	130	15860	10276	PASS	PASS	PASS	PASS	
1/13/2016	0	260	15111	10129	0	130	15111	9869	PASS	PASS	PASS	PASS	
1/14/2016	1	239	15960	10640	0.5	119.5	15959	10401	PASS	PASS	PASS	PASS	
1/15/2016	0	218	15269	10373	0	109	15269	10155	PASS	PASS	PASS	PASS	
1/18/2016	1	242	15563	10323	0.5	121	15562	10081	PASS	PASS	PASS	PASS	
1/19/2016	0	218	15641	10155	0	109	15641	9937	PASS	PASS	PASS	PASS	
1/20/2016	0	241	15524	10454	0	120.5	15524	10213	PASS	PASS	PASS	PASS	
1/21/2016	1	236	15617	10049	0.5	118	15616	9813	PASS	PASS	PASS	PASS	
1/22/2016	1	233	15872	10137	0.5	116.5	15871	9904	PASS	PASS	PASS	PASS	
1/25/2016	0	270	15776	10653	0	135	15776	10383	PASS	PASS	PASS	PASS	
1/26/2016	0	260	16031	10277	0	130	16031	10017	PASS	PASS	PASS	PASS	
1/27/2016	0	252	15336	10026	0	126	15336	9774	PASS	PASS	PASS	PASS	
1/28/2016	0	247	15409	9916	0	123.5	15409	9669	PASS	PASS	PASS	PASS	
1/29/2016	0	246	15578	10237	0	123	15578	9991	PASS	PASS	PASS	PASS	
2/1/2016	0	238	15318	10368	0	119	15318	10130	PASS	PASS	PASS	PASS	
2/2/2016	1	246	15847	10142	0.5	123	15846	9896	PASS	PASS	PASS	PASS	
2/3/2016	1	238	15487	10252	0.5	119	15486	10014	PASS	PASS	PASS	PASS	
2/4/2016	0	226	15698	10349	0	113	15698	10123	PASS	PASS	PASS	PASS	
2/5/2016	0	236	15153	10001	0	118	15153	9765	PASS	PASS	PASS	PASS	
2/8/2016	0	214	15774	10251	0	107	15774	10037	PASS	PASS	PASS	PASS	
2/9/2016	0	250	15845	10282	0	125	15845	10032	PASS	PASS	PASS	PASS	
2/10/2016	1	233	15270	10163	0.5	116.5	15269	9930	PASS	PASS	PASS	PASS	
2/11/2016	0	233	15422	10312	0	116.5	15422	10079	PASS	PASS	PASS	PASS	
2/12/2016	1	226	15291	10219	0.5	113	15290	9993	PASS	PASS	PASS	PASS	
2/15/2016	0	244	15418	9776	0	122	15418	9532	PASS	PASS	PASS	PASS	

268506 Cal Due 09-28-2016

CB&I Federal Services

alpha scan probability for detecting a single count		Time interval for probability to detect another alpha count (in seconds)	
70.8%		13	
Recommended Static MDA		Scan MDA dpm/100cm^2	
Alpha	95	Alpha	N/A
Beta	950	Beta	407

Instrument Model :	2360	Instrument Serial # :	268506	Calibration Date :	9/28/2015
Probe Model :	43-93	Probe Serial # :	PR286559	Calibration Due Date:	9/27/2016
		Active Detector Area:	100	Calibration :	OK

T_{scan} =width of probe / scan speed. (6.93/1.00 for 43-93)

C_{scan}= avg bkgd count rate / T_{scan}

Prob Width (cm)	6.93
Scan Speed (cm/s)	1.00
Release Limit α (dpm/100cm²)	100
Release Limit β (dpm/100cm²)	5,000

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	2 π Instrument Efficiency	Surface Efficiency
Alpha	28	2	2	42.60%	0.25
Beta	243	2	2	30.77%	0.50

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
2/16/2016	1	249	15423	9941	0.5	124.5	15422	9692	PASS	PASS	PASS	PASS	
2/17/2016	0	258	15620	9913	0	129	15620	9655	PASS	PASS	PASS	PASS	
2/18/2016	1	248	15624	10112	0.5	124	15623	9864	PASS	PASS	PASS	PASS	
2/19/2016	0	241	15643	10204	0	120.5	15643	9963	PASS	PASS	PASS	PASS	
2/22/2016	0	247	15501	10259	0	123.5	15501	10012	PASS	PASS	PASS	PASS	
2/23/2016	1	260	15398	10211	0.5	130	15397	9951	PASS	PASS	PASS	PASS	
2/24/2016	0	225	16106	10211	0	112.5	16106	9986	PASS	PASS	PASS	PASS	
2/25/2016	0	213	15672	10156	0	106.5	15672	9943	PASS	PASS	PASS	PASS	
2/26/2016													X
2/29/2016	0	248	15879	10018	0	124	15879	9770	PASS	PASS	PASS	PASS	
3/1/2016	0	254	15544	10036	0	127	15544	9782	PASS	PASS	PASS	PASS	
3/2/2016	0	203	15854	10031	0	101.5	15854	9828	PASS	PASS	PASS	PASS	
3/3/2016	1	233	15927	10269	0.5	116.5	15926	10036	PASS	PASS	PASS	PASS	
3/4/2016	0	238	15788	10027	0	119	15788	9789	PASS	PASS	PASS	PASS	
3/7/2016	0	237	15147	10265	0	118.5	15147	10028	PASS	PASS	PASS	PASS	
3/8/2016	0	249	16069	9981	0	124.5	16069	9732	PASS	PASS	PASS	PASS	
3/9/2016	0	227	15466	10043	0	113.5	15466	9816	PASS	PASS	PASS	PASS	
3/10/2016													X
3/11/2016													X
3/14/2016													X
3/15/2016	0	275	15875	10246	0	137.5	15875	9971	PASS	PASS	PASS	PASS	
3/16/2016	0	229	15409	10459	0	114.5	15409	10230	PASS	PASS	PASS	PASS	
3/17/2016	0	262	15983	10107	0	131	15983	9845	PASS	PASS	PASS	PASS	
3/18/2016	1	226	15775	10399	0.5	113	15774	10173	PASS	PASS	PASS	PASS	
3/21/2016	0	203	15507	10548	0	101.5	15507	10345	PASS	PASS	PASS	PASS	
3/22/2016	1	210	15162	10004	0.5	105	15161	9794	PASS	PASS	PASS	PASS	

268506 Cal Due 09-28-2016

CB&I Federal Services

alpha scan probability for detecting a single count		Time interval for probability to detect another alpha count (in seconds)	
70.8%		13	
Recommended Static MDA		**Scan MDA dpm/100cm^2**	
Alpha	95	**Alpha**	**N/A**
Beta	950	**Beta**	**407**

Instrument Model :	2360	**Instrument Serial # :**	268506	**Calibration Date :**	9/28/2015
Probe Model :	43-93	**Probe Serial # :**	PR286559	**Calibration Due Date:**	9/27/2016
		Active Detector Area:	100	**Calibration :**	OK

T_{scan} =width of probe / scan speed. (6.93/1.00 for 43-93)

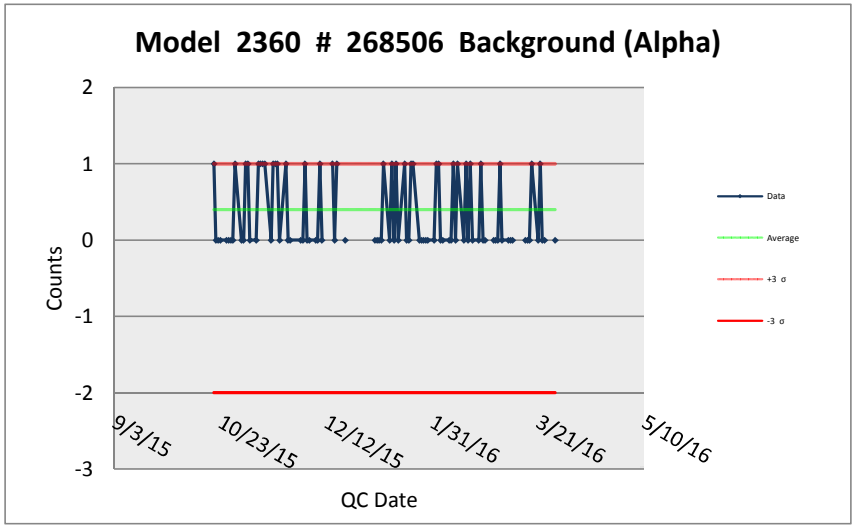
C_{scan}= avg bkgd count rate / T_{scan}

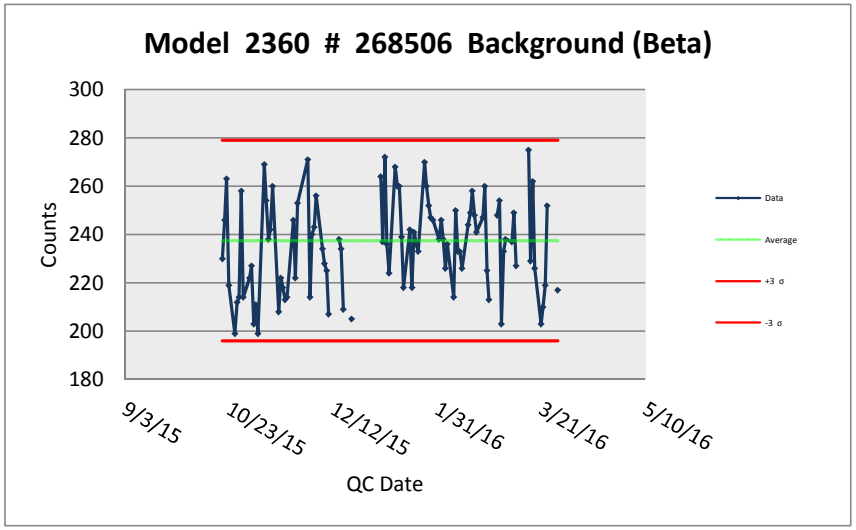
Prob Width (cm)	6.93
Scan Speed (cm/s)	1.00
Release Limit (dpm/100cm²) α	100
β	5,000

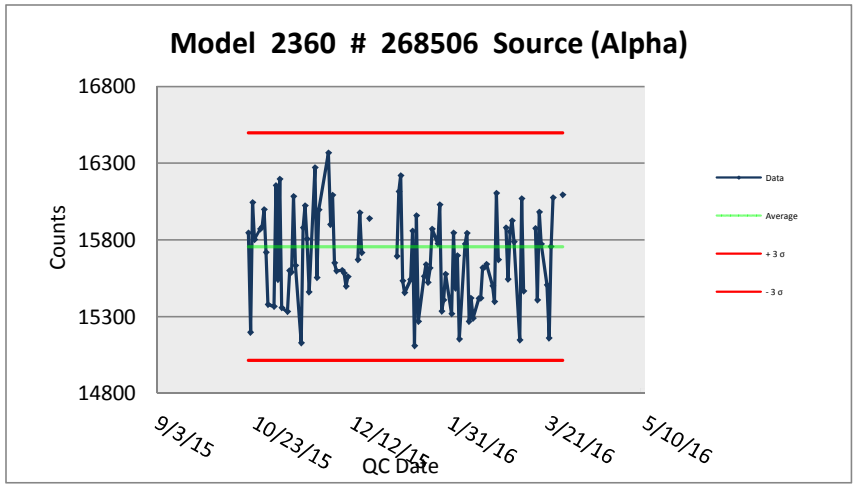
	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	2 π Instrument Efficiency	Surface Efficiency
Alpha	28	2	2	42.60%	0.25
Beta	243	2	2	30.77%	0.50

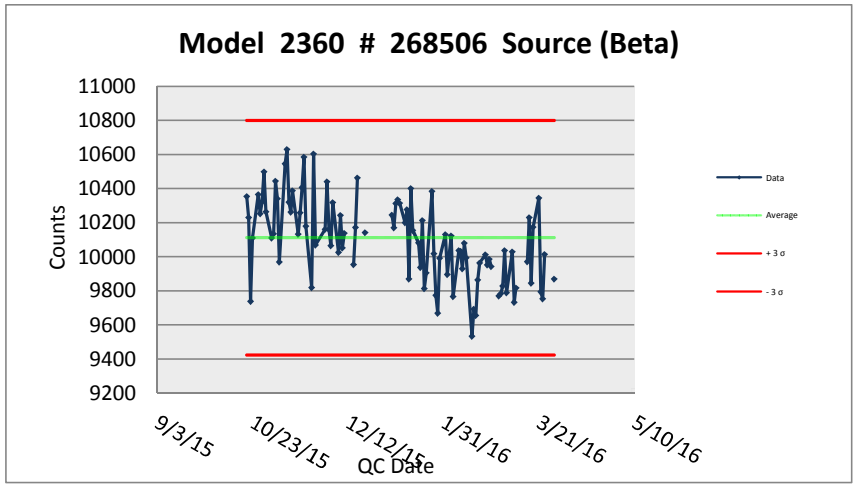
Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
3/23/2016	0	219	15756	9971	0	109.5	15756	9752	PASS	PASS	PASS	PASS	
3/24/2016	0	252	16076	10265	0	126	16076	10013	PASS	PASS	PASS	PASS	
3/28/2016													x
3/29/2016	0	217	16095	10086	0	108.5	16095	9869	PASS	PASS	PASS	PASS	

Control Graphs









268506 Cal Due 09-28-2016

Background Determination (Alpha)

Instrument Model	Probe Model	Instrument Serial #	Probe Serial #	Calibration Due Date
2360	43-93	268506	PR286559	9/28/2016

Surface Type :	Table Top (570 Trailer Lab)	
Date Collected :	10/12/2015	
Collected By :	M. Chi	
Count Time :	2	**Minutes**

#	Gross Counts	CPM
1	0	0
2	0	0
3	0	0
4	1	0.5
5	1	0.5
6	0	0
7	1	0.5
8	1	0.5
9	0	0
10	0	0
Mean:	0.4	0.2
Std Dev:	0.52	

Microsoft Excel® was used for all calculations.

-3 σ Value:	+3 σ Value:
-2	1

Bkgd Count Rate (CPM):	0.2

Completed By :	**Minhsec Chi**	**Date :**	**10/12/2015**
Reviewed By :	**Takeshi Ibuki**	**Date :**	**10/12/2015**

Background Determination (Beta)

Instrument Model	Probe Model	Instrument Serial #	Probe Serial #	Calibration Due Date
2360	43-93	268506	PR286559	9/28/2016

Surface Type :	Table Top (570 Trailer Lab)	
Date Collected :	10/12/2015	
Collected By :	M. Chi	
Count Time :	2	**Minutes**

#	Gross Counts	CPM
1	261	130.5
2	237	118.5
3	243	121.5
4	230	115
5	228	114
6	238	119
7	245	122.5
8	226	113
9	253	126.5
10	213	106.5
Mean	237.4	118.7
Std Dev:	13.98	

Microsoft Excel® was used for all calculations.

-3 σ Value:
196

+3 σ Value:
279

Background Count Rate:	118.7

Completed By :	**Minhsec Chi**	**Date :**	**10/12/2015**
Reviewed By :	**Takeshi Ibuki**	**Date :**	**10/12/2015**

Source Determination (Alpha)

Instrument Model	Probe Model	Instrument Serial #	Probe Serial #	Calibration Due Date
2360	43-93	268506	PR286559	9/28/2016

Source ID #	Source Nuclide	Initial 2π Emission Rate (cpm)	Halflife (Years)	Decayed 2π Emission Rate (cpm)	Assay Date
G4-798	Th-230	41730	75400	41,728	October 13, 2009

Date Collected :	10/12/2015	
Collected By :	M. Chi	
Count Time :	2	**Minutes**
Average Bkgd Counts	0.4	

Microsoft Excel® was used for all calculations.

#	(Gross Cnts) CG	(Net Cnts) Cn	(Net CPM) Cl
1	15484	15483.6	7741.8
2	15614	15613.6	7806.8
3	16113	16112.6	8056.3
4	15426	15425.6	7712.8
5	15980	15979.6	7989.8
6	15719	15718.6	7859.3
7	16026	16025.6	8012.8
8	15544	15543.6	7771.8
9	15969	15968.6	7984.3
10	15687	15686.6	7843.3
Mean $\overline{C}$:	15756.2	15755.8	7877.9
Std Dev:	247.210	247.211	

-3 σ Value:	**+3 σ Value:**
15,015	16,497

Completed By :	**Minhsec Chi**	**Date :**	**10/12/2015**
Reviewed By :	**Takeshi Ibuki**	**Date :**	**10/12/2015**

268506 Cal Due 09-28-2016

Source Determination (Beta)

Instrument Model	Probe Model	Instrument Serial #	Probe Serial #	Calibration Due Date
2360	43-93	268506	PR286559	9/28/2016

Source ID #	Source Nuclide	Initial 2π Emission Rate (cpm)	Halflife (Years)	Decayed 2π Emission Rate (cpm)	Assay Date
G4-796	Tc-99	43500	213000	43,499	October 6, 2009

Date Collected :	10/12/2015	
Collected By :	M. Chi	
Count Time :	2	**Minutes**
Average Bkgd Counts	237.4	

Microsoft Excel® was used for all calculations.

#	(Gross Cnts) CG	(Net Cnts) Cn	(Net CPM) Cl
1	10119	9881.6	4940.8
2	10360	10122.6	5061.3
3	10210	9972.6	4986.3
4	10345	10107.6	5053.8
5	10094	9856.6	4928.3
6	10497	10259.6	5129.8
7	10346	10108.6	5054.3
8	10589	10351.6	5175.8
9	10127	9889.6	4944.8
10	10804	10566.6	5283.3
Mean $\overline{C}$:	10349.1	10111.7	5055.85
Std Dev:	229.30	229.73	

-3 σ Value:	**+3 σ Value:**
9,423	10,800

Completed By :	**Minhsec Chi**	**Date :**	**10/12/2015**
Reviewed By :	**Takeshi Ibuki**	**Date :**	**10/12/2015**

268506 Cal Due 09-28-2016

Designer and Manufacturer of Scientific and Industrial Instruments

55736

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.
501 Oak Street
325-235-5494
Sweetwater, TX 79556, U.S.A.
☐ 10744 Dutchtown Road
865-392-4601
Knoxville, TN 37932, U.S.A.

CUSTOMER CB & I ORDER NO. 20266135/419912

M Ludlum Measurements, Inc. Model 3030 Serial No. 224340

Cal. Date 21-Apr-15 Cal Due Date 21-Apr-16 Cal. Interval 1 Year

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 73 °F RH 32 % Alt 682.8 mm Hg

☐ New Instrument Instrument Received ☑ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Window Operation

☑ Audio ck.

Alpha Sensitivity 120 mV Beta Sensitivity 4 mV Beta Window 50 mV

☑ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89.

nstrument Volt Set 500 V High Voltage set with detector connected.

☑ HV Readout (2 points) Ref./Inst. 500 / 501 V Ref./Inst. 1200 / 1200 V

Instrument in DPM mode.

QC mode turned ☑ OFF ☐ ON

Firmware version: 39013v17

Overload set at 1/4 turn past OFF.

Battery voltage measured at 12.6 Vdc.

C-14 Efficiency ~ 7.9 %(4 pi) Net

(EEPROM Settings)

(PC) Count Time: 1.2

Alpha Alarm: 999999 cpm

Beta Alarm: 999999 cpm

Alpha/Beta Alarm: 999999 cpm

Calibration Due Date: 4/21/2016

LOC (Loss of Count) time = 30 minutes (default)

Alpha Channel Digital Readout	REFERENCE CAL POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
	400K cpm	40032 (0)	40032 (0)
	40K cpm	4003	4003
	4K cpm	400	400
	400 cpm	40	40
	40 cpm	4	4

Beta/Gamma Channel Digital Readout	REFERENCE CAL POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
	400K cpm	40028 (0)	40028 (0)
	40K cpm	4003	4003
	4K cpm	400	400
	400 cpm	40	40
	40 cpm	4	4

*Uncertainty within ± 10% C.F. within ± 20%

(0) indicates 0.1 minute count

COMMENTS:

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978. State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources:

☑ Alpha S/N Pu239 SN:7053 ☑ Beta S/N Tc99 SN:5280 ☐ Other

☑ m 500 S/N 190566 ☐ Oscilloscope S/N ☑ Multimeter S/N 86250390

Calibrated By: Date 21-APR-15

Reviewed By: Date 22 April 5

This certificate shall not be reproduced except in full, without the written approval of Ludlum Measurements, Inc.

AC Inst Only ☑ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed:

Ludlum Measurements,Inc.
Model 3030 Parameters

4/21/2015
10:30:06 AM

Header 1: header1
Header 2: header2
Header 3: header3
Header 4: header4
Header 5: header5
Header 6: header6

Calibration Due Date: 4/21/2016

Model 3030 Date: 4/21/2015
Model 3030 Time: 10:15:02 AM

Count Time Switch (min): 1.0
User PC Time (min): 1.2

Alpha Alarm: 888888
Beta Alarm: 888888
Alpha + Beta Alarm: 888888

High Voltage (VDC): 500

Loss of Count Time (min): 15.0

Count Mode: SCALER

Alpha Efficiency %: 40.6
Beta Efficiency %: 32.6

Background Subtract: OFF
Alpha Background: 1.0
Beta Background: 42.0

Crosstalk Correction: OFF
Alpha to Beta Crosstalk %: 2.2
Beta to Alpha Crosstalk %: 0.1

Show Parameters during startup: Disabled

Daily QC Check: OFF

Last Alpha Efficiency %: 40.0
Last Beta Efficiency %: 32.0

Standard Alpha Efficiency %: 40
Standard Beta Efficiency %: 32

Allowable Alpha QC Efficiency ± %: 15
Allowable Beta QC Efficiency ± %: 15

Alpha Source Size (dpm): 24900
Alpha Source Size (Bq): 415.
Alpha Source Size (µCi): 0.01121621622

Beta Source Size (dpm): 93200
Beta Source Size (Bq): 1553.33
Beta Source Size (µCi): 0.04198198198

Last Alpha QC Background: 0.0
Last Beta QC Background: 45.0

Alpha Background Upper Limit (cpm): 100
Alpha Background Lower Limit (cpm): 0
Beta Background Upper Limit (cpm): 1000
Beta Background Lower Limit (cpm): 0

Next Sample Number: 0004
User-defined Comment: AAAAAAAAAA
Logging Mode: Log QC Only
Recycle Mode: OFF
Printer Mode: OFF

Ludlum Measurements, Inc.
Model 3030 Plateau Data

4/21/2015
10:24:22 AM

Header 1: header1
Header 2: header2
Header 3: header3
Header 4: header4
Header 5: header5
Header 6: header6

Calibration Due Date: 4/21/2016

Model 3030 Date: 4/21/2015
Model 3030 Time: 10:15:02 AM

User PC Time: 1.2

Alpha Isotope: Pu239
Alpha Source Size (dpm): 24900
Alpha Source Size (Bq): 415.0
Alpha Source Size (µCi): 0.011216216

Beta Isotope: Tc99
Beta Source Size (dpm): 93200
Beta Source Size (Bq): 1553.33
Beta Source Size (µCi): 0.041981982

Starting High Voltage: 450
Starting High Voltage: 575
High Voltage Increment: 25

Plateau Count Mode: SCALER
Source Count Time (min): 1.0
Background Count Time (min): 1.0

	ALPHA					BETA				
HV	Source (Beta)		Background	Eff	CrossTalk	Source (Alpha)		Background	Eff	Crosstalk
450	9997	(288)	0	40.1%	2.5%	20444	(51)	41	21.9%	0.2%
475	10113	(274)	1	40.6%	2.3%	25169	(37)	40	27.0%	0.1%
500	10100	(264)	1	40.6%	2.2%	30467	(36)	42	32.6%	0.1%
525	10078	(248)	1	40.5%	1.9%	33766	(40)	60	36.2%	0.1%
550	10074	(249)	0	40.5%	2.0%	33944	(41)	48	36.4%	0.1%
575	10216	(297)	2	41.0%	2.4%	33064	(62)	52	35.4%	0.2%

Ludlum Measurements,Inc.
Model 3030 MDA Calculation Data

/21/2015
0:24:26 AM

lpha Background(cpm): 1.0
Bet ckground(cpm): 42.0

lpha Efficiency %: 40.6
Beta Efficiency %: 32.6

Confidence Level: 95%

Count Time	Alpha MDA(dpm)	Beta MDA(dpm)
0.1	93.6	300.0
0.5	27.4	129.9
1.0	18.1	100.8
2.0	13.3	84.3
5.0	10.2	73.3
10.0	9.2	69.4
50.0	8.3	66.1
PC (1.2)	16.5	95.5

CB&I Federal Services

Instrument Model :	3030	Instrument Serial # :	224340	Calibration Date :	4/21/2015	Recommended MDC	
Probe Model :	N/A	Probe Serial # :	N/A	Calibration Due Date:	4/21/2016	Alpha	18
				Calibration :	OK	Beta	200

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency**	Total Efficiency***
Alpha	17	1	1	40.6%	32.5%
Beta	91	1	1	32.6%	32.6%

* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency provide
*** Instrument Efficiency xAbsor
Asorbtion factor for beta is 1

*Any dates not represented indicates instrument not used.

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
7/14/2015													X
7/15/2015													X
7/16/2015													X
7/17/2015	0	33	12725	7696	0	33	12725	7663	PASS	PASS	PASS	PASS	
7/20/2015	0	23	12489	7772	0	23	12489	7749	PASS	PASS	PASS	PASS	
7/21/2015	0	26	13133	7479	0	26	13133	7453	PASS	PASS	PASS	PASS	
7/22/2015	0	38	12598	7736	0	38	12598	7698	PASS	PASS	PASS	PASS	
7/23/2015	0	20	12838	7748	0	20	12838	7728	PASS	PASS	PASS	PASS	
7/24/2015	0	28	12574	7670	0	28	12574	7642	PASS	PASS	PASS	PASS	
7/27/2015	0	23	12919	7760	0	23	12919	7737	PASS	PASS	PASS	PASS	
7/28/2015	0	34	12764	7495	0	34	12764	7461	PASS	PASS	PASS	PASS	
7/29/2015	1	34	13054	7784	1	34	13053	7750	PASS	PASS	PASS	PASS	
7/30/2015	1	30	12831	7634	1	30	12830	7604	PASS	PASS	PASS	PASS	
7/31/2015	1	30	12841	7498	1	30	12840	7468	PASS	PASS	PASS	PASS	
8/3/2015	0	37	12920	7723	0	37	12920	7686	PASS	PASS	PASS	PASS	
8/4/2015	0	32	12908	7669	0	32	12908	7637	PASS	PASS	PASS	PASS	
8/5/2015	0	33	13218	7502	0	33	13218	7469	PASS	PASS	PASS	PASS	
8/6/2015	0	30	12573	7589	0	30	12573	7559	PASS	PASS	PASS	PASS	
8/7/2015	0	23	12929	7625	0	23	12929	7602	PASS	PASS	PASS	PASS	
8/10/2015	0	23	12708	7634	0	23	12708	7611	PASS	PASS	PASS	PASS	
8/11/2015	0	29	13004	7563	0	29	13004	7534	PASS	PASS	PASS	PASS	
8/12/2015	0	28	12653	7634	0	28	12653	7606	PASS	PASS	PASS	PASS	
8/13/2015	0	31	12759	7648	0	31	12759	7617	PASS	PASS	PASS	PASS	

CB&I Federal Services

Instrument Model :	3030	Instrument Serial # :	224340	Calibration Date :	4/21/2015	Recommended MDC	
Probe Model :	N/A	Probe Serial # :	N/A	Calibration Due Date:	4/21/2016	Alpha	18
		*Active Detector Area:	0	Calibration :	OK	Beta	200

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency	Total Efficiency**
Alpha	17	1	1	40.60%	32.48%
Beta	91	1	1	32.60%	32.60%

* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency xAbsorb

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
8/14/2015	0	34	12622	7673	0	34	12622	7639	PASS	PASS	PASS	PASS	
8/17/2015	0	27	13074	7697	0	27	13074	7670	PASS	PASS	PASS	PASS	
8/18/2015	0	31	12721	7701	0	31	12721	7670	PASS	PASS	PASS	PASS	
8/19/2015	0	32	12604	7713	0	32	12604	7681	PASS	PASS	PASS	PASS	
8/20/2015	0	24	12786	7802	0	24	12786	7778	PASS	PASS	PASS	PASS	
8/21/2015	0	30	12711	7623	0	30	12711	7593	PASS	PASS	PASS	PASS	
8/24/2015	1	44	12827	7650	1	44	12826	7606	PASS	PASS	PASS	PASS	
8/25/2015	0	35	13113	7488	0	35	13113	7453	PASS	PASS	PASS	PASS	
8/26/2015	0	25	12702	7594	0	25	12702	7569	PASS	PASS	PASS	PASS	
8/27/2015	1	31	12422	7729	1	31	12421	7698	PASS	PASS	PASS	PASS	
8/28/2015	0	30	12794	7760	0	30	12794	7730	PASS	PASS	PASS	PASS	
8/31/2015	0	36	13013	7612	0	36	13013	7576	PASS	PASS	PASS	PASS	
9/1/2015	0	34	12743	7608	0	34	12743	7574	PASS	PASS	PASS	PASS	
9/2/2015	0	37	12861	7760	0	37	12861	7723	PASS	PASS	PASS	PASS	
9/3/2015	0	25	12635	7501	0	25	12635	7476	PASS	PASS	PASS	PASS	
9/4/2015	0	37	12500	7538	0	37	12500	7501	PASS	PASS	PASS	PASS	
9/8/2015	0	37	13004	7737	0	37	13004	7700	PASS	PASS	PASS	PASS	
9/9/2015	0	27	12762	7591	0	27	12762	7564	PASS	PASS	PASS	PASS	
9/10/2015	1	34	12613	7614	1	34	12612	7580	PASS	PASS	PASS	PASS	
9/11/2015	0	30	12710	7589	0	30	12710	7559	PASS	PASS	PASS	PASS	
9/14/2015	0	28	12825	7641	0	28	12825	7613	PASS	PASS	PASS	PASS	
9/15/2015	0	33	12793	7582	0	33	12793	7549	PASS	PASS	PASS	PASS	
9/16/2015	0	27	12772	7535	0	27	12772	7508	PASS	PASS	PASS	PASS	
9/17/2015	0	38	12364	7548	0	38	12364	7510	PASS	PASS	PASS	PASS	
9/18/2015	1	31	12754	7647	1	31	12753	7616	PASS	PASS	PASS	PASS	
9/21/2015	0	30	12757	7512	0	30	12757	7482	PASS	PASS	PASS	PASS	

CB&I Federal Services

Instrument Model :	3030	Instrument Serial # :	224340	Calibration Date :	4/21/2015	Recommended MDC	
Probe Model :	N/A	Probe Serial # :	N/A	Calibration Due Date:	4/21/2016	Alpha	18
		*Active Detector Area:	0	Calibration :	OK	Beta	200

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency	Total Efficiency**
Alpha	17	1	1	40.60%	32.48%
Beta	91	1	1	32.60%	32.60%

* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency xAbsorb

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
9/22/2015	0	36	12670	7517	0	36	12670	7481	PASS	PASS	PASS	PASS	
9/23/2015	0	38	12817	7586	0	38	12817	7548	PASS	PASS	PASS	PASS	
9/24/2015	1	28	12502	7572	1	28	12501	7544	PASS	PASS	PASS	PASS	
9/25/2015	0	38	13169	7547	0	38	13169	7509	PASS	PASS	PASS	PASS	
9/28/2015	0	26	12764	7580	0	26	12764	7554	PASS	PASS	PASS	PASS	
9/29/2015	0	22	12374	7566	0	22	12374	7544	PASS	PASS	PASS	PASS	
9/30/2015	1	32	13018	7497	1	32	13017	7465	PASS	PASS	PASS	PASS	
10/1/2015	0	31	12661	7599	0	31	12661	7568	PASS	PASS	PASS	PASS	
10/2/2015	1	21	12990	7647	1	21	12989	7626	PASS	PASS	PASS	PASS	
10/5/2015	0	41	12905	7577	0	41	12905	7536	PASS	PASS	PASS	PASS	
10/6/2015	0	22	12854	7516	0	22	12854	7494	PASS	PASS	PASS	PASS	
10/7/2015	1	26	12800	7517	1	26	12799	7491	PASS	PASS	PASS	PASS	
10/8/2015	1	25	12582	7611	1	25	12581	7586	PASS	PASS	PASS	PASS	
10/9/2015	0	28	12912	7642	0	28	12912	7614	PASS	PASS	PASS	PASS	
10/12/2015	0	42	12781	7662	0	42	12781	7620	PASS	PASS	PASS	PASS	
10/13/2015	0	37	12915	7665	0	37	12915	7628	PASS	PASS	PASS	PASS	
10/14/2015	0	40	12539	7541	0	40	12539	7501	PASS	PASS	PASS	PASS	
10/15/2015	0	26	12681	7600	0	26	12681	7574	PASS	PASS	PASS	PASS	
10/16/2015	1	32	12843	7594	1	32	12842	7562	PASS	PASS	PASS	PASS	
10/19/2015	0	35	12771	7667	0	35	12771	7632	PASS	PASS	PASS	PASS	
10/20/2015	1	30	12910	7480	1	30	12909	7450	PASS	PASS	PASS	PASS	
10/21/2015	0	39	12970	7762	0	39	12970	7723	PASS	PASS	PASS	PASS	
10/22/2015	1	32	12703	7648	1	32	12702	7616	PASS	PASS	PASS	PASS	
10/23/2015	0	28	12913	7555	0	28	12913	7527	PASS	PASS	PASS	PASS	
10/26/2015	0	37	13038	7597	0	37	13038	7560	PASS	PASS	PASS	PASS	
10/27/2015	0	42	12952	7501	0	42	12952	7459	PASS	PASS	PASS	PASS	

CB&I Federal Services

Instrument Model :	3030	Instrument Serial # :	224340	Calibration Date :	4/21/2015	Recommended MDC	
Probe Model :	N/A	Probe Serial # :	N/A	Calibration Due Date:	4/21/2016	Alpha	18
		*Active Detector Area:	0	Calibration :	OK	Beta	200

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency	Total Efficiency**
Alpha	17	1	1	40.60%	32.48%
Beta	91	1	1	32.60%	32.60%

* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency xAbsorb

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
10/28/2015	0	30	12902	7643	0	30	12902	7613	PASS	PASS	PASS	PASS	
10/29/2015	0	43	12341	7529	0	43	12341	7486	PASS	PASS	PASS	PASS	
10/30/2015	0	37	12818	7496	0	37	12818	7459	PASS	PASS	PASS	PASS	
11/2/2015	0	33	12836	7509	0	33	12836	7476	PASS	PASS	PASS	PASS	
11/3/2015	0	40	12370	7712	0	40	12370	7672	PASS	PASS	PASS	PASS	
11/4/2015	0	45	12601	7712	0	45	12601	7667	PASS	PASS	PASS	PASS	
11/5/2015	0	38	12853	7522	0	38	12853	7484	PASS	PASS	PASS	PASS	
11/6/2015	0	26	12318	7803	0	26	12318	7777	PASS	PASS	PASS	PASS	
11/9/2015	1	28	12799	7530	1	28	12798	7502	PASS	PASS	PASS	PASS	
11/10/2015	0	37	12740	7680	0	37	12740	7643	PASS	PASS	PASS	PASS	
11/11/2015	0	37	12975	7503	0	37	12975	7466	PASS	PASS	PASS	PASS	
11/12/2015	0	25	13054	7540	0	25	13054	7515	PASS	PASS	PASS	PASS	
11/13/2015	0	39	12828	7637	0	39	12828	7598	PASS	PASS	PASS	PASS	
11/16/2015	0	33	12620	7734	0	33	12620	7701	PASS	PASS	PASS	PASS	
11/17/2015	1	28	12844	7613	1	28	12843	7585	PASS	PASS	PASS	PASS	
11/18/2015	0	35	12904	7563	0	35	12904	7528	PASS	PASS	PASS	PASS	
11/19/2015	1	30	12716	7616	1	30	12715	7586	PASS	PASS	PASS	PASS	
11/20/2015	0	26	12586	7525	0	26	12586	7499	PASS	PASS	PASS	PASS	
11/23/2015	0	38	12982	7600	0	38	12982	7562	PASS	PASS	PASS	PASS	
11/24/2015	0	33	12561	7642	0	33	12561	7609	PASS	PASS	PASS	PASS	
11/25/2015	0	22	12864	7687	0	22	12864	7665	PASS	PASS	PASS	PASS	
11/30/2015	1	33	12971	7673	1	33	12970	7640	PASS	PASS	PASS	PASS	
12/1/2015	1	27	12830	7560	1	27	12829	7533	PASS	PASS	PASS	PASS	
12/2/2015	0	33	12726	7704	0	33	12726	7671	PASS	PASS	PASS	PASS	
12/3/2015	0	35	12870	7496	0	35	12870	7461	PASS	PASS	PASS	PASS	
12/4/2015	0	33	12767	7596	0	33	12767	7563	PASS	PASS	PASS	PASS	

CB&I Federal Services

Instrument Model :	3030	Instrument Serial # :	224340	Calibration Date :	4/21/2015	Recommended MDC	
Probe Model :	N/A	Probe Serial # :	N/A	Calibration Due Date:	4/21/2016	Alpha	18
		*Active Detector Area:	0	Calibration :	OK	Beta	200

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency	Total Efficiency**
Alpha	17	1	1	40.60%	32.48%
Beta	91	1	1	32.60%	32.60%

* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency xAbsorb

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
12/7/2015	0	38	12880	7616	0	38	12880	7578	PASS	PASS	PASS	PASS	
12/8/2015	0	36	12770	7736	0	36	12770	7700	PASS	PASS	PASS	PASS	
12/9/2015	1	28	12876	7626	1	28	12875	7598	PASS	PASS	PASS	PASS	
12/10/2015	1	36	12869	7573	1	36	12868	7537	PASS	PASS	PASS	PASS	
12/11/2015	0	27	13053	7710	0	27	13053	7683	PASS	PASS	PASS	PASS	
12/14/2015													X
12/15/2015	1	32	13073	7778	1	32	13072	7746	PASS	PASS	PASS	PASS	
12/16/2015	0	29	13062	7771	0	29	13062	7742	PASS	PASS	PASS	PASS	
12/17/2015	0	27	12653	7505	0	27	12653	7478	PASS	PASS	PASS	PASS	
12/18/2015	0	31	12702	7632	0	31	12702	7601	PASS	PASS	PASS	PASS	
12/21/2015	0	28	12892	7577	0	28	12892	7549	PASS	PASS	PASS	PASS	
12/22/2015	1	30	12839	7534	1	30	12838	7504	PASS	PASS	PASS	PASS	
1/4/2016	0	29	12929	7834	0	29	12929	7805	PASS	PASS	PASS	PASS	
1/5/2016	0	35	12624	7672	0	35	12624	7637	PASS	PASS	PASS	PASS	
1/6/2016	0	40	13169	7627	0	40	13169	7587	PASS	PASS	PASS	PASS	
1/7/2016	1	27	12839	7761	1	27	12838	7734	PASS	PASS	PASS	PASS	
1/8/2016	1	41	12904	7723	1	41	12903	7682	PASS	PASS	PASS	PASS	
1/11/2016	0	41	12944	7585	0	41	12944	7544	PASS	PASS	PASS	PASS	
1/12/2016	0	34	12919	7600	0	34	12919	7566	PASS	PASS	PASS	PASS	
1/13/2016	0	30	13209	7593	0	30	13209	7563	PASS	PASS	PASS	PASS	
1/14/2016	0	39	12834	7636	0	39	12834	7597	PASS	PASS	PASS	PASS	
1/15/2016	0	37	13013	7582	0	37	13013	7545	PASS	PASS	PASS	PASS	
1/18/2016	0	27	13063	7640	0	27	13063	7613	PASS	PASS	PASS	PASS	
1/19/2016	0	39	13038	7902	0	39	13038	7863	PASS	PASS	PASS	PASS	
1/20/2016	0	26	12918	7599	0	26	12918	7573	PASS	PASS	PASS	PASS	
1/21/2016	0	20	12795	7717	0	20	12795	7697	PASS	PASS	PASS	PASS	

CB&I Federal Services

Instrument Model :	3030	Instrument Serial # :	224340	Calibration Date :	4/21/2015	Recommended MDC	
Probe Model :	N/A	Probe Serial # :	N/A	Calibration Due Date:	4/21/2016	Alpha	18
		*Active Detector Area:	0	Calibration :	OK	Beta	200

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency	Total Efficiency**
Alpha	17	1	1	40.60%	32.48%
Beta	91	1	1	32.60%	32.60%

* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency xAbsorb

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
1/22/2016	0	28	13097	7692	0	28	13097	7664	PASS	PASS	PASS	PASS	
1/25/2016	0	43	13176	7777	0	43	13176	7734	PASS	PASS	PASS	PASS	
1/26/2016	0	27	12984	7677	0	27	12984	7650	PASS	PASS	PASS	PASS	
1/27/2016	0	34	12796	7779	0	34	12796	7745	PASS	PASS	PASS	PASS	
1/28/2016	0	33	12869	7685	0	33	12869	7652	PASS	PASS	PASS	PASS	
1/29/2016	0	32	12929	7721	0	32	12929	7689	PASS	PASS	PASS	PASS	
2/1/2016	0	31	12825	7873	0	31	12825	7842	PASS	PASS	PASS	PASS	
2/2/2016	0	37	12869	7792	0	37	12869	7755	PASS	PASS	PASS	PASS	
2/3/2016	0	30	13219	7829	0	30	13219	7799	PASS	PASS	PASS	PASS	
2/4/2016	0	24	13060	7578	0	24	13060	7554	PASS	PASS	PASS	PASS	
2/5/2016	0	39	12574	7681	0	39	12574	7642	PASS	PASS	PASS	PASS	
2/8/2016	0	33	12577	7889	0	33	12577	7856	PASS	PASS	PASS	PASS	
2/9/2016	0	25	13000	7710	0	25	13000	7685	PASS	PASS	PASS	PASS	
2/10/2016	0	40	12979	7630	0	40	12979	7590	PASS	PASS	PASS	PASS	
2/11/2016	0	29	12953	7804	0	29	12953	7775	PASS	PASS	PASS	PASS	
2/12/2016	0	26	12622	7694	0	26	12622	7668	PASS	PASS	PASS	PASS	
2/15/2016	0	28	13071	7748	0	28	13071	7720	PASS	PASS	PASS	PASS	
2/16/2016	1	36	12886	7615	1	36	12885	7579	PASS	PASS	PASS	PASS	
2/17/2016	0	33	12620	7623	0	33	12620	7590	PASS	PASS	PASS	PASS	
2/18/2016	0	34	12961	7647	0	34	12961	7613	PASS	PASS	PASS	PASS	
2/19/2016	0	34	12670	7693	0	34	12670	7659	PASS	PASS	PASS	PASS	
2/22/2016	0	29	12857	7608	0	29	12857	7579	PASS	PASS	PASS	PASS	
2/23/2016	0	38	12878	7577	0	38	12878	7539	PASS	PASS	PASS	PASS	
2/24/2016	0	35	13089	7733	0	35	13089	7698	PASS	PASS	PASS	PASS	
2/25/2016	0	33	13085	7739	0	33	13085	7706	PASS	PASS	PASS	PASS	
2/26/2016	0	32	12930	7712	0	32	12930	7680	PASS	PASS	PASS	PASS	

224340 Cal Due 04-21-2016_Set up 7-7-15

CB&I Federal Services

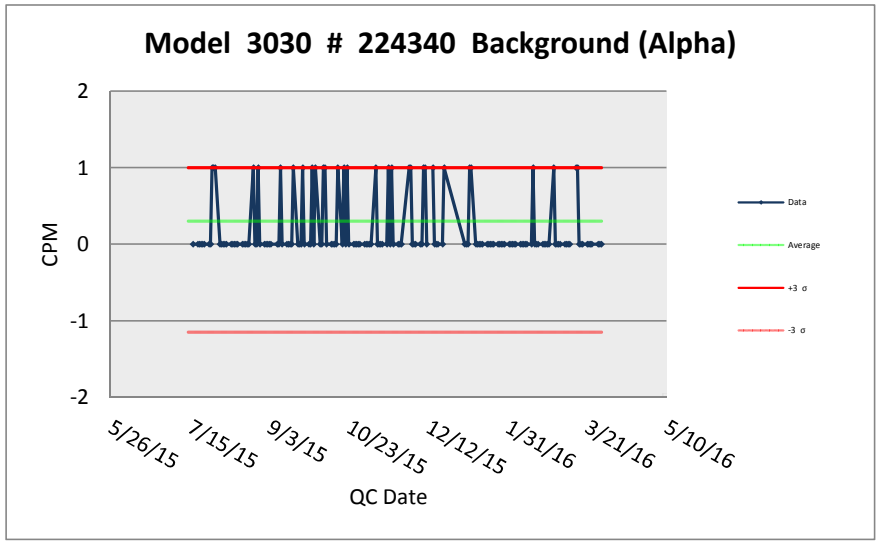
Instrument Model :	3030	Instrument Serial # :	224340	Calibration Date :	4/21/2015	Recommended MDC	
Probe Model :	N/A	Probe Serial # :	N/A	Calibration Due Date:	4/21/2016	Alpha	18
		*Active Detector Area:	0	Calibration :	OK	Beta	200

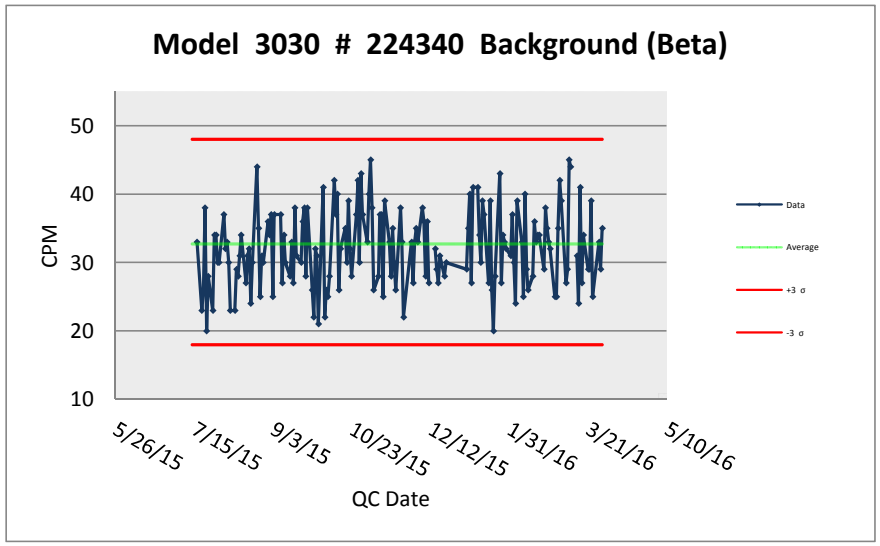
	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency	Total Efficiency**
Alpha	17	1	1	40.60%	32.48%
Beta	91	1	1	32.60%	32.60%

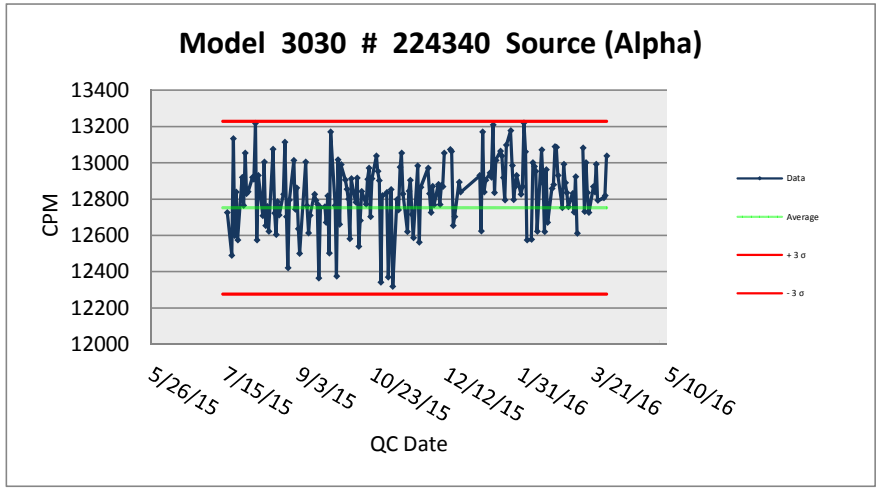
* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency xAbsorb

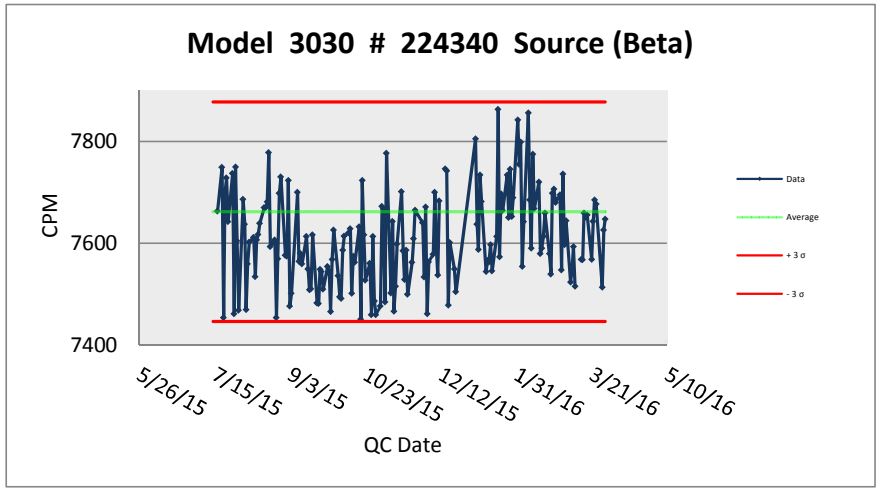
Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
2/29/2016	1	25	12753	7720	1	25	12752	7695	PASS	PASS	PASS	PASS	
3/1/2016	0	25	12991	7572	0	25	12991	7547	PASS	PASS	PASS	PASS	
3/2/2016	0	35	12889	7771	0	35	12889	7736	PASS	PASS	PASS	PASS	
3/3/2016	0	42	12835	7639	0	42	12835	7597	PASS	PASS	PASS	PASS	
3/4/2016	0	39	12757	7683	0	39	12757	7644	PASS	PASS	PASS	PASS	
3/7/2016	0	27	12831	7550	0	27	12831	7523	PASS	PASS	PASS	PASS	
3/8/2016	0	29	12728	7579	0	29	12728	7550	PASS	PASS	PASS	PASS	
3/9/2016	0	45	12923	7638	0	45	12923	7593	PASS	PASS	PASS	PASS	
3/10/2016	0	44	12610	7559	0	44	12610	7515	PASS	PASS	PASS	PASS	
3/11/2016													X
3/14/2016	1	31	13082	7599	1	31	13081	7568	PASS	PASS	PASS	PASS	
3/15/2016	1	24	12731	7591	1	24	12730	7567	PASS	PASS	PASS	PASS	
3/16/2016	0	41	13001	7700	0	41	13001	7659	PASS	PASS	PASS	PASS	
3/17/2016	0	27	12834	7678	0	27	12834	7651	PASS	PASS	PASS	PASS	
3/18/2016	0	34	12726	7689	0	34	12726	7655	PASS	PASS	PASS	PASS	
3/21/2016	0	29	12868	7597	0	29	12868	7568	PASS	PASS	PASS	PASS	
3/22/2016	0	29	12839	7672	0	29	12839	7643	PASS	PASS	PASS	PASS	
3/23/2016	0	39	12991	7724	0	39	12991	7685	PASS	PASS	PASS	PASS	
3/24/2016	0	25	12792	7702	0	25	12792	7677	PASS	PASS	PASS	PASS	
3/28/2016	0	33	12806	7546	0	33	12806	7513	PASS	PASS	PASS	PASS	
3/29/2016	0	29	12818	7655	0	29	12818	7626	PASS	PASS	PASS	PASS	
3/30/2016	0	35	13038	7682	0	35	13038	7647	PASS	PASS	PASS	PASS	

Control Graphs









Background Determination (Alpha)

Instrument Model	Probe Model	Instrument Serial #	Probe Serial #	Calibration Due Date
3030	N/A	224340	N/A	4/21/2016

Surface Type :	Count Table (570 Lab)	
Date Collected :	7/6/2015	
Collected By :	M.Chi	
Count Time :	1	**Minutes**

#	Gross Counts	CPM
1	0	0
2	0	0
3	0	0
4	1	1
5	0	0
6	1	1
7	0	0
8	0	0
9	1	1
10	0	0
Mean:	0.3	0.3
Std Dev:	0.48	

Microsoft Excel® was used for all calculations.

-3 σ Value:	+3 σ Value:
-1	1

Bkgd Count Rate (CPM):	0.3

Completed By :	**Minhsec Chi**	**Date :**	**7/6/2015**
Reviewed By :	**John Massey**	**Date :**	**7/6/2015**

Background Determination (Beta)

Instrument Model	Probe Model	Instrument Serial #	Probe Serial #	Calibration Due Date
3030	N/A	224340	N/A	4/21/2016

Surface Type :	Count Table (570 Lab)	
Date Collected :	7/6/2015	
Collected By :	M.Chi	
Count Time :	1	**Minutes**

#	Gross Counts	CPM
1	32	32
2	30	30
3	36	36
4	38	38
5	35	35
6	38	38
7	34	34
8	24	24
9	24	24
10	36	36
Mean	32.7	32.7
Std Dev:	5.21	

Microsoft Excel® was used for all calculations.

-3 σ Value:	+3 σ Value:
18	48

Background Count Rate:	32.7

Completed By :	**Minhsec Chi**	**Date :**	**7/6/2015**
Reviewed By :	**John Massey**	**Date :**	**7/6/2015**

Source Determination (Alpha)

Instrument Model	Probe Model	Instrument Serial #	Probe Serial #	Calibration Due Date
3030	N/A	224340	N/A	4/21/2016

Source ID #	Source Nuclide	Original Activity (4σ)	Halflife (Years)	Decayed Activity	Source Creation Date
G4-790	Th-230	37,430	75,400	37428.02883	10/14/2009

Date Collected :	7/6/2015	
Collected By :	M.Chi	
Count Time :	1	**Minutes**
Average Bkgd Counts	0.3	

Microsoft Excel® was used for all calculations.

#	(Gross Cnts) CG	(Net Cnts) Cn	(Net CPM) Cl
1	12781	12780.7	12780.7
2	12503	12502.7	12502.7
3	12736	12735.7	12735.7
4	12740	12739.7	12739.7
5	12753	12752.7	12752.7
6	12886	12885.7	12885.7
7	12958	12957.7	12957.7
8	12969	12968.7	12968.7
9	12530	12529.7	12529.7
10	12672	12671.7	12671.7
Mean $\overline{C}$:	12752.8	12752.5	12752.5
Std Dev:	158.606	158.606	

-3 σ Value:	12,277	**+3 σ Value:**	13,228

Completed By :	**Minhsec Chi**	**Date :**	**7/6/2015**
Reviewed By :	**John Massey**	**Date :**	**7/6/2015**

Source Determination (Beta)

Instrument Model	Probe Model	Instrument Serial #	Probe Serial #	Calibration Due Date
3030	N/A	224340	N/A	4/21/2016

Source ID #	Source Nuclide	Original Activity (4σ)	Halflife (Years)	Decayed Activity	Source Creation Date
G4-789	Tc-99	38,670	213,000	38669.27461	10/1/2009

Date Collected :	7/6/2015	
Collected By :	M.Chi	
Count Time :	1	**Minutes**
Average Bkgd Counts	32.7	

Microsoft Excel® was used for all calculations.

#	(Gross Cnts) CG	(Net Cnts) Cn	(Net CPM) Cl
1	7697	7664.3	7664.3
2	7766	7733.3	7733.3
3	7618	7585.3	7585.3
4	7641	7608.3	7608.3
5	7684	7651.3	7651.3
6	7682	7649.3	7649.3
7	7632	7599.3	7599.3
8	7826	7793.3	7793.3
9	7776	7743.3	7743.3
10	7625	7592.3	7592.3
Mean $\overline{C}$:	7694.7	7662.0	7662
Std Dev:	72.09	72.28	

-3 σ Value:	7,446	**+3 σ Value:**	7,878

Completed By :	**Minhsec Chi**	**Date :**	**7/6/2015**
Reviewed By :	**John Massey**	**Date :**	**7/6/2015**

67053

Designer and Manufacturer of Scientific and Industrial Instruments

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.
501 Oak Street
325-235-5494
Sweetwater, TX 79556, U.S.A.
☐ 10744 Dutchtown Road
865-392-4601
Knoxville, TN 37932, U.S.A.

CUSTOMER CB&I ORDER NO. 20263891/418457

Mfg. Ludlum Measurements, Inc. Model 3030 Serial No. 265985

Cal. Date 24-Mar-15 Cal Due Date 24-Mar-16 Cal. Interval 1 Year

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 73 °F RH 32 % Alt 702.8 mm Hg

☐ New Instrument Instrument Received ☑ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☑ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Window Operation

☐ Audio ck.

Alpha Sensitivity 120 mV Beta Sensitivity 4 mV Beta Window 50 mV

☑ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89.

Instrument Volt Set 500 V High Voltage set with detector connected.

☑ HV Readout (2 points) Ref./Inst. 500 / 501 V Ref./Inst. 1200 / 1200 V

Instrument in DPM mode.

QC mode turned ☑ OFF ☐ ON

Firmware version: 39013-27

Overload set at 1/4 turn past OFF.

Battery voltage measured at 12.6 Vdc.

C-14 Efficiency ~ 6.8 %(4 pi) Net

(EEPROM Settings)

(PC) Count Time: 60.0

Alpha Alarm: 999999 cpm

Beta Alarm: 999999 cpm

Alpha/Beta Alarm: 999999 cpm

Calibration Due Date: 3/24/2016

LOC (Loss of Count) time = 30 minutes (default)

Alpha Channel Digital Readout	REFERENCE CAL POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
	400K cpm	40032(0)	40032(0)
	40K cpm	4003	4003
	4K cpm	400	400
	400 cpm	40	40
	40 cpm	4	4

Beta/Gamma Channel Digital Readout	REFERENCE CAL POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
	400K cpm	40028(0)	40028(0)
	40K cpm	4003	4003
	4K cpm	400	400
	400 cpm	40	40
	40 cpm	4	4

*Uncertainty within ± 10% C.F. within ± 20%

(0) indicates 0.1 minute count

COMMENTS:

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978.

State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources:

☑ Alpha S/N Pu239 SN:7053 ☑ Beta S/N Tc99 SN:5280 ☐ Other

☑ m 500 S/N 190566 ☐ Oscilloscope S/N ☑ Multimeter S/N 86250390

Calibrated By: Jason Flan Date 24-Mar-15

Reviewed By: Phil H Date 25 Mar 15

This certificate shall not be reproduced except in full, without the written approval of Ludlum Measurements, Inc.

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed:

Ludlum Measurements, Inc.
Model 3030 Plateau Data

3/24/2015
4:03:27 PM

Header 1: CB&I
Header 2: S/N 265985
Header 3:
Header 4:
Header 5:
Header 6:

Calibration Due Date: 3/17/2016

Model 3030 Date: 3/24/2015
Model 3030 Time: 4:27:30 PM

User PC Time: 60.0

Alpha Isotope: Pu239
Alpha Source Size (dpm): 24900
Alpha Source Size (Bq): 415.0
Alpha Source Size (µCi): 0.011216216

Beta Isotope: Tc99
Beta Source Size (dpm): 93200
Beta Source Size (Bq): 1553.33
Beta Source Size (µCi): 0.041981982

Starting High Voltage: 450
Starting High Voltage: 575
High Voltage Increment: 25

Plateau Count Mode: SCALER
Source Count Time (min): 1.0
Background Count Time (min): 1.0

HV	ALPHA Source	(Beta)	ALPHA Background	Eff	CrossTalk	BETA Source	(Alpha)	BETA Background	Eff	Crosstalk
450	9429	(369)	0	37.9%	3.7%	19357	(35)	20	20.7%	0.2%
475	9865	(298)	0	39.6%	2.7%	24544	(28)	36	26.3%	0.1%
500	10234	(293)	0	41.1%	2.5%	28509	(41)	41	30.5%	0.1%
525	10116	(340)	0	40.6%	2.8%	31866	(49)	56	34.1%	0.2%
550	10232	(277)	0	41.1%	2.2%	33733	(31)	53	36.1%	0.1%
575	10150	(305)	1	40.8%	1.8%	32194	(36)	122	34.4%	0.1%

Ludlum Measurements, Inc.
Model 3030 MDA Calculation Data

3/24/2015
4:03:32 PM

Alpha Background(cpm): 0.0
Beta Background(cpm): 41.0

Alpha Efficiency %: 41.1
Beta Efficiency %: 30.5

Confidence Level: 95%

Count Time	Alpha MDA(dpm)	Beta MDA(dpm)
0.1	65.9	317.9
0.5	13.2	137.4
1.0	6.6	106.6
2.0	3.3	89.0
5.0	1.3	77.4
10.0	0.7	73.3
60.0	0.1	69.8
PC (60.0)	0.1	69.8

Ludlum Measurements, Inc.
Model 3030 Parameters

3/24/2015
4:34:07 PM

Header 1: CB&I
Header 2: S/N 265985
Header 3:
Header 4:
Header 5:
Header 6:

Calibration Due Date: 3/24/2016

Model 3030 Date: 3/24/2015
Model 3030 Time: 4:27:30 PM

Count Time Switch (min): 1.0
User PC Time (min): 60.0

Alpha Alarm: 999999
Beta Alarm: 999999
Alpha + Beta Alarm: 999999

High Voltage (VDC): 500

Loss of Count Time (min): 15.0

Count Mode: SCALER

Alpha Efficiency %: 41.1
Beta Efficiency %: 30.5

Background Subtract: OFF
Alpha Background: 0.0
Beta Background: 48.6

Crosstalk Correction: OFF
Alpha to Beta Crosstalk %: 2.5
Beta to Alpha Crosstalk %: 0.1

Save Parameters during startup: Enabled

Daily QC Check: OFF
Update Efficiency/Background Subtract from QC: OFF
Override QC Count Time: ON

Last Alpha Efficiency %: 39.5
Last Beta Efficiency %: 30.8

Standard Alpha Efficiency %: 41
Standard Beta Efficiency %: 30

Allowable Alpha QC Efficiency ± %: 15
Allowable Beta QC Efficiency ± %: 15

Alpha Source Size (dpm): 24900
Alpha Source Size (Bq): 415.
Alpha Source Size (µCi): 0.01121621622

Beta Source Size (dpm): 93200
Beta Source Size (Bq): 1553.33
Beta Source Size (µCi): 0.04198198198

Alpha QC Count Time (min): 1.0
Beta QC Count Time (min): 1.0
Background QC Count Time (min): 1.0

Last Alpha QC Background: 0.0
Last Beta QC Background: 48.6

Alpha Background Upper Limit (cpm): 10.0
Alpha Background Lower Limit (cpm): 0.0
Beta Background Upper Limit (cpm): 100.0
Beta Background Lower Limit (cpm): 0.0

Next Sample Number: FULL
User defined Comment:
Logging Mode: Log All
Recycle Mode: OFF
Printer Mode: OFF

CB&I Federal Services

Instrument Model :	3030	Instrument Serial # :	265985	Calibration Date :	3/24/2015	Recommended MDC	
Probe Model :	N/A	Probe Serial # :	N/A	Calibration Due Date:	3/24/2016	Alpha	18
				Calibration :	SEND FOR CAL	Beta	200

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency**	Total Efficiency***
Alpha	15	1	1	41.1%	32.9%
Beta	95	1	1	30.5%	30.5%

* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency provide
*** Instrument Efficiency xAbsor
Asorbtion factor for beta is 1

*Any dates not represented indicates instrument not used.

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
6/9/2015	0	37	12637	7416	0	37	12637	7379	PASS	PASS	PASS	PASS	
6/10/2015	0	23	12303	7302	0	23	12303	7279	PASS	PASS	PASS	PASS	
6/11/2015	0	21	12357	7370	0	21	12357	7349	PASS	PASS	PASS	PASS	
6/12/2015	0	31	12207	7378	0	31	12207	7347	PASS	PASS	PASS	PASS	
6/15/2015	1	31	12130	7274	1	31	12129	7243	PASS	PASS	PASS	PASS	
6/16/2015	0	27	12424	7387	0	27	12424	7360	PASS	PASS	PASS	PASS	
6/17/2015	0	36	12227	7448	0	36	12227	7412	PASS	PASS	PASS	PASS	
6/18/2015	1	24	12209	7446	1	24	12208	7422	PASS	PASS	PASS	PASS	
6/19/2015	0	27	12385	7455	0	27	12385	7428	PASS	PASS	PASS	PASS	
6/20/2015	1	23	12459	7464	1	23	12458	7441	PASS	PASS	PASS	PASS	
6/21/2015	0	38	12205	7432	0	38	12205	7394	PASS	PASS	PASS	PASS	
6/22/2015	0	27	12731	7433	0	27	12731	7406	PASS	PASS	PASS	PASS	
6/23/2015	0	23	12414	7415	0	23	12414	7392	PASS	PASS	PASS	PASS	
6/24/2015	0	23	12293	7371	0	23	12293	7348	PASS	PASS	PASS	PASS	
6/25/2015	1	31	12707	7305	1	31	12706	7274	PASS	PASS	PASS	PASS	
6/26/2015	1	31	12388	7350	1	31	12387	7319	PASS	PASS	PASS	PASS	
6/29/2015	0	33	12444	7319	0	33	12444	7286	PASS	PASS	PASS	PASS	
6/30/2015	0	31	12426	7399	0	31	12426	7368	PASS	PASS	PASS	PASS	
7/1/2015	0	29	12419	7317	0	29	12419	7288	PASS	PASS	PASS	PASS	
7/2/2015	0	26	12506	7318	0	26	12506	7292	PASS	PASS	PASS	PASS	
7/6/2015	0	28	12270	7345	0	28	12270	7317	PASS	PASS	PASS	PASS	
7/7/2015	0	31	12460	7441	0	31	12460	7410	PASS	PASS	PASS	PASS	
7/8/2015	1	31	12381	7343	1	31	12380	7312	PASS	PASS	PASS	PASS	

CB&I Federal Services

Instrument Model :	3030	**Instrument Serial # :**	265985	**Calibration Date :**	3/24/2015	**Recommended MDC**	
Probe Model :	N/A	**Probe Serial # :**	N/A	**Calibration Due Date:**	3/24/2016	**Alpha**	18
		***Active Detector Area:**	0	**Calibration :**	SEND FOR CAL	**Beta**	200

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency	Total Efficiency**
Alpha	15	1	1	41.10%	32.88%
Beta	95	1	1	30.50%	30.50%

* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency xAbsorb

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
7/9/2015	1	28	12205	7393	1	28	12204	7365	PASS	PASS	PASS	PASS	
7/10/2015	0	26	12523	7250	0	26	12523	7224	PASS	PASS	PASS	PASS	
7/13/2015	0	27	12571	7380	0	27	12571	7353	PASS	PASS	PASS	PASS	
7/14/2015	0	38	12195	7407	0	38	12195	7369	PASS	PASS	PASS	PASS	
7/15/2015	0	30	12408	7360	0	30	12408	7330	PASS	PASS	PASS	PASS	
7/16/2015	0	26	12450	7387	0	26	12450	7361	PASS	PASS	PASS	PASS	
7/17/2015	0	27	12441	7340	0	27	12441	7313	PASS	PASS	PASS	PASS	
7/20/2015	0	28	12304	7294	0	28	12304	7266	PASS	PASS	PASS	PASS	
7/21/2015	0	33	12485	7315	0	33	12485	7282	PASS	PASS	PASS	PASS	
7/22/2015	1	31	12545	7332	1	31	12544	7301	PASS	PASS	PASS	PASS	
7/23/2015	0	30	12679	7280	0	30	12679	7250	PASS	PASS	PASS	PASS	
7/24/2015	0	26	12337	7340	0	26	12337	7314	PASS	PASS	PASS	PASS	
7/27/2015	0	31	12442	7373	0	31	12442	7342	PASS	PASS	PASS	PASS	
7/28/2015	0	32	12285	7263	0	32	12285	7231	PASS	PASS	PASS	PASS	
7/29/2015	0	29	12558	7483	0	29	12558	7454	PASS	PASS	PASS	PASS	
7/30/2015	0	32	12684	7245	0	32	12684	7213	PASS	PASS	PASS	PASS	
7/31/2015	0	25	12262	7472	0	25	12262	7447	PASS	PASS	PASS	PASS	
8/3/2015	0	21	12656	7368	0	21	12656	7347	PASS	PASS	PASS	PASS	
8/4/2015	0	28	12490	7438	0	28	12490	7410	PASS	PASS	PASS	PASS	
8/5/2015	0	31	12596	7423	0	31	12596	7392	PASS	PASS	PASS	PASS	
8/6/2015	0	23	12248	7280	0	23	12248	7257	PASS	PASS	PASS	PASS	
8/7/2015	0	34	12311	7367	0	34	12311	7333	PASS	PASS	PASS	PASS	
8/10/2015	0	31	12163	7346	0	31	12163	7315	PASS	PASS	PASS	PASS	
8/11/2015	0	28	12329	7238	0	28	12329	7210	PASS	PASS	PASS	PASS	
8/12/2015	0	30	12175	7399	0	30	12175	7369	PASS	PASS	PASS	PASS	
8/13/2015	0	33	12352	7284	0	33	12352	7251	PASS	PASS	PASS	PASS	

265985 Cal Due 03-24-2016

CB&I Federal Services

Instrument Model :	3030	Instrument Serial # :	265985	Calibration Date :	3/24/2015	Recommended MDC	
Probe Model :	N/A	Probe Serial # :	N/A	Calibration Due Date:	3/24/2016	Alpha	18
		*Active Detector Area:	0	Calibration :	SEND FOR CAL	Beta	200

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency	Total Efficiency**
Alpha	15	1	1	41.10%	32.88%
Beta	95	1	1	30.50%	30.50%

* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency xAbsorb

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
8/14/2015	0	30	12119	7404	0	30	12119	7374	PASS	PASS	PASS	PASS	
8/17/2015	0	36	12135	7291	0	36	12135	7255	PASS	PASS	PASS	PASS	
8/18/2015	0	27	12292	7410	0	27	12292	7383	PASS	PASS	PASS	PASS	
8/19/2015	0	32	12169	7376	0	32	12169	7344	PASS	PASS	PASS	PASS	
8/20/2015	0	27	12308	7250	0	27	12308	7223	PASS	PASS	PASS	PASS	
8/21/2015	0	29	12310	7397	0	29	12310	7368	PASS	PASS	PASS	PASS	
8/24/2015	0	27	12192	7447	0	27	12192	7420	PASS	PASS	PASS	PASS	
8/25/2015	0	40	12206	7308	0	40	12206	7268	PASS	PASS	PASS	PASS	
8/26/2015	1	23	12375	7452	1	23	12374	7429	PASS	PASS	PASS	PASS	
8/27/2015	0	21	12507	7334	0	21	12507	7313	PASS	PASS	PASS	PASS	
8/28/2015	0	23	12255	7286	0	23	12255	7263	PASS	PASS	PASS	PASS	
8/31/2015	1	29	12703	7258	1	29	12702	7229	PASS	PASS	PASS	PASS	
9/1/2015	0	34	12192	7433	0	34	12192	7399	PASS	PASS	PASS	PASS	
9/2/2015	0	29	12506	7409	0	29	12506	7380	PASS	PASS	PASS	PASS	
9/3/2015	0	34	12413	7439	0	34	12413	7405	PASS	PASS	PASS	PASS	
9/4/2015	0	28	12317	7374	0	28	12317	7346	PASS	PASS	PASS	PASS	
9/8/2015	0	35	12476	7311	0	35	12476	7276	PASS	PASS	PASS	PASS	
9/9/2015	0	26	12321	7296	0	26	12321	7270	PASS	PASS	PASS	PASS	
9/10/2015	1	22	12261	7255	1	22	12260	7233	PASS	PASS	PASS	PASS	
9/11/2015	0	24	12343	7263	0	24	12343	7239	PASS	PASS	PASS	PASS	
9/14/2015	1	24	12269	7256	1	24	12268	7232	PASS	PASS	PASS	PASS	
9/15/2015	0	30	12183	7288	0	30	12183	7258	PASS	PASS	PASS	PASS	
9/16/2015	0	37	12289	7473	0	37	12289	7436	PASS	PASS	PASS	PASS	
9/17/2015	1	36	12619	7355	1	36	12618	7319	PASS	PASS	PASS	PASS	
9/18/2015	0	32	12247	7306	0	32	12247	7274	PASS	PASS	PASS	PASS	
9/21/2015	0	21	12381	7286	0	21	12381	7265	PASS	PASS	PASS	PASS	

CB&I Federal Services

Instrument Model :	3030	Instrument Serial # :	265985	Calibration Date :	3/24/2015	Recommended MDC	
Probe Model :	N/A	Probe Serial # :	N/A	Calibration Due Date:	3/24/2016	Alpha	18
		*Active Detector Area:	0	Calibration :	SEND FOR CAL	Beta	200

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency	Total Efficiency**
Alpha	15	1	1	41.10%	32.88%
Beta	95	1	1	30.50%	30.50%

* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency xAbsorb

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
9/22/2015	0	36	12242	7405	0	36	12242	7369	PASS	PASS	PASS	PASS	
9/23/2015	0	37	12495	7253	0	37	12495	7216	PASS	PASS	PASS	PASS	
9/24/2015	0	34	12234	7483	0	34	12234	7449	PASS	PASS	PASS	PASS	
9/25/2015	0	21	12437	7327	0	21	12437	7306	PASS	PASS	PASS	PASS	
9/28/2015	0	28	12208	7363	0	28	12208	7335	PASS	PASS	PASS	PASS	
9/29/2015	1	31	12244	7428	1	31	12243	7397	PASS	PASS	PASS	PASS	
9/30/2015	0	22	12258	7447	0	22	12258	7425	PASS	PASS	PASS	PASS	
10/1/2015	0	29	12394	7390	0	29	12394	7361	PASS	PASS	PASS	PASS	
10/2/2015	0	30	12401	7293	0	30	12401	7263	PASS	PASS	PASS	PASS	
10/5/2015	1	30	12311	7246	1	30	12310	7216	PASS	PASS	PASS	PASS	
10/6/2015	0	30	12228	7299	0	30	12228	7269	PASS	PASS	PASS	PASS	
10/7/2015	0	35	12182	7276	0	35	12182	7241	PASS	PASS	PASS	PASS	
10/8/2015	1	28	12260	7281	1	28	12259	7253	PASS	PASS	PASS	PASS	
10/9/2015	0	31	12258	7351	0	31	12258	7320	PASS	PASS	PASS	PASS	
10/12/2015	0	30	12283	7355	0	30	12283	7325	PASS	PASS	PASS	PASS	
10/13/2015	0	29	12270	7357	0	29	12270	7328	PASS	PASS	PASS	PASS	
10/14/2015	0	26	12609	7347	0	26	12609	7321	PASS	PASS	PASS	PASS	
10/15/2015	0	24	12698	7269	0	24	12698	7245	PASS	PASS	PASS	PASS	
10/16/2015	0	30	12465	7453	0	30	12465	7423	PASS	PASS	PASS	PASS	
10/19/2015	0	26	12563	7257	0	26	12563	7231	PASS	PASS	PASS	PASS	
10/20/2015	0	33	12562	7368	0	33	12562	7335	PASS	PASS	PASS	PASS	
10/21/2015	0	41	12468	7335	0	41	12468	7294	PASS	PASS	PASS	PASS	
10/22/2015	0	34	12565	7349	0	34	12565	7315	PASS	PASS	PASS	PASS	
10/23/2015	0	31	12597	7321	0	31	12597	7290	PASS	PASS	PASS	PASS	
10/26/2015	0	30	12325	7305	0	30	12325	7275	PASS	PASS	PASS	PASS	
10/27/2015	0	33	12470	7362	0	33	12470	7329	PASS	PASS	PASS	PASS	

CB&I Federal Services

Instrument Model :	3030	Instrument Serial # :	265985	Calibration Date :	3/24/2015	Recommended MDC	
Probe Model :	N/A	Probe Serial # :	N/A	Calibration Due Date:	3/24/2016	Alpha	18
		*Active Detector Area:	0	Calibration :	SEND FOR CAL	Beta	200

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency	Total Efficiency**
Alpha	15	1	1	41.10%	32.88%
Beta	95	1	1	30.50%	30.50%

* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency xAbsorb

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
10/28/2015	0	31	12275	7366	0	31	12275	7335	PASS	PASS	PASS	PASS	
10/29/2015	0	27	12667	7298	0	27	12667	7271	PASS	PASS	PASS	PASS	
10/30/2015	1	35	12227	7291	1	35	12226	7256	PASS	PASS	PASS	PASS	
11/2/2015	0	33	12524	7379	0	33	12524	7346	PASS	PASS	PASS	PASS	
11/3/2015	0	33	12552	7309	0	33	12552	7276	PASS	PASS	PASS	PASS	
11/4/2015	0	27	12538	7482	0	27	12538	7455	PASS	PASS	PASS	PASS	
11/5/2015	0	28	12580	7366	0	28	12580	7338	PASS	PASS	PASS	PASS	
11/6/2015	0	23	12384	7297	0	23	12384	7274	PASS	PASS	PASS	PASS	
11/9/2015	0	26	12867	7456	0	26	12867	7430	PASS	PASS	PASS	PASS	
11/10/2015	0	27	12222	7479	0	27	12222	7452	PASS	PASS	PASS	PASS	
11/11/2015	0	39	12356	7478	0	39	12356	7439	PASS	PASS	PASS	PASS	
11/12/2015	0	34	12390	7464	0	34	12390	7430	PASS	PASS	PASS	PASS	
11/13/2015	0	31	12323	7473	0	31	12323	7442	PASS	PASS	PASS	PASS	
11/16/2015	0	36	12267	7380	0	36	12267	7344	PASS	PASS	PASS	PASS	
11/17/2015	0	27	12422	7264	0	27	12422	7237	PASS	PASS	PASS	PASS	
11/18/2015	0	38	12571	7352	0	38	12571	7314	PASS	PASS	PASS	PASS	
11/19/2015	0	35	12628	7428	0	35	12628	7393	PASS	PASS	PASS	PASS	
11/20/2015	0	30	12454	7379	0	30	12454	7349	PASS	PASS	PASS	PASS	
11/23/2015	0	34	12419	7438	0	34	12419	7404	PASS	PASS	PASS	PASS	
11/24/2015	0	39	12276	7469	0	39	12276	7430	PASS	PASS	PASS	PASS	
11/25/2015	1	24	12271	7287	1	24	12270	7263	PASS	PASS	PASS	PASS	
11/30/2015	0	29	12608	7386	0	29	12608	7357	PASS	PASS	PASS	PASS	
12/1/2015	0	31	12163	7315	0	31	12163	7284	PASS	PASS	PASS	PASS	
12/2/2015	0	22	12337	7418	0	22	12337	7396	PASS	PASS	PASS	PASS	
12/3/2015	0	38	12262	7449	0	38	12262	7411	PASS	PASS	PASS	PASS	
12/4/2015	0	24	12317	7273	0	24	12317	7249	PASS	PASS	PASS	PASS	

CB&I Federal Services

Instrument Model :	3030	Instrument Serial # :	265985	Calibration Date :	3/24/2015	Recommended MDC	
Probe Model :	N/A	Probe Serial # :	N/A	Calibration Due Date:	3/24/2016	Alpha	18
		*Active Detector Area:	0	Calibration :	SEND FOR CAL	Beta	200

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency	Total Efficiency**
Alpha	15	1	1	41.10%	32.88%
Beta	95	1	1	30.50%	30.50%

* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency xAbsorb

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		Inst. Not Used
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
12/7/2015	0	25	12176	7368	0	25	12176	7343	PASS	PASS	PASS	PASS	
12/8/2015	0	38	12314	7468	0	38	12314	7430	PASS	PASS	PASS	PASS	
12/9/2015	0	32	12520	7401	0	32	12520	7369	PASS	PASS	PASS	PASS	
12/10/2015	0	35	12300	7413	0	35	12300	7378	PASS	PASS	PASS	PASS	
12/11/2015	0	34	12492	7321	0	34	12492	7287	PASS	PASS	PASS	PASS	
12/14/2015													X
12/15/2015	0	32	12158	7452	0	32	12158	7420	PASS	PASS	PASS	PASS	
12/16/2015	0	23	12423	7266	0	23	12423	7243	PASS	PASS	PASS	PASS	
12/17/2015	1	33	12523	7428	1	33	12522	7395	PASS	PASS	PASS	PASS	
12/18/2015	0	32	12138	7341	0	32	12138	7309	PASS	PASS	PASS	PASS	
12/21/2015	0	34	12419	7300	0	34	12419	7266	PASS	PASS	PASS	PASS	
12/22/2015	0	27	12601	7304	0	27	12601	7277	PASS	PASS	PASS	PASS	
1/4/2016	0	26	12460	7438	0	26	12460	7412	PASS	PASS	PASS	PASS	
1/5/2016	0	37	12407	7342	0	37	12407	7305	PASS	PASS	PASS	PASS	
1/6/2016	0	36	12737	7410	0	36	12737	7374	PASS	PASS	PASS	PASS	
1/7/2016	0	30	12471	7285	0	30	12471	7255	PASS	PASS	PASS	PASS	
1/8/2016	0	23	12344	7333	0	23	12344	7310	PASS	PASS	PASS	PASS	
1/11/2016	0	21	12371	7366	0	21	12371	7345	PASS	PASS	PASS	PASS	
1/12/2016	0	31	12360	7399	0	31	12360	7368	PASS	PASS	PASS	PASS	
1/13/2016	0	27	12268	7419	0	27	12268	7392	PASS	PASS	PASS	PASS	
1/14/2016	0	24	12291	7455	0	24	12291	7431	PASS	PASS	PASS	PASS	
1/15/2016	1	26	12276	7424	1	26	12275	7398	PASS	PASS	PASS	PASS	
1/18/2016	0	36	12187	7327	0	36	12187	7291	PASS	PASS	PASS	PASS	
1/19/2016	0	35	12330	7393	0	35	12330	7358	PASS	PASS	PASS	PASS	
1/20/2016	0	31	12324	7419	0	31	12324	7388	PASS	PASS	PASS	PASS	
1/21/2016	0	37	12419	7401	0	37	12419	7364	PASS	PASS	PASS	PASS	

CB&I Federal Services

Instrument Model :	3030	Instrument Serial # :	265985	Calibration Date :	3/24/2015	Recommended MDC	
Probe Model :	N/A	Probe Serial # :	N/A	Calibration Due Date:	3/24/2016	Alpha	18
		*Active Detector Area:	0	Calibration :	SEND FOR CAL	Beta	200

	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency	Total Efficiency**
Alpha	15	1	1	41.10%	32.88%
Beta	95	1	1	30.50%	30.50%

* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency xAbsorb

Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
1/22/2016	0	27	12285	7347	0	27	12285	7320	PASS	PASS	PASS	PASS	
1/25/2016	0	24	12190	7388	0	24	12190	7364	PASS	PASS	PASS	PASS	
1/26/2016	0	23	12329	7390	0	23	12329	7367	PASS	PASS	PASS	PASS	
1/27/2016	0	24	12291	7426	0	24	12291	7402	PASS	PASS	PASS	PASS	
1/28/2016	0	21	12453	7429	0	21	12453	7408	PASS	PASS	PASS	PASS	
1/29/2016	0	33	12285	7275	0	33	12285	7242	PASS	PASS	PASS	PASS	
2/1/2016	1	36	12189	7261	1	36	12188	7225	PASS	PASS	PASS	PASS	
2/2/2016	0	34	12228	7390	0	34	12228	7356	PASS	PASS	PASS	PASS	
2/3/2016	0	32	12457	7380	0	32	12457	7348	PASS	PASS	PASS	PASS	
2/4/2016	0	21	12206	7393	0	21	12206	7372	PASS	PASS	PASS	PASS	
2/5/2016	0	34	12316	7346	0	34	12316	7312	PASS	PASS	PASS	PASS	
2/8/2016	0	25	12298	7305	0	25	12298	7280	PASS	PASS	PASS	PASS	
2/9/2016	0	25	12295	7258	0	25	12295	7233	PASS	PASS	PASS	PASS	
2/10/2016	1	30	12381	7268	1	30	12380	7238	PASS	PASS	PASS	PASS	
2/11/2016	0	29	12281	7346	0	29	12281	7317	PASS	PASS	PASS	PASS	
2/12/2016	0	26	12163	7265	0	26	12163	7239	PASS	PASS	PASS	PASS	
2/15/2016	1	28	12380	7436	1	28	12379	7408	PASS	PASS	PASS	PASS	
2/16/2016	0	35	12495	7373	0	35	12495	7338	PASS	PASS	PASS	PASS	
2/17/2016	1	33	12400	7314	1	33	12399	7281	PASS	PASS	PASS	PASS	
2/18/2016	0	36	12464	7318	0	36	12464	7282	PASS	PASS	PASS	PASS	
2/19/2016	0	26	12451	7263	0	26	12451	7237	PASS	PASS	PASS	PASS	
2/22/2016	0	34	12411	7264	0	34	12411	7230	PASS	PASS	PASS	PASS	
2/23/2016	1	32	12332	7286	1	32	12331	7254	PASS	PASS	PASS	PASS	
2/24/2016	0	22	12215	7332	0	22	12215	7310	PASS	PASS	PASS	PASS	
2/25/2016	0	37	12236	7472	0	37	12236	7435	PASS	PASS	PASS	PASS	
2/26/2016	0	25	12235	7311	0	25	12235	7286	PASS	PASS	PASS	PASS	

CB&I Federal Services

Instrument Model :	3030	Instrument Serial # :	265985	Calibration Date :	3/24/2015	Recommended MDC	
Probe Model :	N/A	Probe Serial # :	N/A	Calibration Due Date:	3/24/2016	Alpha	18
		*Active Detector Area:	0	Calibration :	SEND FOR CAL	Beta	200

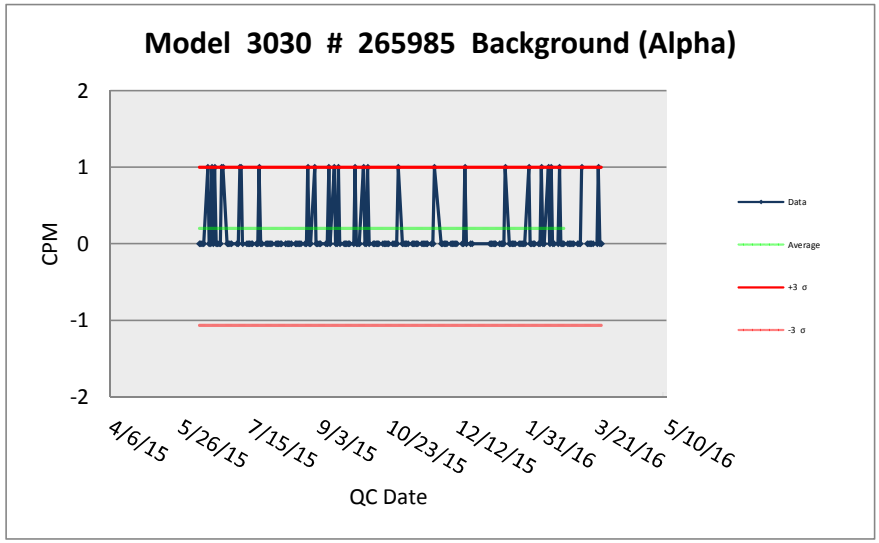
	MDC (DPM/ 100cm^2)	Bkgd. Count Time	Source Count Time	Instrument Efficiency	Total Efficiency**
Alpha	15	1	1	41.10%	32.88%
Beta	95	1	1	30.50%	30.50%

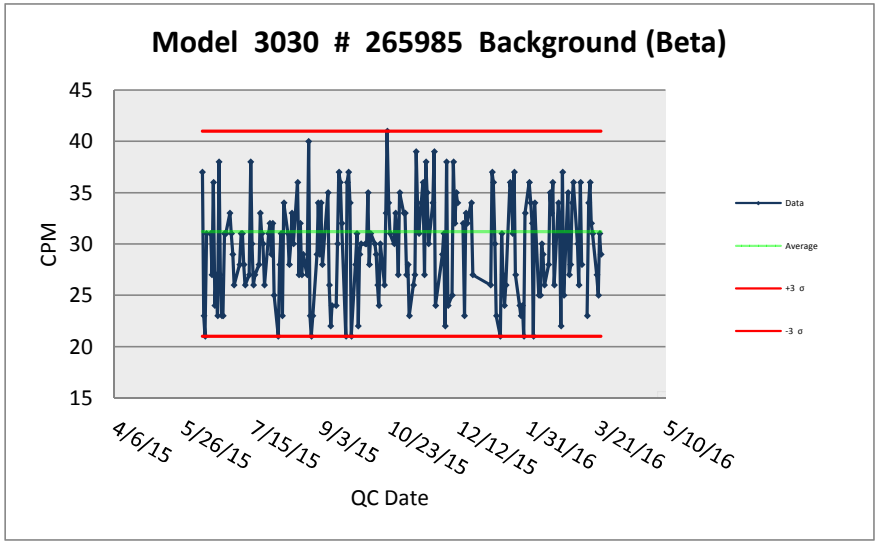
* For Ludlum 3030, the Active De
Area is equal to the smear area (
** Instrument Efficiency xAbsorb

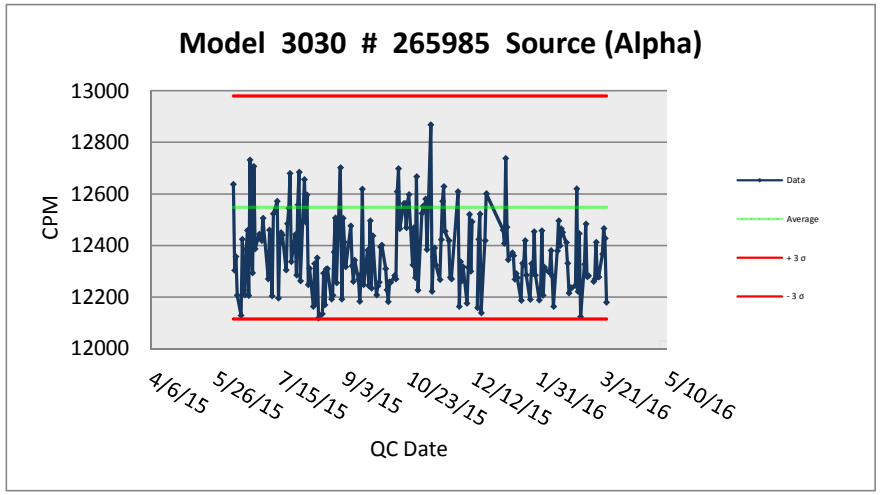
Date	Daily Bkgd.		Daily Source		Daily Bkgd. Rate CPM		Net Source		Bkgd. Pass/Fail		Source Pass/Fail		
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	
2/29/2016	0	35	12245	7242	0	35	12245	7207	PASS	PASS	PASS	PASS	
3/1/2016	0	27	12620	7366	0	27	12620	7339	PASS	PASS	PASS	PASS	
3/2/2016	0	28	12222	7288	0	28	12222	7260	PASS	PASS	PASS	PASS	
3/3/2016	0	34	12446	7326	0	34	12446	7292	PASS	PASS	PASS	PASS	
3/4/2016	0	36	12123	7309	0	36	12123	7273	PASS	PASS	PASS	PASS	
3/7/2016	0	30	12327	7273	0	30	12327	7243	PASS	PASS	PASS	PASS	
3/8/2016	0	26	12483	7347	0	26	12483	7321	PASS	PASS	PASS	PASS	
3/9/2016	0	36	12279	7339	0	36	12279	7303	PASS	PASS	PASS	PASS	
3/10/2016	1	28	12283	7357	1	28	12282	7329	PASS	PASS	PASS	PASS	
3/11/2016													X
3/14/2016	0	23	12260	7258	0	23	12260	7235	PASS	PASS	PASS	PASS	
3/15/2016	0	34	12270	7307	0	34	12270	7273	PASS	PASS	PASS	PASS	
3/16/2016	0	36	12412	7374	0	36	12412	7338	PASS	PASS	PASS	PASS	
3/17/2016	0	32	12292	7241	0	32	12292	7209	PASS	PASS	PASS	PASS	
3/18/2016	0	31	12277	7394	0	31	12277	7363	PASS	PASS	PASS	PASS	
3/21/2016	0	27	12366	7440	0	27	12366	7413	PASS	PASS	PASS	PASS	
3/22/2016	1	25	12467	7234	1	25	12466	7209	PASS	PASS	PASS	PASS	
3/23/2016	0	31	12427	7268	0	31	12427	7237	PASS	PASS	PASS	PASS	
~~3/24/2016~~	0	29	12179	7267	0	29	12179	7238	PASS	PASS	PASS	PASS	X (final check prior to ship)

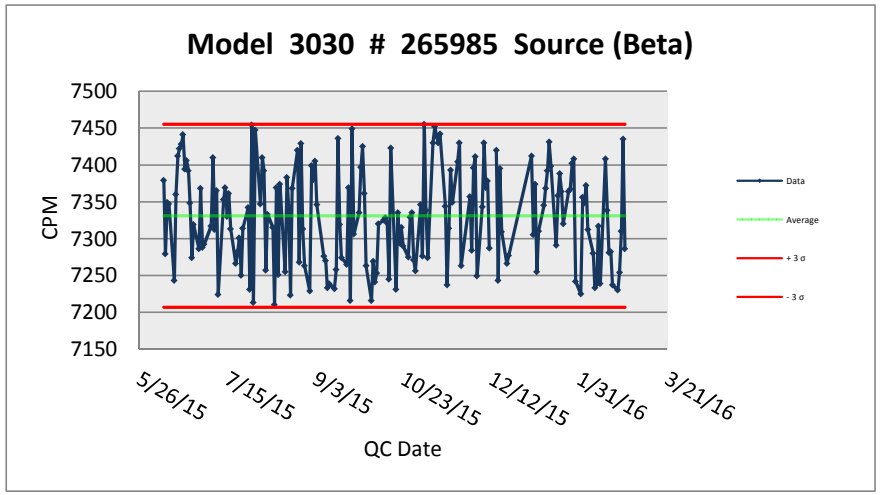
265985 Cal Due 03-24-2016

Control Graphs









265985 Cal Due 03-24-2016

Background Determination (Alpha)

Instrument Model	Probe Model	Instrument Serial #	Probe Serial #	Calibration Due Date
3030	N/A	265985	N/A	3/24/2016

Surface Type :	Count Table (570 Lab)	
Date Collected :	6/8/2015	
Collected By :	T.Ibuki	
Count Time :	1	**Minutes**

#	Gross Counts	CPM
1	1	1
2	0	0
3	0	0
4	0	0
5	1	1
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
Mean:	0.2	0.2
Std Dev:	0.42	

Microsoft Excel® was used for all calculations.

-3 σ Value:
-1

+3 σ Value:
1

Bkgd Count Rate (CPM):	0.2

Completed By :	**Takeshi Ibuki**	**Date :**	**6/8/2015**

Reviewed By :	**John Massey**	**Date :**	**6/8/2015**

Background Determination (Beta)

Instrument Model	Probe Model	Instrument Serial #	Probe Serial #	Calibration Due Date
3030	N/A	265985	N/A	3/24/2016

Surface Type :	Count Table (570 Lab)	
Date Collected :	6/8/2015	
Collected By :	T.Ibuki	
Count Time :	1	**Minutes**

#	Gross Counts	CPM
1	33	33
2	33	33
3	35	35
4	27	27
5	32	32
6	26	26
7	36	36
8	33	33
9	27	27
10	30	30
Mean	31.2	31.2
Std Dev:	3.52	

Microsoft Excel® was used for all calculations.

-3 σ Value:
21

+3 σ Value:
41

Background Count Rate:	31.2

Completed By :	**Takeshi Ibuki**	**Date :**	**6/8/2015**
Reviewed By :	**John Massey**	**Date :**	**6/8/2015**

Source Determination (Alpha)

Instrument Model	Probe Model	Instrument Serial #	Probe Serial #	Calibration Due Date
3030	N/A	265985	N/A	3/24/2016

Source ID #	Source Nuclide	Original Activity (4σ)	Halflife (Years)	Decayed Activity	Source Creation Date
G4-790	Th-230	37,430	75,400	37428.05523	10/14/2009

Date Collected :	6/8/2015	
Collected By :	T.Ibuki	
Count Time :	1	**Minutes**
Average Bkgd Counts	0.2	

Microsoft Excel® was used for all calculations.

#	(Gross Cnts) CG	(Net Cnts) Cn	(Net CPM) Cl
1	12635	12634.8	12634.8
2	12550	12549.8	12549.8
3	12676	12675.8	12675.8
4	12463	12462.8	12462.8
5	12676	12675.8	12675.8
6	12243	12242.8	12242.8
7	12459	12458.8	12458.8
8	12607	12606.8	12606.8
9	12456	12455.8	12455.8
10	12712	12711.8	12711.8
Mean $\overline{C}$:	12547.7	12547.5	12547.5
Std Dev:	144.281	144.281	

-3 σ Value:	12,115	**+3 σ Value:**	12,980

Completed By :	**Takeshi Ibuki**	**Date :**	**6/8/2015**
Reviewed By :	**John Massey**	**Date :**	**6/8/2015**

265985 Cal Due 03-24-2016

Source Determination (Beta)

Instrument Model	Probe Model	Instrument Serial #	Probe Serial #	Calibration Due Date
3030	N/A	265985	N/A	3/24/2016

Source ID #	Source Nuclide	Original Activity (4σ)	Halflife (Years)	Decayed Activity	Source Creation Date
G4-789	Tc-99	38,670	213,000	38669.28427	10/1/2009

Date Collected :	6/8/2015	
Collected By :	T.Ibuki	
Count Time :	1	**Minutes**
Average Bkgd Counts	31.2	

Microsoft Excel® was used for all calculations.

#	(Gross Cnts) CG	(Net Cnts) Cn	(Net CPM) Cl
1	7384	7352.8	7352.8
2	7438	7406.8	7406.8
3	7387	7355.8	7355.8
4	7360	7328.8	7328.8
5	7384	7352.8	7352.8
6	7342	7310.8	7310.8
7	7362	7330.8	7330.8
8	7355	7323.8	7323.8
9	7281	7249.8	7249.8
10	7330	7298.8	7298.8
Mean $\overline{C}$:	7362.3	7331.1	7331.1
Std Dev:	41.37	41.52	

-3 σ Value:	7,207	**+3 σ Value:**	7,455

Completed By :	**Takeshi Ibuki**	**Date :**	**6/8/2015**
Reviewed By :	**John Massey**	**Date :**	**6/8/2015**

265985 Cal Due 03-24-2016

RADIATION SOLUTIONS INC

CALIBRATION SHEET

Instrument: **RSX-1**

Customer: CB&I
Contact:
Console : 7236
Detector 1: 5447
Detector 2: 5448

Date: Feb. 26, 2014
Tech.: GP
Job Order: SO#2634
Customer PO PO#1105766-000 OP

Channels: 1024 **ADC Offset:** N/A

	A1	A2	A3	A4	A5
High Voltages	595	619			

Stripping Constant	"this system"	"normal"
Alpha	**0.268**	0.250
Beta	**0.401**	0.400
Gamma	**0.744**	0.810
a	**0.049**	0.060
b	**0.001**	0.000
g	**-0.001**	0.003

ROI#	Channel	IAEA Specification [keV]	Label
1	137-937	410-2810	Total Count
2	457-523	1370-1570	Potassium K
3	553-620	1660-1860	Uranium U
4	803-937	2410-2810	Thorium Th
5			
6			
7			
8	553-620	1660-1860	Uranium Upper U

Det#	Peak Cs	Cs FWHM		Peak Th	Th FWHM
A1	220.15	7.53		872.98	4.50
A2	220.28	7.20		873.19	4.28
A3					
A4					
Sum Dn	**220.23**	**7.35**		**873.08**	**4.37**
Sum Up					

386 Watline Avenue Mississauga ♦ Ontario Canada L4Z 1X2 ♦ Tel (905) 890 1111 ♦ Fax (905) 890 1964 ♦ e-mail sales@radiationsolutions.ca

February 2016 RSI-700 Cs-137 System Test Log

Date	Detector 1				Detector 2				Detector 1+2				RCT	QC
	Peak	+/-	FWHM	+/-	Peak	+/-	FWHM	+/-	Peak	+/-	FWHM	+/-	Initials	Initials
Cal	**220.15**		**7.53**		**220.28**		**7.2**		**220.23**		**7.35**			
2/1/2016	220.70	0.068	7.68	0.155	219.52	0.063	7.67	0.144	220.10	0.054	7.67	0.123	AO	LMC
2/8/2016	220.71	0.046	7.62	0.105	219.76	0.051	7.51	0.116	220.24	0.036	7.52	0.087	AO	LMC
2/9/2016	220.73	0.035	7.70	0.081	219.62	0.038	7.46	0.084	220.17	0.025	7.58	0.056	AO	LMC
2/10/2016	220.66	0.038	7.73	0.087	219.96	0.054	7.43	0.119	220.34	0.030	7.54	0.071	AO	LMC
2/11/2016	220.55	0.030	7.63	0.068	220.08	0.053	7.55	0.120	220.33	0.034	7.56	0.081	AO	LMC
2/12/2016	220.48	0.041	7.60	0.100	219.95	0.044	7.43	0.099	220.20	0.031	7.54	0.070	AO	LMC
2/15/2016	220.55	0.058	7.69	0.133	220.10	0.052	7.47	0.118	220.34	0.047	7.58	0.115	TW	TI
2/16/2016	220.53	0.060	7.71	0.139	219.89	0.038	7.45	0.086	220.21	0.043	7.58	0.098	TW	TI
2/17/2016	220.44	0.041	7.66	0.094	220.22	0.048	7.43	0.113	220.34	0.036	7.55	0.087	JG	LMC
2/22/2016	220.90	0.045	7.57	0.103	219.58	0.053	7.52	0.120	220.22	0.038	7.59	0.087	AO	LMC
2/23/2016	220.73	0.046	7.65	0.105	219.92	0.054	7.49	0.120	220.34	0.029	7.55	0.070	AO	LMC
2/24/2016	220.54	0.050	7.62	0.114	219.69	0.051	7.54	0.114	220.10	0.040	7.57	0.090	AO	LMC
2/25/2016	220.57	0.039	7.71	0.090	220.71	0.055	7.57	0.124	220.64	0.038	7.64	0.087	AO	LMC
2/26/2016	220.71	0.050	7.78	0.117	219.19	0.053	7.47	0.119	220.29	0.043	7.63	0.097	AO	LMC
2/29/2016	220.80	0.037	7.74	0.085	219.39	0.051	7.47	0.120	220.04	0.037	7.62	0.084	AO	LMC

System Test Parameters		
Parameter	**Best**	**Acceptable**
GAIN Range	0.95 - 1.05	0.85 - 1.15
Peak range - Cs	219 - 221	218 - 222
FWHM - Cs - DOWN	6 - 9	9.0 - 9.5
Peak range - Th	870 - 874	868 - 876
FWHM - Th - DOWN	3.5 - 5	6.0 - 6.5
ERROR RANGE	+/- 0.2	+/- 1.0

February 2016 RSI-700 Th-232 System Test Log

Date	Detector 1				Detector 2				Detector 1+2				RCT	QC
	Peak	+/-	FWHM	+/-	Peak	+/-	FWHM	+/-	Peak	+/-	FWHM	+/-	Initials	Initials
Cal	**872.98**		**4.5**		**873.19**		**4.28**		**873.08**		**4.37**			
2/1/2016	873.72	0.111	4.50	0.290	873.95	0.159	4.38	0.415	873.79	0.104	4.46	0.267	AO	LMC
2/8/2016	874.52	0.215	4.60	0.543	874.24	0.287	4.22	0.734	874.26	0.185	4.42	0.460	AO	LMC
2/9/2016	873.47	0.295	4.53	0.778	873.99	0.301	4.32	0.785	873.67	0.216	4.44	0.554	AO	LMC
2/10/2016	873.93	0.304	4.70	0.776	874.16	0.261	4.35	0.678	874.08	0.197	4.56	0.678	AO	LMC
2/11/2016	873.78	0.303	4.50	0.805	873.63	0.267	4.37	0.681	873.70	0.189	4.41	0.484	AO	LMC
2/12/2016	873.49	0.279	4.68	0.705	874.08	0.258	4.16	0.656	873.70	0.202	4.33	0.521	AO	LMC
2/15/2016	873.63	0.275	4.62	0.701	873.52	0.260	4.44	0.664	873.59	0.204	4.55	0.508	TW	TI
2/16/2016	872.72	0.257	4.70	0.667	873.65	0.246	4.35	0.664	873.09	0.204	4.53	0.534	TW	TI
2/17/2016	873.84	0.269	4.46	0.678	873.54	0.298	4.35	0.747	873.72	0.208	4.38	0.524	JG	TI
2/22/2016	873.83	0.245	4.64	0.629	873.68	0.268	4.50	0.683	873.74	0.200	4.56	0.511	AO	LMC
2/23/2016	873.40	0.271	4.46	0.693	874.14	0.305	4.44	0.770	873.77	0.216	4.44	0.546	AO	LMC
2/24/2016	873.66	0.267	4.66	0.688	874.01	0.258	4.42	0.655	873.78	0.200	4.56	0.513	AO	LMC
2/25/2016	873.24	0.279	4.57	0.715	873.86	0.315	4.22	0.816	873.53	0.209	4.43	0.535	AO	LMC
2/26/2016	872.43	0.270	4.61	0.690	873.75	0.273	4.39	0.679	873.12	0.196	4.48	0.505	AO	LMC
2/29/2016	873.68	0.232	4.50	0.592	873.87	0.237	4.49	0.608	873.77	0.185	4.49	0.472	AO	LMC

System Test Parameters		
Parameter	**Best**	**Acceptable**
GAIN Range	0.95 - 1.05	0.85 - 1.15
Peak range - Cs	219 - 221	218 - 222
FWHM - Cs - DOWN	6 - 9	9.0 - 9.5
Peak range - Th	870 - 874	868 - 876
FWHM - Th - DOWN	3.5 - 5	6.0 - 6.5
ERROR RANGE	+/- 0.2	+/- 1.0

Appendix E
Dose and Risk Modeling Outputs

Summary : RESRAD Default Parameters
File : C:\USERS\TINA.PIQUET\DESKTOP\RESRAD\WSP.RAD

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary ... 2
Site-Specific Parameter Summary 5
Summary of Pathway Selections 9
Contaminated Zone and Total Dose Summary 10
Total Dose Components
Time = 0.000E+00 11
Time = 1.000E+00 12
Time = 3.000E+00 13
Time = 1.000E+01 14
Time = 3.000E+01 15
Time = 1.000E+02 16
Time = 3.000E+02 17
Time = 1.000E+03 18
Dose/Source Ratios Summed Over All Pathways 19
Single Radionuclide Soil Guidelines 20
Dose Per Nuclide Summed Over All Pathways 21
Soil Concentration Per Nuclide 23

Dose Conversion Factor (and Related) Parameter Summary
Dose Library: DCFPAK3.02 (Adult)

Menu	Parameter	Current Value#	Base Case*	Parameter Name
A-1	DCF's for external ground radiation, (mrem/yr)/(pCi/g)			
A-1	At-218 (Source: DCFPAK3.02)	5.567E-05	5.567E-05	DCF1(1)
A-1	Bi-210 (Source: DCFPAK3.02)	5.473E-03	5.474E-03	DCF1(2)
A-1	Bi-214 (Source: DCFPAK3.02)	9.135E+00	9.136E+00	DCF1(3)
A-1	Hg-206 (Source: DCFPAK3.02)	6.127E-01	6.128E-01	DCF1(4)
A-1	Pb-210 (Source: DCFPAK3.02)	2.092E-03	2.092E-03	DCF1(5)
A-1	Pb-214 (Source: DCFPAK3.02)	1.257E+00	1.257E+00	DCF1(6)
A-1	Po-210 (Source: DCFPAK3.02)	5.641E-05	5.642E-05	DCF1(7)
A-1	Po-214 (Source: DCFPAK3.02)	4.801E-04	4.801E-04	DCF1(8)
A-1	Po-218 (Source: DCFPAK3.02)	9.228E-09	9.229E-09	DCF1(9)
A-1	Ra-226 (Source: DCFPAK3.02)	3.176E-02	3.176E-02	DCF1(10)
A-1	Rn-218 (Source: DCFPAK3.02)	4.259E-03	4.260E-03	DCF1(11)
A-1	Rn-222 (Source: DCFPAK3.02)	2.130E-03	2.130E-03	DCF1(12)
A-1	Tl-206 (Source: DCFPAK3.02)	1.278E-02	1.278E-02	DCF1(13)
A-1	Tl-210 (Source: DCFPAK3.02)	1.677E+01	1.678E+01	DCF1(14)
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Pb-210+D	3.709E-02	2.077E-02	DCF2(1)
B-1	Pb-210+D1	3.709E-02	2.077E-02	DCF2(2)
B-1	Pb-210+D2	2.129E-02	2.077E-02	DCF2(3)
B-1	Pb-210+D3	2.080E-02	2.077E-02	DCF2(4)
B-1	Ra-226+D	3.531E-02	3.517E-02	DCF2(5)
B-1	Ra-226+D1	3.531E-02	3.517E-02	DCF2(8)
B-1	Ra-226+D2	3.526E-02	3.517E-02	DCF2(11)
B-1	Ra-226+D3	3.526E-02	3.517E-02	DCF2(14)
B-1	Ra-226+D4	3.520E-02	3.517E-02	DCF2(17)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Pb-210+D	7.065E-03	2.575E-03	DCF3(1)
D-1	Pb-210+D1	7.065E-03	2.575E-03	DCF3(2)
D-1	Pb-210+D2	2.585E-03	2.575E-03	DCF3(3)
D-1	Pb-210+D3	2.580E-03	2.575E-03	DCF3(4)
D-1	Ra-226+D	1.041E-03	1.036E-03	DCF3(5)
D-1	Ra-226+D1	1.041E-03	1.036E-03	DCF3(8)
D-1	Ra-226+D2	1.040E-03	1.036E-03	DCF3(11)
D-1	Ra-226+D3	1.040E-03	1.036E-03	DCF3(14)
D-1	Ra-226+D4	1.040E-03	1.036E-03	DCF3(17)
D-34	Food transfer factors:			
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(1,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(1,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(1,3)
D-34				
D-34	Pb-210+D1 , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(2,1)
D-34	Pb-210+D1 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(2,2)
D-34	Pb-210+D1 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(2,3)
D-34				
D-34	Pb-210+D2 , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(3,1)
D-34	Pb-210+D2 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(3,2)
D-34	Pb-210+D2 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(3,3)

Dose Conversion Factor (and Related) Parameter Summary (continued)
Dose Library: DCFPAK3.02 (Adult)

Menu	Parameter	Current Value#	Base Case*	Parameter Name
D-34	Pb-210+D3 , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(4,1)
D-34	Pb-210+D3 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(4,2)
D-34	Pb-210+D3 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(4,3)
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(5,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(5,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(5,3)
D-34				
D-34	Ra-226+D1 , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(8,1)
D-34	Ra-226+D1 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(8,2)
D-34	Ra-226+D1 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(8,3)
D-34				
D-34	Ra-226+D2 , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(11,1)
D-34	Ra-226+D2 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(11,2)
D-34	Ra-226+D2 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(11,3)
D-34				
D-34	Ra-226+D3 , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(14,1)
D-34	Ra-226+D3 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(14,2)
D-34	Ra-226+D3 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(14,3)
D-34				
D-34	Ra-226+D4 , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(17,1)
D-34	Ra-226+D4 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(17,2)
D-34	Ra-226+D4 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(17,3)
D-34				
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(1,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(1,2)
D-5				
D-5	Pb-210+D1 , fish	3.000E+02	3.000E+02	BIOFAC(2,1)
D-5	Pb-210+D1 , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(2,2)
D-5				
D-5	Pb-210+D2 , fish	3.000E+02	3.000E+02	BIOFAC(3,1)
D-5	Pb-210+D2 , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(3,2)
D-5				
D-5	Pb-210+D3 , fish	3.000E+02	3.000E+02	BIOFAC(4,1)
D-5	Pb-210+D3 , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(4,2)
D-5				
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(5,1)
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(5,2)
D-5				
D-5	Ra-226+D1 , fish	5.000E+01	5.000E+01	BIOFAC(8,1)
D-5	Ra-226+D1 , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(8,2)
D-5				
D-5	Ra-226+D2 , fish	5.000E+01	5.000E+01	BIOFAC(11,1)
D-5	Ra-226+D2 , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(11,2)
D-5				
D-5	Ra-226+D3 , fish	5.000E+01	5.000E+01	BIOFAC(14,1)
D-5	Ra-226+D3 , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(14,2)
D-5				

Dose Conversion Factor (and Related) Parameter Summary (continued)
Dose Library: DCFPAK3.02 (Adult)

Menu	Parameter	Current Value#	Base Case*	Parameter Name
D-5	Ra-226+D4 , fish	5.000E+01	5.000E+01	BIOFAC(17,1)
D-5	Ra-226+D4 , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(17,2)
D-5				

#For DCF1(xxx) only, factors are for infinite depth & area. See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	2.878E+02	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	2.000E+00	2.000E+00	---	THICK0
R011	Fraction of contamination that is submerged	0.000E+00	0.000E+00	---	SUBMFRACT
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	1.200E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Pb-210	3.810E-01	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Ra-226	3.810E-01	0.000E+00	---	S1(5)
R012	Concentration in groundwater (pCi/L): Pb-210	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(5)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.500E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.000E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.500E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	4.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	2.000E-01	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	5.300E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	4.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.500E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	2.000E-01	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Pb-210				
R016	Contaminated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.663E-03	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for Ra-226				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(5)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(5,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(5)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.374E-03	ALEACH(5)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(5)
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	1.000E-04	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	7.000E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	5.000E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.600E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	9.200E+01	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	5.400E+00	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	5.100E+02	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	1.000E+00	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	1.000E+00	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	5.000E-01	5.000E-01	---	FR9
R018	Contamination fraction of plant food	-1	-1	0.144E+00	FPLANT
R018	Contamination fraction of meat	-1	-1	0.144E-01	FMEAT
R018	Contamination fraction of milk	-1	-1	0.144E-01	FMILK
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	5.000E-01	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	1.100E+00	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	2.500E-01	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	8.000E-02	8.000E-02	---	TE(3)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	1.000E+00	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	1.000E+00	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	257	---	---	KYMAX

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	active
4 -- meat ingestion	active
5 -- milk ingestion	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	suppressed

Summary : RESRAD Default Parameters

File : C:\USERS\TINA.PIQUET\DESKTOP\RESRAD\WSP.RAD

Contaminated Zone Dimensions

Area:	287.80 square meters
Thickness:	2.00 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g

Pb-210	3.810E-01
Ra-226	3.810E-01

Total Dose TDOSE(t), mrem/yr

Basic Radiation Dose Limit = 1.200E+01 mrem/yr

Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	3.136E+00	3.129E+00	3.113E+00	3.057E+00	2.898E+00	2.388E+00	1.363E+00	8.108E-01
M(t):	2.614E-01	2.607E-01	2.594E-01	2.547E-01	2.415E-01	1.990E-01	1.136E-01	6.757E-02

Maximum TDOSE(t): 3.136E+00 mrem/yr at t = 0.000E+00 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	1.542E-03	0.0005	6.145E-04	0.0002	0.000E+00	0.0000	6.631E-01	0.2114	2.267E-03	0.0007	1.105E-03	0.0004	2.086E-02	0.0067
Ra-226	2.031E+00	0.6476	6.034E-04	0.0002	0.000E+00	0.0000	4.090E-01	0.1304	1.213E-03	0.0004	1.440E-03	0.0005	3.447E-03	0.0011
Total	2.033E+00	0.6481	1.218E-03	0.0004	0.000E+00	0.0000	1.072E+00	0.3418	3.480E-03	0.0011	2.544E-03	0.0008	2.431E-02	0.0078

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.895E-01	0.2198
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.447E+00	0.7802
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.136E+00	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	1.492E-03	0.0005	5.946E-04	0.0002	0.000E+00	0.0000	6.416E-01	0.2051	2.194E-03	0.0007	1.069E-03	0.0003	2.019E-02	0.0065
Ra-226	2.026E+00	0.6474	6.206E-04	0.0002	0.000E+00	0.0000	4.285E-01	0.1370	1.283E-03	0.0004	1.471E-03	0.0005	4.078E-03	0.0013
Total	2.027E+00	0.6479	1.215E-03	0.0004	0.000E+00	0.0000	1.070E+00	0.3420	3.477E-03	0.0011	2.540E-03	0.0008	2.426E-02	0.0078

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.672E-01	0.2132
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.462E+00	0.7868
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.129E+00	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	1.397E-03	0.0004	5.567E-04	0.0002	0.000E+00	0.0000	6.008E-01	0.1930	2.054E-03	0.0007	1.001E-03	0.0003	1.890E-02	0.0061
Ra-226	2.014E+00	0.6471	6.530E-04	0.0002	0.000E+00	0.0000	4.648E-01	0.1493	1.408E-03	0.0005	1.527E-03	0.0005	5.271E-03	0.0017
Total	2.016E+00	0.6476	1.210E-03	0.0004	0.000E+00	0.0000	1.066E+00	0.3423	3.462E-03	0.0011	2.528E-03	0.0008	2.417E-02	0.0078

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.247E-01	0.2007
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.488E+00	0.7993
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.113E+00	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	1.110E-03	0.0004	4.423E-04	0.0001	0.000E+00	0.0000	4.773E-01	0.1561	1.632E-03	0.0005	7.950E-04	0.0003	1.502E-02	0.0049
Ra-226	1.975E+00	0.6463	7.478E-04	0.0002	0.000E+00	0.0000	5.718E-01	0.1871	1.778E-03	0.0006	1.691E-03	0.0006	8.822E-03	0.0029
Total	1.976E+00	0.6466	1.190E-03	0.0004	0.000E+00	0.0000	1.049E+00	0.3432	3.409E-03	0.0011	2.486E-03	0.0008	2.384E-02	0.0078

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.963E-01	0.1624
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.560E+00	0.8376
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.057E+00	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	5.750E-04	0.0002	2.291E-04	0.0001	0.000E+00	0.0000	2.472E-01	0.0853	8.453E-04	0.0003	4.118E-04	0.0001	7.778E-03	0.0027
Ra-226	1.868E+00	0.6447	9.032E-04	0.0003	0.000E+00	0.0000	7.524E-01	0.2596	2.404E-03	0.0008	1.951E-03	0.0007	1.500E-02	0.0052
Total	1.869E+00	0.6449	1.132E-03	0.0004	0.000E+00	0.0000	9.996E-01	0.3450	3.250E-03	0.0011	2.363E-03	0.0008	2.278E-02	0.0079

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.571E-01	0.0887
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.641E+00	0.9113
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.898E+00	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	5.753E-05	0.0000	2.292E-05	0.0000	0.000E+00	0.0000	2.474E-02	0.0104	8.457E-05	0.0000	4.121E-05	0.0000	7.783E-04	0.0003
Ra-226	1.535E+00	0.6429	9.137E-04	0.0004	0.000E+00	0.0000	8.033E-01	0.3364	2.609E-03	0.0011	1.911E-03	0.0008	1.815E-02	0.0076
Total	1.535E+00	0.6430	9.366E-04	0.0004	0.000E+00	0.0000	8.281E-01	0.3468	2.693E-03	0.0011	1.953E-03	0.0008	1.893E-02	0.0079

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.572E-02	0.0108
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.362E+00	0.9892
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.388E+00	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	8.007E-08	0.0000	3.190E-08	0.0000	0.000E+00	0.0000	3.443E-05	0.0000	1.177E-07	0.0000	5.735E-08	0.0000	1.083E-06	0.0000
Ra-226	8.758E-01	0.6427	5.347E-04	0.0004	0.000E+00	0.0000	4.728E-01	0.3470	1.538E-03	0.0011	1.115E-03	0.0008	1.081E-02	0.0079
Total	8.758E-01	0.6427	5.348E-04	0.0004	0.000E+00	0.0000	4.729E-01	0.3470	1.538E-03	0.0011	1.115E-03	0.0008	1.081E-02	0.0079

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.580E-05	0.0000
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.363E+00	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.363E+00	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	8.053E-18	0.0000	3.209E-18	0.0000	0.000E+00	0.0000	3.463E-15	0.0000	1.184E-17	0.0000	5.768E-18	0.0000	1.089E-16	0.0000
Ra-226	1.228E-01	0.1514	7.496E-05	0.0001	0.000E+00	0.0000	6.629E-02	0.0818	2.156E-04	0.0003	1.563E-04	0.0002	1.516E-03	0.0019
Total	1.228E-01	0.1514	7.496E-05	0.0001	0.000E+00	0.0000	6.629E-02	0.0818	2.156E-04	0.0003	1.563E-04	0.0002	1.516E-03	0.0019

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	1.092E-14	0.0000	2.288E-17	0.0000	0.000E+00	0.0000	2.422E-16	0.0000	2.691E-18	0.0000	2.209E-18	0.0000	1.479E-14	0.0000
Ra-226	6.049E-01	0.7461	1.111E-03	0.0014	0.000E+00	0.0000	1.344E-02	0.0166	1.559E-04	0.0002	1.720E-04	0.0002	8.108E-01	1.0000
Total	6.049E-01	0.7461	1.111E-03	0.0014	0.000E+00	0.0000	1.344E-02	0.0166	1.559E-04	0.0002	1.720E-04	0.0002	8.108E-01	1.0000

*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Thread Fraction	DSR(j,t) At Time in Years (mrem/yr)/(pCi/g) 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Pb-210+D	Pb-210+D	1.000E+00	1.810E+00	1.751E+00	1.640E+00	1.303E+00	6.747E-01	6.751E-02	9.396E-05	3.882E-14
Pb-210+D1	Pb-210+D1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pb-210+D2	Pb-210+D2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pb-210+D3	Pb-210+D3	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ra-226+D	Ra-226+D	9.996E-01	6.385E+00	6.367E+00	6.331E+00	6.208E+00	5.869E+00	4.822E+00	2.751E+00	6.672E-01
Ra-226+D	Pb-210+D1	9.996E-01	3.345E-02	8.970E-02	1.947E-01	5.076E-01	1.058E+00	1.374E+00	8.236E-01	1.460E+00
Ra-226+D	∑DSR(j)		6.418E+00	6.456E+00	6.526E+00	6.715E+00	6.926E+00	6.196E+00	3.574E+00	2.127E+00
Ra-226+D	Ra-226+D	1.319E-06	8.428E-06	8.404E-06	8.357E-06	8.194E-06	7.747E-06	6.365E-06	3.631E-06	8.807E-07
Ra-226+D	Pb-210+D2	1.319E-06	1.635E-08	4.389E-08	9.530E-08	2.486E-07	5.178E-07	6.729E-07	4.033E-07	7.059E-07
Ra-226+D	∑DSR(j)		8.444E-06	8.448E-06	8.452E-06	8.443E-06	8.265E-06	7.038E-06	4.034E-06	1.587E-06
Ra-226+D	Ra-226+D	1.899E-08	1.213E-07	1.210E-07	1.203E-07	1.179E-07	1.115E-07	9.162E-08	5.226E-08	1.268E-08
Ra-226+D	Pb-210+D3	1.899E-08	3.285E-10	9.070E-10	1.992E-09	5.227E-09	1.091E-08	1.419E-08	8.505E-09	1.052E-08
Ra-226+D	∑DSR(j)		1.216E-07	1.219E-07	1.223E-07	1.232E-07	1.224E-07	1.058E-07	6.077E-08	2.320E-08
Ra-226+D1	Ra-226+D1	2.100E-04	3.133E-03	3.124E-03	3.107E-03	3.046E-03	2.880E-03	2.366E-03	1.350E-03	2.483E-04
Ra-226+D1	Pb-210+D1	2.100E-04	7.025E-06	1.884E-05	4.089E-05	1.066E-04	2.221E-04	2.886E-04	1.730E-04	3.067E-04
Ra-226+D1	∑DSR(j)		3.140E-03	3.143E-03	3.147E-03	3.153E-03	3.102E-03	2.655E-03	1.523E-03	5.550E-04
Ra-226+D1	Ra-226+D1	2.771E-10	4.135E-09	4.124E-09	4.101E-09	4.021E-09	3.801E-09	3.123E-09	1.782E-09	3.278E-10
Ra-226+D1	Pb-210+D2	2.771E-10	3.433E-12	9.219E-12	2.002E-11	5.221E-11	1.088E-10	1.413E-10	8.472E-11	1.483E-10
Ra-226+D1	∑DSR(j)		4.139E-09	4.133E-09	4.121E-09	4.073E-09	3.910E-09	3.265E-09	1.866E-09	4.761E-10
Ra-226+D1	Ra-226+D1	3.989E-12	5.952E-11	5.936E-11	5.903E-11	5.788E-11	5.472E-11	4.496E-11	2.564E-11	4.719E-12
Ra-226+D1	Pb-210+D3	3.989E-12	6.899E-14	1.905E-13	4.185E-13	1.098E-12	2.292E-12	2.980E-12	1.786E-12	2.210E-12
Ra-226+D1	∑DSR(j)		5.959E-11	5.955E-11	5.944E-11	5.898E-11	5.701E-11	4.794E-11	2.743E-11	6.929E-12
Ra-226+D2	Ra-226+D2	1.998E-04	1.144E-03	1.141E-03	1.134E-03	1.112E-03	1.051E-03	8.639E-04	4.928E-04	1.253E-04
Ra-226+D2	Pb-210+D1	1.998E-04	6.684E-06	1.793E-05	3.891E-05	1.014E-04	2.113E-04	2.746E-04	1.646E-04	2.918E-04
Ra-226+D2	∑DSR(j)		1.151E-03	1.159E-03	1.173E-03	1.214E-03	1.263E-03	1.138E-03	6.574E-04	4.171E-04
Ra-226+D2	Ra-226+D2	2.637E-10	1.510E-09	1.506E-09	1.497E-09	1.468E-09	1.388E-09	1.140E-09	6.505E-10	1.654E-10
Ra-226+D2	Pb-210+D2	2.637E-10	3.266E-12	8.771E-12	1.905E-11	4.967E-11	1.035E-10	1.345E-10	8.060E-11	1.411E-10
Ra-226+D2	∑DSR(j)		1.513E-09	1.514E-09	1.516E-09	1.518E-09	1.491E-09	1.275E-09	7.311E-10	3.065E-10
Ra-226+D2	Ra-226+D2	3.795E-12	2.173E-11	2.167E-11	2.155E-11	2.113E-11	1.998E-11	1.641E-11	9.363E-12	2.381E-12
Ra-226+D2	Pb-210+D3	3.795E-12	6.564E-14	1.813E-13	3.981E-13	1.045E-12	2.181E-12	2.835E-12	1.700E-12	2.103E-12
Ra-226+D2	∑DSR(j)		2.180E-11	2.185E-11	2.195E-11	2.218E-11	2.216E-11	1.925E-11	1.106E-11	4.484E-12
Ra-226+D3	Ra-226+D3	4.196E-08	5.983E-07	5.967E-07	5.933E-07	5.818E-07	5.500E-07	4.519E-07	2.578E-07	4.795E-08
Ra-226+D3	Pb-210+D1	4.196E-08	1.404E-09	3.765E-09	8.172E-09	2.131E-08	4.439E-08	5.768E-08	3.457E-08	6.128E-08
Ra-226+D3	∑DSR(j)		5.997E-07	6.004E-07	6.015E-07	6.031E-07	5.944E-07	5.096E-07	2.923E-07	1.092E-07

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Thread Fraction	DSR(j,t) At Time in Years (mrem/yr)/(pCi/g) 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-226+D3	Ra-226+D3	5.538E-14	7.898E-13	7.876E-13	7.832E-13	7.679E-13	7.260E-13	5.965E-13	3.403E-13	6.329E-14
Ra-226+D3	Pb-210+D2	5.538E-14	6.861E-16	1.842E-15	4.000E-15	1.043E-14	2.174E-14	2.824E-14	1.693E-14	2.963E-14
Ra-226+D3	∑DSR(j)		7.905E-13	7.894E-13	7.872E-13	7.784E-13	7.478E-13	6.248E-13	3.572E-13	9.292E-14
Ra-226+D3	Ra-226+D3	7.972E-16	1.137E-14	1.134E-14	1.127E-14	1.105E-14	1.045E-14	8.586E-15	4.898E-15	9.110E-16
Ra-226+D3	Pb-210+D3	7.972E-16	1.379E-17	3.807E-17	8.363E-17	2.194E-16	4.580E-16	5.955E-16	3.570E-16	4.416E-16
Ra-226+D3	∑DSR(j)		1.138E-14	1.137E-14	1.136E-14	1.127E-14	1.091E-14	9.182E-15	5.255E-15	1.353E-15
Ra-226+D4	Ra-226+D4	2.000E-07	2.154E-07	2.148E-07	2.136E-07	2.094E-07	1.980E-07	1.627E-07	9.280E-08	6.931E-08
Ra-226+D4	Pb-210+D1	2.000E-07	6.692E-09	1.795E-08	3.895E-08	1.016E-07	2.116E-07	2.749E-07	1.648E-07	2.921E-07
Ra-226+D4	∑DSR(j)		2.221E-07	2.328E-07	2.526E-07	3.110E-07	4.096E-07	4.376E-07	2.576E-07	3.614E-07
Ra-226+D4	Ra-226+D4	2.640E-13	2.843E-13	2.835E-13	2.820E-13	2.765E-13	2.614E-13	2.148E-13	1.225E-13	9.149E-14
Ra-226+D4	Pb-210+D2	2.640E-13	3.270E-15	8.781E-15	1.907E-14	4.973E-14	1.036E-13	1.346E-13	8.070E-14	1.412E-13
Ra-226+D4	∑DSR(j)		2.876E-13	2.923E-13	3.010E-13	3.262E-13	3.650E-13	3.494E-13	2.032E-13	2.327E-13
Ra-226+D4	Ra-226+D4	3.800E-15	4.093E-15	4.081E-15	4.058E-15	3.980E-15	3.762E-15	3.091E-15	1.763E-15	1.317E-15
Ra-226+D4	Pb-210+D3	3.800E-15	6.572E-17	1.815E-16	3.986E-16	1.046E-15	2.183E-15	2.839E-15	1.702E-15	2.105E-15
Ra-226+D4	∑DSR(j)		4.158E-15	4.263E-15	4.457E-15	5.025E-15	5.946E-15	5.930E-15	3.465E-15	3.422E-15

The DSR includes contributions from associated (half-life ≤ 180 days) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 1.200E+01 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Pb-210	6.631E+00	6.853E+00	7.319E+00	9.213E+00	1.778E+01	1.777E+02	1.277E+05	*7.632E+13
Ra-226	1.868E+00	1.857E+00	1.838E+00	1.786E+00	1.731E+00	1.936E+00	3.355E+00	5.639E+00

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 0.000E+00 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Pb-210	3.810E-01	0.000E+00	0.000E+00	*7.632E+13	1.810E+00	6.631E+00
Pb-210	3.810E-01	0.000E+00	1.810E+00	6.631E+00	1.810E+00	6.631E+00
Ra-226	3.810E-01	32.44 ± 0.06	6.933E+00	1.731E+00	6.422E+00	1.868E+00

*At specific activity limit

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Pb-210	Pb-210	1.000E+00	6.895E-01	6.672E-01	6.247E-01	4.963E-01	2.571E-01	2.572E-02	3.580E-05	1.479E-14
Pb-210	Pb-210	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pb-210	∑DOSE(j)		6.895E-01	6.672E-01	6.247E-01	4.963E-01	2.571E-01	2.572E-02	3.580E-05	1.479E-14
Pb-210	Pb-210	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pb-210	Pb-210	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pb-210	Ra-226	1.319E-06	6.228E-09	1.672E-08	3.631E-08	9.470E-08	1.973E-07	2.564E-07	1.537E-07	2.689E-07
Pb-210	Ra-226	2.771E-10	1.308E-12	3.512E-12	7.627E-12	1.989E-11	4.144E-11	5.385E-11	3.228E-11	5.649E-11
Pb-210	Ra-226	2.637E-10	1.245E-12	3.342E-12	7.256E-12	1.893E-11	3.943E-11	5.123E-11	3.071E-11	5.375E-11
Pb-210	Ra-226	5.538E-14	2.614E-16	7.019E-16	1.524E-15	3.975E-15	8.282E-15	1.076E-14	6.450E-15	1.129E-14
Pb-210	Ra-226	2.640E-13	1.246E-15	3.346E-15	7.265E-15	1.895E-14	3.948E-14	5.129E-14	3.075E-14	5.381E-14
Pb-210	∑DOSE(j)		6.230E-09	1.673E-08	3.633E-08	9.474E-08	1.974E-07	2.565E-07	1.537E-07	2.691E-07
Ra-226	Ra-226	9.996E-01	2.433E+00	2.426E+00	2.412E+00	2.365E+00	2.236E+00	1.837E+00	1.048E+00	2.542E-01
Ra-226	Ra-226	1.319E-06	3.211E-06	3.202E-06	3.184E-06	3.122E-06	2.952E-06	2.425E-06	1.383E-06	3.355E-07
Ra-226	∑DOSE(j)		2.433E+00	2.426E+00	2.412E+00	2.365E+00	2.236E+00	1.837E+00	1.048E+00	2.542E-01
Pb-210	Ra-226	9.996E-01	1.274E-02	3.418E-02	7.418E-02	1.934E-01	4.029E-01	5.235E-01	3.138E-01	5.563E-01
Pb-210	Ra-226	2.100E-04	2.677E-06	7.179E-06	1.558E-05	4.062E-05	8.463E-05	1.100E-04	6.591E-05	1.168E-04
Pb-210	Ra-226	1.998E-04	2.547E-06	6.830E-06	1.482E-05	3.865E-05	8.052E-05	1.046E-04	6.271E-05	1.112E-04
Pb-210	Ra-226	4.196E-08	5.349E-10	1.435E-09	3.114E-09	8.118E-09	1.691E-08	2.197E-08	1.317E-08	2.335E-08
Pb-210	Ra-226	2.000E-07	2.550E-09	6.838E-09	1.484E-08	3.870E-08	8.062E-08	1.047E-07	6.279E-08	1.113E-07
Pb-210	∑DOSE(j)		1.275E-02	3.419E-02	7.421E-02	1.935E-01	4.031E-01	5.237E-01	3.139E-01	5.565E-01
Ra-226	Ra-226	1.899E-08	4.622E-08	4.609E-08	4.583E-08	4.494E-08	4.249E-08	3.491E-08	1.991E-08	4.830E-09
Ra-226	Ra-226	2.100E-04	1.194E-03	1.190E-03	1.184E-03	1.161E-03	1.097E-03	9.015E-04	5.142E-04	9.462E-05
Ra-226	∑DOSE(j)		1.194E-03	1.190E-03	1.184E-03	1.161E-03	1.097E-03	9.015E-04	5.143E-04	9.463E-05
Pb-210	Ra-226	1.899E-08	1.251E-10	3.456E-10	7.591E-10	1.992E-09	4.158E-09	5.405E-09	3.240E-09	4.009E-09
Pb-210	Ra-226	3.989E-12	2.629E-14	7.259E-14	1.594E-13	4.183E-13	8.733E-13	1.135E-12	6.806E-13	8.420E-13
Pb-210	Ra-226	3.795E-12	2.501E-14	6.906E-14	1.517E-13	3.980E-13	8.308E-13	1.080E-12	6.475E-13	8.011E-13
Pb-210	Ra-226	7.972E-16	5.253E-18	1.451E-17	3.186E-17	8.360E-17	1.745E-16	2.269E-16	1.360E-16	1.683E-16
Pb-210	Ra-226	3.800E-15	2.504E-17	6.915E-17	1.519E-16	3.985E-16	8.319E-16	1.082E-15	6.483E-16	8.021E-16
Pb-210	∑DOSE(j)		1.252E-10	3.457E-10	7.594E-10	1.992E-09	4.159E-09	5.408E-09	3.242E-09	4.010E-09
Ra-226	Ra-226	2.771E-10	1.576E-09	1.571E-09	1.562E-09	1.532E-09	1.448E-09	1.190E-09	6.788E-10	1.249E-10
Ra-226	Ra-226	3.989E-12	2.268E-11	2.262E-11	2.249E-11	2.205E-11	2.085E-11	1.713E-11	9.770E-12	1.798E-12
Ra-226	∑DOSE(j)		1.598E-09	1.594E-09	1.585E-09	1.554E-09	1.469E-09	1.207E-09	6.886E-10	1.267E-10
Ra-226	Ra-226	1.998E-04	4.358E-04	4.346E-04	4.322E-04	4.237E-04	4.006E-04	3.291E-04	1.878E-04	4.775E-05
Ra-226	Ra-226	2.637E-10	5.753E-10	5.737E-10	5.704E-10	5.593E-10	5.288E-10	4.345E-10	2.478E-10	6.303E-11
Ra-226	∑DOSE(j)		4.358E-04	4.346E-04	4.322E-04	4.237E-04	4.006E-04	3.291E-04	1.878E-04	4.775E-05
Ra-226	Ra-226	3.795E-12	8.280E-12	8.257E-12	8.211E-12	8.051E-12	7.612E-12	6.254E-12	3.567E-12	9.073E-13
Ra-226	Ra-226	4.196E-08	2.280E-07	2.273E-07	2.261E-07	2.217E-07	2.096E-07	1.722E-07	9.821E-08	1.827E-08
Ra-226	∑DOSE(j)		2.280E-07	2.273E-07	2.261E-07	2.217E-07	2.096E-07	1.722E-07	9.822E-08	1.827E-08
Ra-226	Ra-226	5.538E-14	3.009E-13	3.001E-13	2.984E-13	2.926E-13	2.766E-13	2.273E-13	1.296E-13	2.411E-14
Ra-226	Ra-226	7.972E-16	4.331E-15	4.319E-15	4.295E-15	4.211E-15	3.982E-15	3.271E-15	1.866E-15	3.471E-16
Ra-226	∑DOSE(j)		3.052E-13	3.044E-13	3.027E-13	2.968E-13	2.806E-13	2.305E-13	1.315E-13	2.446E-14

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-226	Ra-226	2.000E-07	8.207E-08	8.184E-08	8.138E-08	7.980E-08	7.544E-08	6.199E-08	3.536E-08	2.641E-08
Ra-226	Ra-226	2.640E-13	1.083E-13	1.080E-13	1.074E-13	1.053E-13	9.958E-14	8.182E-14	4.667E-14	3.486E-14
Ra-226	∑DOSE(j)		8.207E-08	8.184E-08	8.138E-08	7.980E-08	7.544E-08	6.199E-08	3.536E-08	2.641E-08
Ra-226	Ra-226	3.800E-15	1.559E-15	1.555E-15	1.546E-15	1.516E-15	1.433E-15	1.178E-15	6.718E-16	5.017E-16

THF(i) is the thread fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Pb-210	Pb-210	1.000E+00	3.810E-01	3.687E-01	3.452E-01	2.742E-01	1.421E-01	1.421E-02	1.978E-05	1.989E-15
Pb-210	Pb-210	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pb-210	∑S(j):		3.810E-01	3.687E-01	3.452E-01	2.742E-01	1.421E-01	1.421E-02	1.978E-05	1.989E-15
Pb-210	Pb-210	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pb-210	Pb-210	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pb-210	Ra-226	1.319E-06	0.000E+00	1.542E-08	4.465E-08	1.318E-07	2.851E-07	3.747E-07	2.248E-07	3.151E-08
Pb-210	Ra-226	2.771E-10	0.000E+00	3.239E-12	9.378E-12	2.768E-11	5.989E-11	7.869E-11	4.721E-11	6.619E-12
Pb-210	Ra-226	2.637E-10	0.000E+00	3.081E-12	8.923E-12	2.634E-11	5.698E-11	7.487E-11	4.492E-11	6.298E-12
Pb-210	Ra-226	5.538E-14	0.000E+00	6.472E-16	1.874E-15	5.532E-15	1.197E-14	1.573E-14	9.435E-15	1.323E-15
Pb-210	Ra-226	2.640E-13	0.000E+00	3.085E-15	8.933E-15	2.637E-14	5.705E-14	7.496E-14	4.498E-14	6.305E-15
Pb-210	∑S(j):		0.000E+00	1.543E-08	4.467E-08	1.319E-07	2.852E-07	3.748E-07	2.249E-07	3.153E-08
Ra-226	Ra-226	9.996E-01	3.808E-01	3.798E-01	3.776E-01	3.703E-01	3.501E-01	2.876E-01	1.641E-01	2.300E-02
Ra-226	Ra-226	1.319E-06	5.027E-07	5.013E-07	4.985E-07	4.888E-07	4.621E-07	3.797E-07	2.166E-07	3.036E-08
Ra-226	∑S(j):		3.808E-01	3.798E-01	3.777E-01	3.703E-01	3.501E-01	2.876E-01	1.641E-01	2.300E-02
Pb-210	Ra-226	9.996E-01	0.000E+00	1.168E-02	3.382E-02	9.985E-02	2.160E-01	2.838E-01	1.703E-01	2.387E-02
Pb-210	Ra-226	2.100E-04	0.000E+00	2.454E-06	7.105E-06	2.097E-05	4.537E-05	5.962E-05	3.577E-05	5.015E-06
Pb-210	Ra-226	1.998E-04	0.000E+00	2.334E-06	6.760E-06	1.995E-05	4.317E-05	5.672E-05	3.403E-05	4.771E-06
Pb-210	Ra-226	4.196E-08	0.000E+00	4.903E-10	1.420E-09	4.191E-09	9.067E-09	1.191E-08	7.148E-09	1.002E-09
Pb-210	Ra-226	2.000E-07	0.000E+00	2.337E-09	6.768E-09	1.998E-08	4.322E-08	5.679E-08	3.407E-08	4.777E-09
Pb-210	∑S(j):		0.000E+00	1.169E-02	3.384E-02	9.989E-02	2.161E-01	2.839E-01	1.704E-01	2.388E-02
Ra-226	Ra-226	1.899E-08	7.236E-09	7.216E-09	7.175E-09	7.036E-09	6.652E-09	5.465E-09	3.117E-09	4.370E-10
Ra-226	Ra-226	2.100E-04	7.999E-05	7.977E-05	7.932E-05	7.778E-05	7.353E-05	6.042E-05	3.446E-05	4.831E-06
Ra-226	∑S(j):		8.000E-05	7.978E-05	7.933E-05	7.779E-05	7.354E-05	6.042E-05	3.447E-05	4.831E-06
Pb-210	Ra-226	1.899E-08	0.000E+00	2.219E-10	6.427E-10	1.897E-09	4.104E-09	5.393E-09	3.236E-09	4.536E-10
Pb-210	Ra-226	3.989E-12	0.000E+00	4.662E-14	1.350E-13	3.985E-13	8.620E-13	1.133E-12	6.796E-13	9.528E-14
Pb-210	Ra-226	3.795E-12	0.000E+00	4.435E-14	1.284E-13	3.791E-13	8.202E-13	1.078E-12	6.466E-13	9.065E-14
Pb-210	Ra-226	7.972E-16	0.000E+00	9.316E-18	2.698E-17	7.963E-17	1.723E-16	2.264E-16	1.358E-16	1.904E-17
Pb-210	Ra-226	3.800E-15	0.000E+00	4.441E-17	1.286E-16	3.796E-16	8.211E-16	1.079E-15	6.474E-16	9.076E-17
Pb-210	∑S(j):		0.000E+00	2.220E-10	6.429E-10	1.898E-09	4.106E-09	5.395E-09	3.237E-09	4.538E-10
Ra-226	Ra-226	2.771E-10	1.056E-10	1.053E-10	1.047E-10	1.027E-10	9.706E-11	7.975E-11	4.549E-11	6.377E-12
Ra-226	Ra-226	3.989E-12	1.520E-12	1.516E-12	1.507E-12	1.478E-12	1.397E-12	1.148E-12	6.548E-13	9.179E-14
Ra-226	∑S(j):		1.071E-10	1.068E-10	1.062E-10	1.041E-10	9.846E-11	8.090E-11	4.615E-11	6.469E-12
Ra-226	Ra-226	1.998E-04	7.611E-05	7.589E-05	7.547E-05	7.400E-05	6.996E-05	5.748E-05	3.279E-05	4.596E-06
Ra-226	Ra-226	2.637E-10	1.005E-10	1.002E-10	9.962E-11	9.768E-11	9.235E-11	7.588E-11	4.328E-11	6.067E-12
Ra-226	∑S(j):		7.611E-05	7.589E-05	7.547E-05	7.400E-05	6.996E-05	5.748E-05	3.279E-05	4.596E-06
Ra-226	Ra-226	3.795E-12	1.446E-12	1.442E-12	1.434E-12	1.406E-12	1.329E-12	1.092E-12	6.230E-13	8.733E-14
Ra-226	Ra-226	4.196E-08	1.599E-08	1.594E-08	1.585E-08	1.554E-08	1.469E-08	1.207E-08	6.887E-09	9.654E-10
Ra-226	∑S(j):		1.599E-08	1.594E-08	1.585E-08	1.554E-08	1.470E-08	1.207E-08	6.888E-09	9.655E-10
Ra-226	Ra-226	5.538E-14	2.110E-14	2.104E-14	2.092E-14	2.052E-14	1.940E-14	1.594E-14	9.091E-15	1.274E-15
Ra-226	Ra-226	7.972E-16	3.037E-16	3.029E-16	3.012E-16	2.953E-16	2.792E-16	2.294E-16	1.309E-16	1.834E-17
Ra-226	∑S(j):		2.141E-14	2.135E-14	2.123E-14	2.081E-14	1.968E-14	1.617E-14	9.222E-15	1.293E-15

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-226	Ra-226	2.000E-07	7.620E-08	7.599E-08	7.556E-08	7.409E-08	7.005E-08	5.755E-08	3.283E-08	4.602E-09
Ra-226	Ra-226	2.640E-13	1.006E-13	1.003E-13	9.974E-14	9.780E-14	9.246E-14	7.597E-14	4.333E-14	6.074E-15
Ra-226	∑S(j):		7.620E-08	7.599E-08	7.556E-08	7.409E-08	7.005E-08	5.755E-08	3.283E-08	4.602E-09
Ra-226	Ra-226	3.800E-15	1.448E-15	1.444E-15	1.436E-15	1.408E-15	1.331E-15	1.093E-15	6.237E-16	8.743E-17

THF(i) is the thread fraction of the parent nuclide.

RESCALC.EXE execution time = 1.20 seconds

Table of Contents

Part III: Intake Quantities and Health Risk Factors

Cancer Risk Slope Factors 2
Risk Slope and ETFG for the Ground Pathway 4
Amount of Intake Quantities and Excess Cancer Risks
Time= 0.000E+00 5
Time= 1.000E+00 8
Time= 3.000E+00 11
Time= 1.000E+01 14
Time= 3.000E+01 17
Time= 1.000E+02 20
Time= 3.000E+02 23
Time= 1.000E+03 26

Cancer Risk Slope Factors Summary Table
Risk Library: DCFPAK3.02 Morbidity

Menu	Parameter	Current Value	Base Case*	Parameter Name
Sf-1	Ground external radiation slope factors, 1/yr per (pCi/g):			
Sf-1	Pb-210+D	4.30E-09	1.48E-09	SLPF(1,1)
Sf-1	Pb-210+D1	4.30E-09	1.48E-09	SLPF(2,1)
Sf-1	Pb-210+D2	1.04E-08	1.48E-09	SLPF(3,1)
Sf-1	Pb-210+D3	4.91E-07	1.48E-09	SLPF(4,1)
Sf-1	Ra-226+D	8.36E-06	2.50E-08	SLPF(5,1)
Sf-1	Ra-226+D1	2.18E-05	2.50E-08	SLPF(8,1)
Sf-1	Ra-226+D2	7.37E-06	2.50E-08	SLPF(11,1)
Sf-1	Ra-226+D3	2.08E-05	2.50E-08	SLPF(14,1)
Sf-1	Ra-226+D4	3.05E-08	2.50E-08	SLPF(17,1)
Sf-2	Inhalation, slope factors, 1/(pCi):			
Sf-2	Pb-210+D	3.09E-08	1.59E-08	SLPF(1,2)
Sf-2	Pb-210+D1	3.09E-08	1.59E-08	SLPF(2,2)
Sf-2	Pb-210+D2	1.64E-08	1.59E-08	SLPF(3,2)
Sf-2	Pb-210+D3	1.59E-08	1.59E-08	SLPF(4,2)
Sf-2	Ra-226+D	2.83E-08	2.81E-08	SLPF(5,2)
Sf-2	Ra-226+D1	2.83E-08	2.81E-08	SLPF(8,2)
Sf-2	Ra-226+D2	2.82E-08	2.81E-08	SLPF(11,2)
Sf-2	Ra-226+D3	2.82E-08	2.81E-08	SLPF(14,2)
Sf-2	Ra-226+D4	2.82E-08	2.81E-08	SLPF(17,2)
Sf-3	Food ingestion, slope factors, 1/(pCi):			
Sf-3	Pb-210+D	3.44E-09	1.18E-09	SLPF(1,3)
Sf-3	Pb-210+D1	3.44E-09	1.18E-09	SLPF(2,3)
Sf-3	Pb-210+D2	1.19E-09	1.18E-09	SLPF(3,3)
Sf-3	Pb-210+D3	1.18E-09	1.18E-09	SLPF(4,3)
Sf-3	Ra-226+D	5.15E-10	5.14E-10	SLPF(5,3)
Sf-3	Ra-226+D1	5.15E-10	5.14E-10	SLPF(8,3)
Sf-3	Ra-226+D2	5.14E-10	5.14E-10	SLPF(11,3)
Sf-3	Ra-226+D3	5.14E-10	5.14E-10	SLPF(14,3)
Sf-3	Ra-226+D4	5.14E-10	5.14E-10	SLPF(17,3)
Sf-3	Water ingestion, slope factors, 1/(pCi):			
Sf-3	Pb-210+D	2.67E-09	8.84E-10	SLPF(1,4)
Sf-3	Pb-210+D1	2.67E-09	8.84E-10	SLPF(2,4)
Sf-3	Pb-210+D2	8.93E-10	8.84E-10	SLPF(3,4)
Sf-3	Pb-210+D3	8.84E-10	8.84E-10	SLPF(4,4)
Sf-3	Ra-226+D	3.86E-10	3.85E-10	SLPF(5,4)
Sf-3	Ra-226+D1	3.86E-10	3.85E-10	SLPF(8,4)
Sf-3	Ra-226+D2	3.85E-10	3.85E-10	SLPF(11,4)
Sf-3	Ra-226+D3	3.85E-10	3.85E-10	SLPF(14,4)
Sf-3	Ra-226+D4	3.85E-10	3.85E-10	SLPF(17,4)
Sf-3	Soil ingestion, slope factors, 1/(pCi):			
Sf-3	Pb-210+D	3.44E-09	1.18E-09	SLPF(1,5)
Sf-3	Pb-210+D1	3.44E-09	1.18E-09	SLPF(2,5)
Sf-3	Pb-210+D2	1.19E-09	1.18E-09	SLPF(3,5)
Sf-3	Pb-210+D3	1.18E-09	1.18E-09	SLPF(4,5)
Sf-3	Ra-226+D	5.15E-10	5.14E-10	SLPF(5,5)

Cancer Risk Slope Factors Summary Table (continued)
Risk Library: DCFPAK3.02 Morbidity

Menu	Parameter	Current Value	Base Case*	Parameter Name
Sf-3	Ra-226+D1	5.15E-10	5.14E-10	SLPF(8,5)
Sf-3	Ra-226+D2	5.14E-10	5.14E-10	SLPF(11,5)
Sf-3	Ra-226+D3	5.14E-10	5.14E-10	SLPF(14,5)
Sf-3	Ra-226+D4	5.14E-10	5.14E-10	SLPF(17,5)
Sf-Rn	Radon Inhalation slope factors, 1/(pCi):			
Sf-Rn	Rn-222	1.80E-12	1.80E-12	SLPFRN(1,1)
Sf-Rn	Po-218	3.70E-12	3.70E-12	SLPFRN(1,2)
Sf-Rn	Pb-214	6.20E-12	6.20E-12	SLPFRN(1,3)
Sf-Rn	Bi-214	1.50E-11	1.50E-11	SLPFRN(1,4)
Sf-Rn	Radon K factors, (mrem/WLM):			
Sf-Rn	Rn-222 Indoor	3.88E+02	3.88E+02	KFACTR(1,1)
Sf-Rn	Rn-222 Outdoor	3.88E+02	3.88E+02	KFACTR(1,2)

*Base Case means Default.Lib w/o Associate Nuclide contributions.

Risk Slope and Environmental Transport Factors for the Ground Pathway

Nuclide (i)	Slope(i)*	ETFG(i,t) At Time in Years (dimensionless) t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
At-218	2.740E-11	5.098E-01	5.098E-01	5.098E-01	5.098E-01	5.098E-01	5.098E-01	5.098E-01	5.098E-01
Bi-210	2.770E-09	5.192E-01	5.192E-01	5.192E-01	5.192E-01	5.192E-01	5.192E-01	5.192E-01	5.192E-01
Bi-214	7.340E-06	5.098E-01	5.098E-01	5.098E-01	5.098E-01	5.098E-01	5.098E-01	5.098E-01	5.098E-01
Hg-206	4.830E-07	5.262E-01	5.262E-01	5.262E-01	5.262E-01	5.262E-01	5.262E-01	5.262E-01	5.262E-01
Pb-210	1.480E-09	5.948E-01	5.948E-01	5.948E-01	5.948E-01	5.948E-01	5.948E-01	5.948E-01	5.948E-01
Pb-214	9.940E-07	5.262E-01	5.262E-01	5.262E-01	5.262E-01	5.262E-01	5.262E-01	5.262E-01	5.262E-01
Po-210	4.510E-11	5.096E-01	5.096E-01	5.096E-01	5.096E-01	5.096E-01	5.096E-01	5.096E-01	5.096E-01
Po-214	3.850E-10	5.080E-01	5.080E-01	5.080E-01	5.080E-01	5.080E-01	5.080E-01	5.080E-01	5.080E-01
Po-218	6.840E-15	5.320E-01	5.320E-01	5.320E-01	5.320E-01	5.320E-01	5.320E-01	5.320E-01	5.320E-01
Ra-226	2.500E-08	5.296E-01	5.296E-01	5.296E-01	5.296E-01	5.296E-01	5.296E-01	5.296E-01	5.296E-01
Rn-218	3.390E-09	5.080E-01	5.080E-01	5.080E-01	5.080E-01	5.080E-01	5.080E-01	5.080E-01	5.080E-01
Rn-222	1.690E-09	5.088E-01	5.088E-01	5.088E-01	5.088E-01	5.088E-01	5.088E-01	5.088E-01	5.088E-01
Tl-206	6.110E-09	5.088E-01	5.088E-01	5.088E-01	5.088E-01	5.088E-01	5.088E-01	5.088E-01	5.088E-01
Tl-210	1.340E-05	5.096E-01	5.096E-01	5.096E-01	5.096E-01	5.096E-01	5.096E-01	5.096E-01	5.096E-01

* - Units are 1/yr per (pCi/g) at infinite depth and area. Multiplication by ETFG(i,t) converts to site conditions.

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 0.000E+00 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Pb-210	1.684E-02	9.541E+01	3.261E-01	1.589E-01	3.002E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	9.889E+01
Ra-226	1.684E-02	3.816E+02	1.112E+00	1.362E+00	3.002E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.871E+02

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 0.000E+00 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	2.600E-08	0.0004	1.514E-08	0.0002	9.601E-06	0.1532	3.304E-08	0.0005	1.604E-08	0.0003	3.012E-07	0.0048
Ra-226	4.693E-05	0.7488	1.370E-08	0.0002	5.652E-06	0.0902	1.648E-08	0.0003	2.018E-08	0.0003	4.446E-08	0.0007
Total	4.695E-05	0.7493	2.884E-08	0.0005	1.525E-05	0.2434	4.952E-08	0.0008	3.622E-08	0.0006	3.456E-07	0.0055

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Plant		Meat		Milk		All Pathways**	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.993E-06	0.1595
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.267E-05	0.8405
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.267E-05	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 0.000E+00 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	1.701E-08	0.0003	9.909E-09	0.0002	0.000E+00	0.0000	6.265E-06	0.1000	2.142E-08	0.0003	1.044E-08	0.0002	1.971E-07	0.0031
Ra-226	4.694E-05	0.7490	1.893E-08	0.0003	0.000E+00	0.0000	8.988E-06	0.1434	2.810E-08	0.0004	2.578E-08	0.0004	1.485E-07	0.0024
Total	4.695E-05	0.7493	2.884E-08	0.0005	0.000E+00	0.0000	1.525E-05	0.2434	4.952E-08	0.0008	3.622E-08	0.0006	3.456E-07	0.0055

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.521E-06	0.1041
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.615E-05	0.8959
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.267E-05	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 1.000E+00 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Pb-210	1.681E-02	9.557E+01	3.291E-01	1.597E-01	2.997E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	9.905E+01
Ra-226	1.679E-02	3.806E+02	1.110E+00	1.358E+00	2.993E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.860E+02

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 1.000E+00 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	2.594E-08	0.0004	1.511E-08	0.0002	9.584E-06	0.1533	3.301E-08	0.0005	1.602E-08	0.0003	3.005E-07	0.0048
Ra-226	4.680E-05	0.7487	1.366E-08	0.0002	5.636E-06	0.0902	1.643E-08	0.0003	2.012E-08	0.0003	4.433E-08	0.0007
Total	4.682E-05	0.7491	2.877E-08	0.0005	1.522E-05	0.2435	4.944E-08	0.0008	3.614E-08	0.0006	3.449E-07	0.0055

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Plant		Meat		Milk		All Pathways**	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.975E-06	0.1596
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.253E-05	0.8404
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.250E-05	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 1.000E+00 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	1.646E-08	0.0003	9.589E-09	0.0002	0.000E+00	0.0000	6.062E-06	0.0970	2.073E-08	0.0003	1.010E-08	0.0002	1.907E-07	0.0031
Ra-226	4.681E-05	0.7489	1.918E-08	0.0003	0.000E+00	0.0000	9.158E-06	0.1465	2.871E-08	0.0005	2.604E-08	0.0004	1.542E-07	0.0025
Total	4.682E-05	0.7491	2.877E-08	0.0005	0.000E+00	0.0000	1.522E-05	0.2435	4.944E-08	0.0008	3.614E-08	0.0006	3.449E-07	0.0055

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.310E-06	0.1010
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.619E-05	0.8990
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.250E-05	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 3.000E+00 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Pb-210	1.675E-02	9.524E+01	3.280E-01	1.592E-01	2.986E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	9.871E+01
Ra-226	1.670E-02	3.784E+02	1.103E+00	1.351E+00	2.977E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.839E+02

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 3.000E+00 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	2.583E-08	0.0004	1.505E-08	0.0002	9.544E-06	0.1535	3.287E-08	0.0005	1.595E-08	0.0003	2.993E-07	0.0048
Ra-226	4.653E-05	0.7485	1.358E-08	0.0002	5.605E-06	0.0902	1.634E-08	0.0003	2.001E-08	0.0003	4.408E-08	0.0007
Total	4.656E-05	0.7490	2.863E-08	0.0005	1.515E-05	0.2437	4.921E-08	0.0008	3.596E-08	0.0006	3.434E-07	0.0055

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Plant		Meat		Milk		All Pathways**	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.933E-06	0.1598
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.223E-05	0.8402
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.217E-05	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 3.000E+00 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	1.541E-08	0.0002	8.978E-09	0.0001	0.000E+00	0.0000	5.676E-06	0.0913	1.941E-08	0.0003	9.455E-09	0.0002	1.786E-07	0.0029
Ra-226	4.654E-05	0.7487	1.965E-08	0.0003	0.000E+00	0.0000	9.472E-06	0.1524	2.980E-08	0.0005	2.650E-08	0.0004	1.648E-07	0.0027
Total	4.656E-05	0.7490	2.863E-08	0.0005	0.000E+00	0.0000	1.515E-05	0.2437	4.921E-08	0.0008	3.596E-08	0.0006	3.434E-07	0.0055

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.908E-06	0.0950
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.626E-05	0.9050
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.217E-05	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 1.000E+01 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Pb-210	1.654E-02	9.399E+01	3.237E-01	1.571E-01	2.947E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	9.742E+01
Ra-226	1.637E-02	3.711E+02	1.082E+00	1.325E+00	2.919E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.764E+02

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 1.000E+01 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	2.544E-08	0.0004	1.482E-08	0.0002	9.398E-06	0.1541	3.236E-08	0.0005	1.571E-08	0.0003	2.947E-07	0.0048
Ra-226	4.563E-05	0.7480	1.332E-08	0.0002	5.496E-06	0.0901	1.602E-08	0.0003	1.962E-08	0.0003	4.323E-08	0.0007
Total	4.565E-05	0.7485	2.814E-08	0.0005	1.489E-05	0.2442	4.839E-08	0.0008	3.532E-08	0.0006	3.379E-07	0.0055

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Plant		Meat		Milk		All Pathways**	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.781E-06	0.1604
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.122E-05	0.8396
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.100E-05	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 1.000E+01 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	1.225E-08	0.0002	7.132E-09	0.0001	0.000E+00	0.0000	4.509E-06	0.0739	1.542E-08	0.0003	7.511E-09	0.0001	1.419E-07	0.0023
Ra-226	4.564E-05	0.7483	2.100E-08	0.0003	0.000E+00	0.0000	1.038E-05	0.1703	3.297E-08	0.0005	2.781E-08	0.0005	1.961E-07	0.0032
Total	4.565E-05	0.7485	2.814E-08	0.0005	0.000E+00	0.0000	1.489E-05	0.2442	4.839E-08	0.0008	3.532E-08	0.0006	3.379E-07	0.0055

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.693E-06	0.0769
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.630E-05	0.9231
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.100E-05	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 3.000E+01 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Pb-210	1.583E-02	8.998E+01	3.098E-01	1.504E-01	2.822E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	9.326E+01
Ra-226	1.548E-02	3.508E+02	1.023E+00	1.252E+00	2.759E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.558E+02

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 3.000E+01 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	2.425E-08	0.0004	1.412E-08	0.0002	8.959E-06	0.1551	3.085E-08	0.0005	1.497E-08	0.0003	2.809E-07	0.0049
Ra-226	4.314E-05	0.7470	1.259E-08	0.0002	5.196E-06	0.0900	1.515E-08	0.0003	1.855E-08	0.0003	4.087E-08	0.0007
Total	4.316E-05	0.7475	2.672E-08	0.0005	1.415E-05	0.2451	4.600E-08	0.0008	3.352E-08	0.0006	3.218E-07	0.0056

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Plant		Meat		Milk		All Pathways**	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.324E-06	0.1615
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.842E-05	0.8385
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.774E-05	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 3.000E+01 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	6.343E-09	0.0001	3.695E-09	0.0001	0.000E+00	0.0000	2.336E-06	0.0405	7.986E-09	0.0001	3.891E-09	0.0001	7.349E-08	0.0013
Ra-226	4.316E-05	0.7474	2.302E-08	0.0004	0.000E+00	0.0000	1.182E-05	0.2047	3.801E-08	0.0007	2.963E-08	0.0005	2.483E-07	0.0043
Total	4.316E-05	0.7475	2.672E-08	0.0005	0.000E+00	0.0000	1.415E-05	0.2451	4.600E-08	0.0008	3.352E-08	0.0006	3.218E-07	0.0056

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.431E-06	0.0421
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.531E-05	0.9579
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.774E-05	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 1.000E+02 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Pb-210	1.318E-02	7.490E+01	2.579E-01	1.252E-01	2.349E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.764E+01
Ra-226	1.272E-02	2.882E+02	8.404E-01	1.029E+00	2.267E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.924E+02

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 1.000E+02 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	2.010E-08	0.0004	1.171E-08	0.0002	7.425E-06	0.1563	2.556E-08	0.0005	1.241E-08	0.0003	2.328E-07	0.0049
Ra-226	3.544E-05	0.7460	1.035E-08	0.0002	4.269E-06	0.0898	1.245E-08	0.0003	1.524E-08	0.0003	3.358E-08	0.0007
Total	3.546E-05	0.7464	2.205E-08	0.0005	1.169E-05	0.2461	3.801E-08	0.0008	2.765E-08	0.0006	2.664E-07	0.0056

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Plant		Meat		Milk		All Pathways**	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.727E-06	0.1626
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.978E-05	0.8374
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.751E-05	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 1.000E+02 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	6.347E-10	0.0000	3.697E-10	0.0000	0.000E+00	0.0000	2.337E-07	0.0049	7.990E-10	0.0000	3.893E-10	0.0000	7.353E-09	0.0002
Ra-226	3.546E-05	0.7464	2.168E-08	0.0005	0.000E+00	0.0000	1.146E-05	0.2412	3.721E-08	0.0008	2.726E-08	0.0006	2.591E-07	0.0055
Total	3.546E-05	0.7464	2.205E-08	0.0005	0.000E+00	0.0000	1.169E-05	0.2461	3.801E-08	0.0008	2.765E-08	0.0006	2.664E-07	0.0056

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.433E-07	0.0051
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.727E-05	0.9949
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.751E-05	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 3.000E+02 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Pb-210	7.531E-03	4.280E+01	1.474E-01	7.153E-02	1.342E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.437E+01
Ra-226	7.255E-03	1.644E+02	4.794E-01	5.869E-01	1.293E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.668E+02

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 3.000E+02 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	1.148E-08	0.0004	6.685E-09	0.0002	4.240E-06	0.1564	1.460E-08	0.0005	7.086E-09	0.0003	1.330E-07	0.0049
Ra-226	2.022E-05	0.7459	5.901E-09	0.0002	2.435E-06	0.0898	7.100E-09	0.0003	8.692E-09	0.0003	1.915E-08	0.0007
Total	2.023E-05	0.7463	1.259E-08	0.0005	6.675E-06	0.2463	2.170E-08	0.0008	1.578E-08	0.0006	1.521E-07	0.0056

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Plant		Meat		Milk		All Pathways**	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.413E-06	0.1628
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.269E-05	0.8372
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.711E-05	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 3.000E+02 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	8.834E-13	0.0000	5.145E-13	0.0000	0.000E+00	0.0000	3.253E-10	0.0000	1.112E-12	0.0000	5.418E-13	0.0000	1.023E-11	0.0000
Ra-226	2.023E-05	0.7463	1.259E-08	0.0005	0.000E+00	0.0000	6.675E-06	0.2463	2.170E-08	0.0008	1.578E-08	0.0006	1.521E-07	0.0056
Total	2.023E-05	0.7463	1.259E-08	0.0005	0.000E+00	0.0000	6.675E-06	0.2463	2.170E-08	0.0008	1.578E-08	0.0006	1.521E-07	0.0056

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.386E-10	0.0000
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.711E-05	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.711E-05	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 1.000E+03 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Pb-210	1.056E-03	6.000E+00	2.066E-02	1.003E-02	1.882E-01	7.077E+01	1.482E-01	1.570E+00	1.749E-02	1.433E-02	7.874E+01
Ra-226	1.017E-03	2.305E+01	6.720E-02	8.227E-02	1.813E-01	1.007E+02	6.108E-02	2.251E+00	3.105E-02	6.793E-02	1.265E+02

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 1.000E+03 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	1.609E-09	0.0001	9.372E-10	0.0001	5.944E-07	0.0545	2.047E-09	0.0002	9.933E-10	0.0001	1.864E-08	0.0017
Ra-226	2.834E-06	0.2599	8.272E-10	0.0001	3.413E-07	0.0313	9.952E-10	0.0001	1.218E-09	0.0001	2.685E-09	0.0002
Total	2.835E-06	0.2601	1.764E-09	0.0002	9.357E-07	0.0858	3.042E-09	0.0003	2.212E-09	0.0002	2.132E-08	0.0020

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Plant		Meat		Milk		All Pathways**	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	5.712E-06	0.5239	1.541E-08	0.0014	1.633E-07	0.0150	1.818E-09	0.0002	1.490E-09	0.0001	6.512E-06	0.5973
Ra-226	1.172E-06	0.1075	9.489E-10	0.0001	3.497E-08	0.0032	4.823E-10	0.0000	1.055E-09	0.0001	4.390E-06	0.4027
Total	6.883E-06	0.6314	1.636E-08	0.0015	1.982E-07	0.0182	2.301E-09	0.0002	2.545E-09	0.0002	1.090E-05	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 1.000E+03 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	8.884E-23	0.0000	5.174E-23	0.0000	0.000E+00	0.0000	3.271E-20	0.0000	1.118E-22	0.0000	5.449E-23	0.0000	1.029E-21	0.0000
Ra-226	2.835E-06	0.2601	1.764E-09	0.0002	0.000E+00	0.0000	9.357E-07	0.0858	3.042E-09	0.0003	2.212E-09	0.0002	2.132E-08	0.0020
Total	2.835E-06	0.2601	1.764E-09	0.0002	0.000E+00	0.0000	9.357E-07	0.0858	3.042E-09	0.0003	2.212E-09	0.0002	2.132E-08	0.0020

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Pb-210	8.423E-20	0.0000	2.274E-22	0.0000	0.000E+00	0.0000	2.407E-21	0.0000	2.674E-23	0.0000	2.195E-23	0.0000	1.210E-19	0.0000
Ra-226	6.883E-06	0.6314	1.636E-08	0.0015	0.000E+00	0.0000	1.982E-07	0.0182	2.301E-09	0.0002	2.545E-09	0.0002	1.090E-05	1.0000
Total	6.883E-06	0.6314	1.636E-08	0.0015	0.000E+00	0.0000	1.982E-07	0.0182	2.301E-09	0.0002	2.545E-09	0.0002	1.090E-05	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Appendix F
Photograph Log

Appendix F: Photographic Log

Location: Treasure Island, San Francisco, CA,
Contract No: N62473-12-D-2005, CTO 0012
CB&I Project No. 500475

Photograph No. 1 **Site:** Wooden Stave – Site Wide **Photograph Date:** 12/7/2015	
Description: Looking northwest up the swale. Subtronic marking out subsurface utilities.	

Photograph No. 2 **Site:** Wooden Stave – Site Wide **Photograph Date:** 12/9/2015	
Description: Posted warning signs and contact list.	

Appendix F: Photographic Log

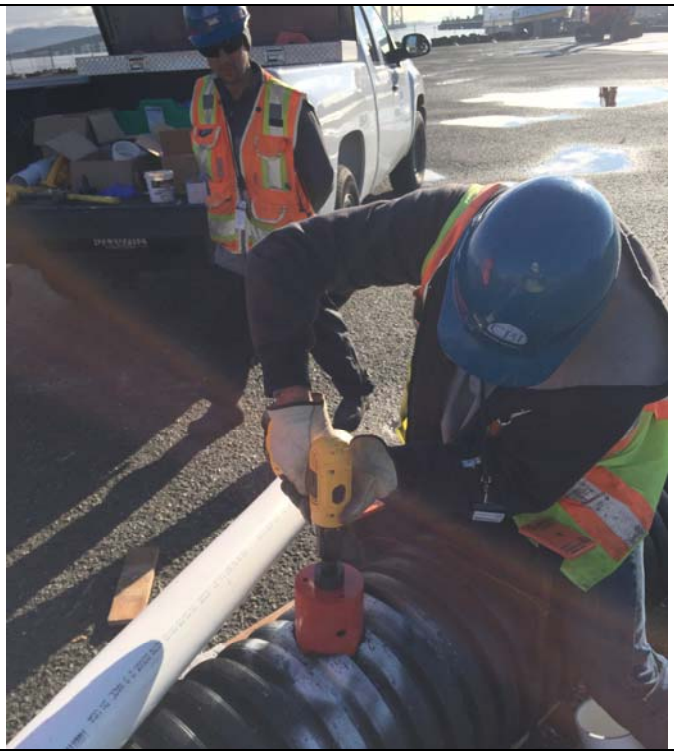
Location: Treasure Island, San Francisco, CA,
Contract No: N62473-12-D-2005, CTO 0012
CB&I Project No. 500475

Photograph No. 3 **Site:** Wood Stave, Pump Station **Photograph Date:** 12/17/2015	
Description: Attaching first piece of bypass to gasket and existing 14” line.	

Photograph No. 4 **Site:** Wood Stave **Photograph Date:** 01/04/2016	
Description: Uncovered Buried electrical access vault (pothole #4) gamma scan.	

Appendix F: Photographic Log

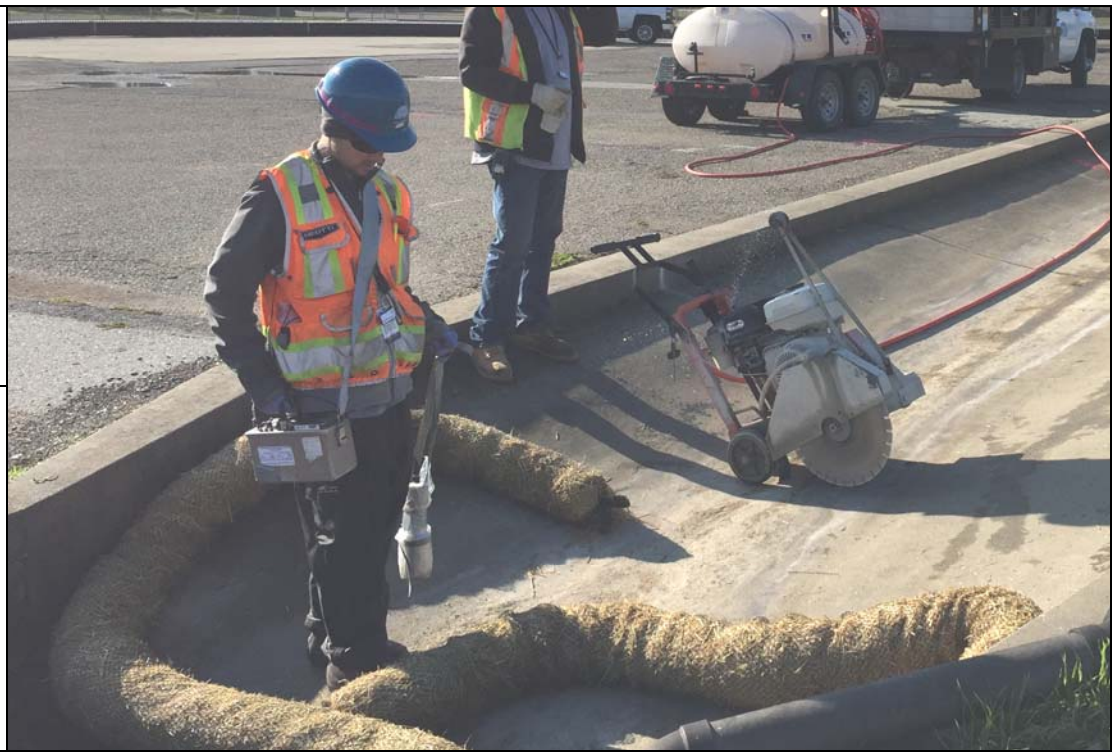
Location: Treasure Island, San Francisco, CA,
Contract No: N62473-12-D-2005, CTO 0012
CB&I Project No. 500475

Photograph No. 5 **Site:** Wood Stave **Photograph Date:** 01/07/2016	
Description: 4” to 16” pipe connection during testing. No leaks.	

Photograph No. 6 **Site:** Wood Stave **Photograph Date:** 01/07/2016	
Description: Final 4” bypass setup with 16” bypass.	

Appendix F: Photographic Log

Location: Treasure Island, San Francisco, CA,
Contract No: N62473-12-D-2005, CTO 0012
CB&I Project No. 500475

Photograph No. 7 **Site:** Wood Stave **Photograph Date:** 01/07/2016	
Description: Scanning curing concrete cutting.	

Photograph No. 8 **Site:** Wood Stave **Photograph Date:** 01/08/2016	
Description: RAD scan of bottom side of removed concrete swale.	

Appendix F: Photographic Log

Location: Treasure Island, San Francisco, CA,
Contract No: N62473-12-D-2005, CTO 0012
CB&I Project No. 500475

Photograph No. 9 **Site:** Wood Stave **Photograph Date:** 01/11/2016	
Description: Baseline RAD survey of new RSY pad location north of swale.	

Photograph No. 10 **Site:** Wood Stave – West Side **Photograph Date:** 01/12/2016	
Description: Investigating ductal iron pipe found in excavation at 2' bgs.	

Appendix F: Photographic Log

Location: Treasure Island, San Francisco, CA,
Contract No: N62473-12-D-2005, CTO 0012
CB&I Project No. 500475

Photograph No. 11 **Site:** Wood Stave **Photograph Date:** 01/12/2016	
Description: Gamma scan of overburden soil on temporary clean soil stockpile prior to use to make berm for stockpile.	

Photograph No. 12 **Site:** Wood Stave RSY 233A **Photograph Date:** 01/13/2016	
Description: Construction of RSY Pad.	

Appendix F: Photographic Log

Location: Treasure Island, San Francisco, CA,
Contract No: N62473-12-D-2005, CTO 0012
CB&I Project No. 500475

Photograph No. 13 **Site:** Wood Stave – Section 3W **Photograph Date:** 01/20/2016	
Description: In process gamma scanning of overburden soil in Section 3W	

Photograph No. 14 **Site:** Wood Stave – Section 6W **Photograph Date:** 01/26/2016	
Description: Pipeline structure within Section 6W after removal of concrete slurry.	

Appendix F: Photographic Log

Location: Treasure Island, San Francisco, CA,
Contract No: N62473-12-D-2005, CTO 0012
CB&I Project No. 500475

Photograph No. 15 **Site:** Wood Stave – Section 6W **Photograph Date:** 01/26/2016	
Description: Surveying wood debris from north sidewall.	

Photograph No. 16 **Site:** Wood Stave – Section 7W **Photograph Date:** 01/27/2016	
Description: Fairly intact piece of pipe with concrete slurry removed from section 7W.	

Appendix F: Photographic Log

Location: Treasure Island, San Francisco, CA,
Contract No: N62473-12-D-2005, CTO 0012
CB&I Project No. 500475

Photograph No. 17 **Site:** Wood Stave – RCA Concrete Stockpile **Photograph Date:** 01/27/2016	
Description: Concrete slurry pieces labeled by section and stockpiled within RCA being prepped for scanning.	

Photograph No. 18 **Site:** Wood Stave – RCA **Photograph Date:** 01/29/2016	
Description: Collecting concrete samples.	

Appendix F: Photographic Log

Location: Treasure Island, San Francisco, CA,
Contract No: N62473-12-D-2005, CTO 0012
CB&I Project No. 500475

Photograph No. 19 **Site:** Wood Stave – RCA **Photograph Date:** 02/02/2016	
Description: Surveying soil excavated near wood stave pipe in Section 1E	

Photograph No. 20 **Site:** RCA – RSY Pad 233A **Photograph Date:** 02/09/2016	
Description: Grading out RSY Pad 233A	

Appendix F: Photographic Log

Location: Treasure Island, San Francisco, CA,
Contract No: N62473-12-D-2005, CTO 0012
CB&I Project No. 500475

Photograph No. 21 **Site:** RCA – RSY Pad 233A **Photograph Date:** 02/09/2016	
Description: Measuring thickness of soil at one of the locations: height above soil layer was subtracted from height of hay bale (16” – 8” = 8” soil thickness)	

Photograph No. 22 **Site:** RCA – RSY Pad 233A **Photograph Date:** 02/12/2016	
Description: Performing walkover survey with RSI.	

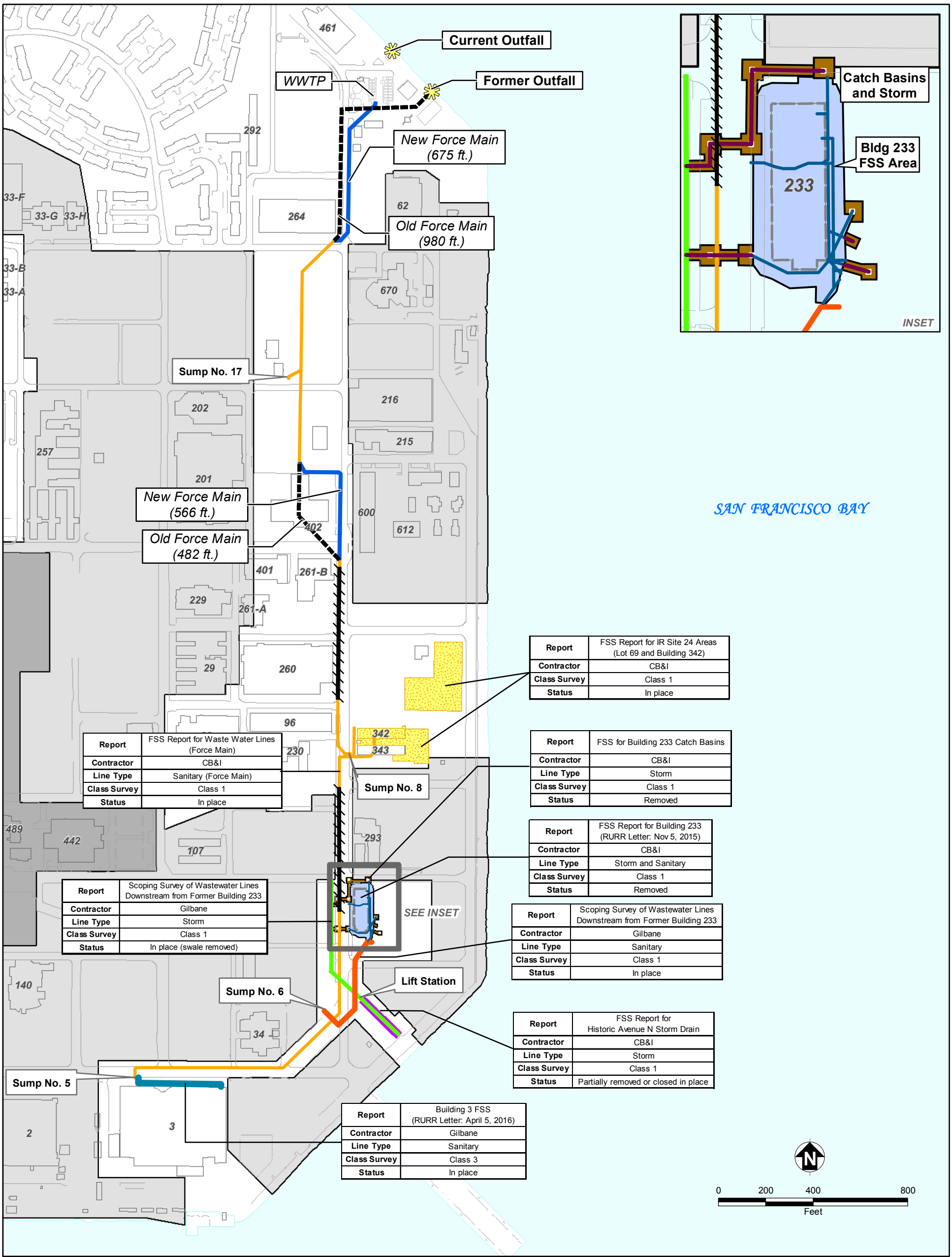
Appendix F: Photographic Log

Location: Treasure Island, San Francisco, CA,
Contract No: N62473-12-D-2005, CTO 0012
CB&I Project No. 500475

Photograph No. 23 **Site:** RCA – RSY Pad 233A **Photograph Date:** 02/15/2016	
Description: Taking biased statics in NE corner of pad following RSI 100% gamma survey.	

Photograph No. 24 **Site:** RCA – RSY Pad 233A **Photograph Date:** 02/15/2016	
Description: Systematic sampling set up on RSY Pad 233A, Use 1 and static sampling at sample locations after collection.	

Appendix G
Radiological Investigations Within Utility Corridors 1 and 2



Report	FSS Report for IR Site 24 Areas (Lot 69 and Building 342)
Contractor	CB&I
Class Survey	Class 1
Status	In place

Report	FSS Report for Waste Water Lines (Force Main)
Contractor	CB&I
Line Type	Sanitary (Force Main)
Class Survey	Class 1
Status	In place

Report	FSS for Building 233 Catch Basins
Contractor	CB&I
Line Type	Storm
Class Survey	Class 1
Status	Removed

Report	FSS Report for Building 233 (RURR Letter: Nov 5, 2015)
Contractor	CB&I
Line Type	Storm and Sanitary
Class Survey	Class 1
Status	Removed

Report	Scoping Survey of Wastewater Lines Downstream from Former Building 233
Contractor	Gilbane
Line Type	Storm
Class Survey	Class 1
Status	In place (swale removed)

Report	Scoping Survey of Wastewater Lines Downstream from Former Building 233
Contractor	Gilbane
Line Type	Sanitary
Class Survey	Class 1
Status	In place

Report	FSS Report for Historic Avenue N Storm Drain
Contractor	CB&I
Line Type	Storm
Class Survey	Class 1
Status	Partially removed or closed in place

Report	Building 3 FSS (RURR Letter: April 5, 2016)
Contractor	Gilbane
Line Type	Sanitary
Class Survey	Class 3
Status	In place

- Gilbane – Bldg 233 Storm
- Gilbane – Bldg 3 Sanitary
- Gilbane – Bldg 233 Sanitary
- CB&I – Sanitary Force Main
- Outfall Location
- Removed Sewer Line Segment
- New Sewer Line Segment
- Line Inspected by Video Camera (1,055 ft)
- CB&I – Bldg 233 Catch Basins and Storm
- CB&I – Bldg 233 FSS Area Sanitary and Storm
- CB&I – Avenue N Storm
- Site 24 Radiologically Impacted Areas
- TIDA Upland Parcel
- Job Corps Parcel
- Road Edge
- Building

TriEco A Joint Venture

Naval Station Treasure Island

Department of the Navy, BRAC PMO West, San Diego, CA

STORM AND WASTE WATER LINES ASSOCIATED WITH BUILDINGS 3, 233, AND 342

7/12/2016 V:\Treasure Island\Projects\FOST\Snapshots\STORM AND WASTE WATER LINES BLDGS 3_233_342.mxd TtEMI-OAK yashekia.evans

Appendix H
Technical Basis Document, Gamma Scanning Surveys
(dated March 2015)

FINAL
TECHNICAL BASIS DOCUMENT
Gamma Scanning Surveys
Former Naval Station Treasure Island
San Francisco, California

March 2015

Submitted to:

Base Realignment and Closure
Program Management Office West Naval Facilities Engineering Command
1455 Frazee Road, Suite 900
San Diego, California 92108

Submitted by:

CB&I Federal Services LLC
4005 Port Chicago Highway, Suite 200
Concord, California 94520-1120

FINAL
TECHNICAL BASIS DOCUMENT
Gamma Scanning Surveys
Former Naval Station Treasure Island
San Francisco, California

March 2015

Prepared by: _____
John Hackett, PE, CHP, PMP
Technical Lead

Approved by: _____
Ulrika Messer, PE
Program Manager

Approved by: _____
Mark Somerville, PhD, CHP
License Radiation Safety Officer

Table of Contents

List of Tables (in text) ii
List of Appendices ii
Acronyms and Abbreviations iii

1.0 Introduction 1-1
- 1.1 Summary of Work Activities 1-1
- 1.2 Guiding Technical Documents 1-1
  - 1.2.1 Project Work Plans 1-2
  - 1.2.2 Radiation Protection Plan 1-2
- 1.3 Radiological Criteria 1-2
- 1.4 Instrumentation 1-3
  - 1.4.1 3x3 NaI 1-3
  - 1.4.2 256 Cubic Inch NaI 1-3
- 1.5 General Calculation Approach 1-4
- 1.6 General Assumptions 1-7

2.0 Gamma Surveys with 3x3 NaI 2-1
- 2.1 Instrument Setup 2-1
- 2.2 General Calculation Assumptions 2-1
- 2.3 Example Calculation 2-1
- 2.4 Additional Modeling and Results 2-9
- 2.5 Summary of Calculations 2-9

3.0 Gamma Surveys with RS-700 256-Cubic Inch NaI 3-1
- 3.1 Instrument Setup 3-1
- 3.2 General Calculation Assumptions 3-1
- 3.3 Example Calculation 3-2
- 3.4 Additional Modeling and Results 3-9
- 3.5 Summary of Calculations 3-9

4.0 Summary and Conclusion 4-1

5.0 References 5-1

List of Tables (in text)

Table 1 Soil Composition
Table 2 Calculation of FRER, 3x3 NaI
Table 3 Probability of Interaction with Detector, 3x3 NaI
Table 4 Relative Detector Response, 3x3 NaI
Table 5 Instrument Count Rate to Exposure Rate Ratio, 3x3 NaI
Table 6 Calculation of Total Energy-Weighted Count Rate to Exposure Rate Ratio, 3x3 NaI
Table 7 Summary of Scan MDC Calculations, 3x3 NaI
Table 8 Calculation of FRER, RS-700
Table 9 Probability of Interaction with Detector, RS-700
Table 10 Relative Detector Response, RS-700
Table 11 Instrument Count Rate to Exposure Rate Ratio, RS-700
Table 12 Calculation of Total Energy-Weighted Count Rate to Exposure Rate Ratio, RS-700
Table 13 Summary of Scan MDC Calculations, RS-700

List of Appendices

Appendix A 3x3 NaI Microshield Modeling and MDC Calculations
Appendix B RS-700 Microshield Modeling and MDC Calculations

Acronyms and Abbreviations

^{137}Cs	cesium-137
^{226}Ra	radium-226
3x3	3-inch by 3-inch
µCi	microcurie
µR/hr	microroentgen per hour
APP/SSHP	*Final Accident Prevention Plan, Radiological Surveys at Various Areas, Former Naval Station Treasure Island, San Francisco, California*
CB&I	CB&I Federal Services LLC
cm	centimeter(s)
cm^2/g	square centimeters per gram
cpm	counts per minute
cpm/µR/hr	counts per minute per microroentgen per hour
FRER	fluence rate to exposure rate
g/cm^3	grams per cubic centimeter
GPS	global positional system
keV	kilo electron volts
MARSSIM	*Multi-Agency Radiation Survey and Site Investigation Manual*
MDC	minimum detectable concentration
MDCR	minimum detectable count rate
$MDCR_{Surveyor}$	minimum detectable count rate, surveyor
NaI	sodium iodide
Navy	U.S. Department of the Navy
NRC	U.S. Nuclear Regulatory Commission
NSTI	former Naval Station Treasure Island
pCi/g	picocurie per gram
RDR	relative detector response
RSI	Radiation Solutions, Inc.
RSY	radiological screening yard
Sitewide RPP	*Sitewide Radiation Protection Plan, Naval Station Treasure Island, San Francisco, California*
TBD	Technical Basis Document

1.0 Introduction

This Technical Basis Document (TBD) presents the basis for the gamma count rate survey procedures to be used by CB&I Federal Services LLC (CB&I) to conduct radiological characterization activities at the former Naval Station Treasure Island (NSTI) for the U.S. Department of the Navy (Navy), Naval Facilities Engineering Command Southwest.

Work performed under this TBD will follow the provisions of the project-specific work plans, task-specific plans, and accident prevention plans. In addition, work involving radioactive materials will be performed under the *Sitewide Radiation Protection Plan, Naval Station Treasure Island, San Francisco, California* (Sitewide RPP; CB&I, 2014, as updated or revised).

1.1 Summary of Work Activities

The scope of work to be conducted by CB&I at NSTI includes the following activities:

- Project and site management
- Construction and operation of radiological screening yard (RSY) pads
- Radiological survey and sampling of surface soil for characterization and release
- Excavation of potentially chemically and radiologically impacted soil
- Radiological survey of selected buildings and materials for characterization and release
- Other radiological work in support of project activities

1.2 Guiding Technical Documents

Work activities will be accomplished in accordance with California Radioactive Material License 7889-07 and the procedures and methodologies detailed in the documents discussed in the following subsections.

In general, the calculations described in this TBD are based on the survey process and calculations presented in the following guidance documents:

- NUREG-1575, Revision 1: *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM; U.S Nuclear Regulatory Commission [NRC] et al, 2000)
- NUREG-1507: *Minimum Detectable Concentrations With Typical Radiation Survey Instruments for Various Contaminants and Field Conditions* (NRC, 1998)

1.2.1 Project Work Plans

The project work plans are specific deliverables for each contract task order, and they provide the project-wide processes and procedures. The supporting documents appended to project work plans typically include a sampling and analysis plan, an environmental protection plan, and a contractor quality control plan.

1.2.2 Radiation Protection Plan

The Sitewide RPP (CB&I, 2014, as updated or revised) was prepared to support work performed by CB&I at all radiologically impacted (confirmed or potential) sites at NSTI. It is a standalone document tied to California Radioactive Material License 7889-07. The Sitewide RPP documents contractor requirements and standard operating procedures to ensure qualified personnel, proper radiological controls, and approved standard operating procedures are used to perform radiological work at NSTI.

1.3 Radiological Criteria

The primary radionuclide of concern at NSTI is radium-226 (^{226}Ra). The project release criterion for soil at NSTI is the demonstration of site ^{226}Ra soil concentrations to be at levels that are indistinguishable from background.

Soil analytical data will be evaluated for similarity to ^{226}Ra concentrations in the sitewide background data set. Background surface soil samples were collected from 20 random non-impacted locations at NSTI. These 20 samples were analyzed for ^{226}Ra using gamma spectroscopy. Data from these samples are provided in Table 1, and are discussed in additional detail in the memorandum *Analysis of Gamma Survey and Radium-226 Soil Concentration Data at the NSTI Sitewide Background Areas and the Area 7 Background Reference Area* (Shaw Environmental, Inc., 2012a). The mean ^{226}Ra concentration in these 20 soil samples is 0.69 pCi/g.

To aid in remediation decisions, a conservative ^{226}Ra soil screening criterion was also developed. The screening criterion is 1 pCi/g of ^{226}Ra above the mean background in the background reference area. Therefore, the screening criterion inclusive of background is defined as 1.69 pCi/g of ^{226}Ra. Soil or material with ^{226}Ra concentrations exceeding the screening criterion will be segregated for disposal as low-level radioactive waste. To date, ^{226}Ra contamination present at NSTI has been present as discrete objects or models as discrete objects (e.g., a degraded radiological commodity with limited adjacent soil contamination). Observed soil concentrations associated with commodities resulting in soil remediation have been significantly higher than the screening criterion, and are detectable primarily by gamma scan surveys. Soil sampling will be performed primarily to confirm that soil ^{226}Ra concentrations are consistent with background.

Gamma scanning surveys are performed at NSTI to verify the absence of discrete radiological objects or localized contaminated soil. Based on NSTI site history, these objects are assumed to contain ^{226}Ra as the primary radionuclide.

The background reference area for use in evaluating gamma scanning and static measurements on soil is Area 7, which is located to the south of Building 453 at NSTI. Prior to use of an instrument at an impacted soil sites, instrument-specific reference area data will be collected Area 7 and evaluated to determine instrument-specific investigation levels.

A background reference area for paved roadways at the former NSTI has been identified and qualified for use. Area 9 is located in the southeastern corner of the former NSTI, at the east end of California Avenue, on the south side of the street. The background reference area is described and further discussed in a technical memorandum dated May 17, 2012, entitled, *Analysis of the Treasure Island Asphalt Background Areas – Gamma Survey and Radium-226 Concentration Data* (Shaw Environmental, Inc., 2012b).

Additional reference areas may be added where required by survey conditions or environments.

1.4 Instrumentation

CB&I will use two primary types of gamma radiation detectors at NSTI. A summary of the instruments and expected uses are listed below.

1.4.1 3x3 NaI

The 3-inch by 3-inch (3x3) sodium iodide (NaI) gamma scintillation detector (Ludlum Model 44-20 or equivalent) will be coupled with an appropriate ratemeter/scaler (e.g., Ludlum Model 2221 or equivalent). The 3x3 NaI may be used for general area or focused scanning measurements. In addition, it may be used as a follow-up tool to further delineate elevated areas identified by other means. The 3x3 is typically paired with an external Trimble global positioning system (GPS) antenna and data logger, but may be used without the GPS and data logger.

1.4.2 256 Cubic Inch NaI

A large area gamma scanning system (RS-700) will also be used at NSTI. The system consists of two Radiation Solutions, Inc. (RSI), RSX-1 4-inch by 4-inch by 16-inch (256 cubic inch) NaI scintillation detectors with advanced digital spectrometry capability coupled with a RS-701 console and external Trimble GPS antenna. The RS-700 system will be used for scanning land or building floor surfaces.

1.5 General Calculation Approach

The calculations described in Sections 2 and 3 follow the method described by NUREG-1507, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions* (NRC, 1998), to determine the minimum detectable concentration (MDC) of a distributed source of ^{226}Ra in soil and a small commodity containing ^{226}Ra under different geometries and site conditions. Microshield Version 8.02 (Grove Software, Inc., 2009) was used to model the gamma fluence (output files are presented in Appendices A and B).

The following paragraphs describe the general calculation process from Section 6.8.2 of NUREG-1507 (NRC, 1998). Additional information is provided in that document. Scenario or detector specific information is provided in Sections 2 and 3 as variables to the calculation.

The calculation uses known or assumed background count rates and scanning speed (resulting in a specific observation interval). Using this information, the minimum detectable count rate (MDCR) is calculated, and a surveyor efficiency is then applied to calculate the $MDCR_{Surveyor}$. It is then necessary to correlate the $MDCR_{Surveyor}$ (in counts per minute [cpm]) to a radionuclide concentration in soil (in picocuries per gram [pCi/g] or similar). This is accomplished by first establishing the relationship between detector net count rate and net exposure rate (in units of cpm per microroentgen per hour [cpm/µR/hr]). Then, the relationship between concentration and exposure rate is determined using gamma fluence modeling.

The MDCR and $MDCR_{Surveyor}$ are calculated using the following equations.

$$s_i = d'\sqrt{b_i} \qquad \textbf{Equation 1}$$

$$MDCR = s_i \times (60/i) \qquad \textbf{Equation 2}$$

$$MDCR_{Surveyor} = \frac{MDCR}{\sqrt{p}} \qquad \textbf{Equation 3}$$

Where:

s_i	number of source counts required for a specified level of measurement performance and observation interval *i*, in counts
d'	measurement performance parameter, determined from desired true positive and false positive rates from MARSSIM Table 6.5, unitless
b_i	number of background counts observed during observation interval *i*, in counts
MDCR	minimum detectable count rate, in cpm
$MDCR_{Surveyor}$	minimum detectable count rate accounting for surveyor efficiency, in cpm

p	surveyor efficiency

The calculated $MDCR_{Surveyor}$ value is then used to determine the minimum detectable exposure rate using the energy-weighted cpm/µR/hr for the detector.

The initial step is to calculate the ratio of the gamma fluence rate to exposure rate (FRER) as a function of gamma energy using the following equation:

$$Fluence\ Rate\ to\ Exposure\ Rate\ \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_{\gamma}\left(\frac{\mu_{en}}{\rho}\right)_{air}} \qquad \textbf{Equation 4}$$

Where:

E_{γ}	Gamma energy in kilo electron volts (keV)
$(\mu_{en}/\rho)_{air}$	Mass energy absorption coefficient for air, in units of square centimeters per gram (cm^2/g). Values were obtained from *Radiological Health Handbook* (U.S. Department of Health, Education, and Welfare, 1970).

Then the probability of gamma interaction with the NaI scintillation crystal (assuming the primary interaction occurs through the side/end of the detector parallel with surface being surveyed) as a function of gamma energy is calculated using the following equation:

$$Probabilty\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)} \qquad \textbf{Equation 5}$$

Where:

P	Probability of gamma interaction with the NaI crystal
$(\mu/\rho)_{NaI}$	Mass attenuation coefficient for NaI, in units of square centimeters per gram (cm^2/g). Values were obtained from *Radiological Health Handbook* (1970).
x	Length of detector parallel to surveyed surface, in centimeters (cm)
ρ_{NaI}	Density of NaI, equal to 3.67 grams per cubic centimeter (g/cm^3)

The relative detector response (RDR) for each gamma energy is then calculated by multiplying the FRER by the probability of interaction as follows:

$$RDR = FRER\ \times P \qquad \textbf{Equation 6}$$

Using the expected detector response for the 662 keV gamma energy of cesium-137 (^{137}Cs), the count rate to exposure rate ratios can be determined for the other gamma energies of interest. The

ratios are then summed to determine the total energy-weighted cpm/µR/hr rate. The count rate to exposure rate ratio for a given energy is determined by the following equation:

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{RDR_{E_i}}{RDR_{Cs-137}} \qquad \textbf{Equation 7}$$

Where:

cpm/µR/hr, E_i	Count rate to exposure rate ratio as a function of gamma energy, E_i
$cpm_{Cs\text{-}137}$	Estimated or reported detector response to ^{137}Cs 662 keV gamma energy
RDR_{Ei}	RDR for Ei calculated using Equation 6
$RDR_{Cs\text{-}137}$	RDR for 662 keV emission from ^{137}Cs calculated using Equation 6

Using the modeled exposure rates from the Microshield model for each gamma energy, the total energy-weighted cpm/µR/hr ratio is calculated as follows:

$$weighted\left(cpm/\frac{\mu R}{hr}\right) = \sum\left(\frac{\dot{X}_{E_i}}{\dot{X}_{Total}} \times \frac{cpm}{\mu R/_{hr}}, E_i\right) \qquad \textbf{Equation 8}$$

Where:

$\dot{X}_{Ei}$	Exposure rate as a function of gamma energy, E_i, as determined by Microshield model
$\dot{X}_{Total}$	Total exposure rate as determined by Microshield model
cpm/µR/hr, E_i	Count rate to exposure rate ratio as a function of gamma energy, E_i

The exposure rate equivalent to the $MDCR_{Surveyor}$ calculated using Equations 1 through 3 is determined using the following equation:

$$\dot{X}, MDCR_{Surveyor} = \frac{MDCR_{Surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)} \qquad \textbf{Equation 9}$$

The scan MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6 g/cm^3 is then calculated as follows:

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{\dot{X}, MDCR_{Surveyor}}{\dot{X}_{Total}.} \qquad \textbf{Equation 10}$$

Where:

Modeled Conc.	Normalized soil concentration of ^{226}Ra modeled by Microshield, equal to 1 pCi/g

This process results in a volumetric soil activity concentration that represents the lower scan sensitivity of the detector. For discrete objects, the volume and density of the object is used to determine the minimum detectable source activity for the detector.

1.6 General Assumptions

The following general assumptions were made in the calculations:

- ^{226}Ra source was modeled as a distributed soil source in a cylinder 15 cm in height and with a 28 cm radius (the NUREG-1507 default source term), and as an object 2.54 cm in height and with a 1.5 cm radius.
- The distributed source consisted of soil comprised of the components from Federal Guidance Report 12, *External Exposure to Radionuclides in Air, Water, and Soil* (U.S. Environmental Protection Agency, 1993), listed as shown in Table 1.

Table 1
Soil Composition

Element	Mass Fraction
H – Hydrogen	0.021
C – Carbon	0.016
O – Oxygen	0.577
Al – Aluminum	0.050
Si – Silicon	0.271
K – Potassium	0.013
Ca – Calcium	0.041
Fe – Iron	0.011
Total	1.000

- The density of the soil in the distributed source was 1.6 g/cm^3, assumed to be dry soil.
- The radiological source was modeled as a discrete object with a density of 1.6 g/cm^3.
- Density of NaI in the 3x3 and RSI crystals is equal to 3.67 g/cm^3.
- The ^{226}Ra source term was assumed to have full equilibrium with decay progeny (modeling performed after 30-year decay).
- The modeled density of air is 0.00122 g/cm^3.
- Scan speed for the 3x3 NaI is equal to 0.5 meters per second. Scan speed for the RS-700 is 0.25 meters per second.

- Detector height for the 3x3 NaI is 10 cm. Detector height for the RS-700 is 15.24 cm.
- Mass energy absorption and mass attenuation coefficients used were obtained from the *Radiological Health Handbook* (1970).
- The Microshield modeling runs utilized buildup in the material resulting in the most mean free path lengths.

2.0 Gamma Surveys with 3x3 NaI

As noted in Section 1, surveys to be performed with the 3x3 NaI include characterization, remediation support, and final status scanning surveys that may be logged and position-correlated with an external GPS unit. In addition, the 3x3 NaI may be used for follow-up investigation scanning and status measurements.

2.1 Instrument Setup

Per the Sitewide RPP and CB&I procedures, instruments to be used will be calibrated annually. Prior to use in the field, the instrument will be used to collect reference area data which will be used to determine an instrument- and media-specific investigation level. The specific instrument setup parameters for the 3x3 NaI are detailed in work instruction TIWI-12-01, *Operation and Use of Portable Instruments at Treasure Island* (Shaw Environmental, Inc., 2012).

2.2 General Calculation Assumptions

The general assumptions and modeling inputs for the 3x3 NaI are as follows:

- Ambient background count rate of 18,000 cpm, based on the general observed average count rate from the TI Area 7 soil reference area.
- Count rate to exposure rate ratio of 2,300 cpm per microroentgen per hour (μR/hr) for ^{137}Cs (manufacturer's reported ratio for Ludlum Model 44-20 3x3 NaI detector)
- Length of the 3x3 NaI parallel to the surveyed surface is equal to 3 inches (7.6 cm).
- For scans using the 3x3, level of performance (d') is equal to 1.38, corresponding to 95% true positive detection rate and 60% false positive detection rate – for the 3x3 NaI a higher false positive detection rate is acceptable as the technician performing the scanning surveys will have the flexibility to investigate audible or visible changes in count rate (i.e., conduct "second stage scanning", per MARSSIM).
- The thickness of the aluminum housing for the Ludlum 44-20 3x3 NaI is 0.02 inches (0.051 cm), with a density of 2.7 g/cm^3.
- Scan speed is 0.5 meters per second, resulting in an observation interval of 1 second
- Surveyor efficiency of 0.50

2.3 Example Calculation

The example calculation for the 3x3 NaI presented in this section is for the measurement of the NUREG-1507 default distributed soil source term, following the process described in Section 1.5.

Calculation of MDCR and $MDCR_{Surveyor}$

$$s_i = d'\sqrt{b_i}$$

$$MDCR = s_i \times (60/i)$$

$$MDCR_{Surveyor} = \frac{MDCR}{\sqrt{p}}$$

Where:

d'	measurement performance parameter, determined from desired true positive and false positive rates from MARSSIM Table 6.5, unitless, equal to 1.38
b_i	number of background counts observed during observation interval *i*, in counts, equal to: $$\frac{18{,}000\ counts}{minute} \times \frac{1\ minute}{60\ seconds} = 300\ counts$$ assuming a background count rate of 18,000 cpm and an observation interval, *i*, of 1 second
s_i	number of source counts required for a specified level of measurement performance and observation interval *i*, in counts: $$s_i = 1.38\sqrt{300} = 23.9\ counts$$
MDCR	minimum detectable count rate, in cpm $$MDCR = 23.9 \times (60/1) = 1{,}434\ cpm$$
$MDCR_{Surveyor}$	minimum detectable count rate accounting for surveyor efficiency, in cpm
p	surveyor efficiency, equal to 0.5

$$MDCR_{Surveyor} = \frac{1{,}434\ cpm}{\sqrt{0.5}} = 2{,}028\ cpm$$

Calculation of the FRER

$$Fluence\ Rate\ to\ Exposure\ Rate\ \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Table 2
Calculation of FRER, 3x3 NaI

Gamma Energy (keV)	$(\mu_{en}/\rho)_{air}$ (cm^2/g)	FRER
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Calculation of probability of interaction through the detector

$$Probabilty\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

Where

x	Length of detector parallel to surveyed surface, equal to 7.6 cm
ρ_{NaI}	Density of NaI, equal to 3.67 grams per cubic centimeter (g/cm^3)

Table 3
Probability of Interaction with Detector, 3x3 NaI

Energy$_\gamma$ (keV)	$(\mu/\rho)_{NaI}$, (cm^2/g)	P
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	0.99
400	0.117	0.96
500	0.0955	0.93
600	0.0826	0.90
800	0.0676	0.85
1,000	0.0586	0.80
1,500	0.0469	0.73
2,000	0.0413	0.68

Calculation of RDR

$$RDR = FRER \times P$$

Table 4
Relative Detector Response, 3x3 NaI

$Energy_{\gamma}$ (keV)	FRER	P	RDR
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	0.99	0.1146
400	0.0845	0.96	0.0812
500	0.0673	0.93	0.0626
600	0.0563	0.90	0.0507
800	0.0433	0.85	0.0367
1,000	0.0357	0.80	0.0287
1,500	0.0261	0.73	0.0191
2,000	0.0214	0.68	0.0146

Calculation of the FRER, P, and RDR for 662 keV gamma emission from ^{137}Cs, and detector response relative to ^{137}Cs

At 662 keV, $(\mu_{en}/\rho)_{air}$ is equal to 0.0294 cm^2/g, and $(\mu/\rho)_{NaI}$ is equal to 0.0780 cm^2/g.

$$FRER \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}} = \frac{1}{(662)(0.0294)} = 0.0514$$

$$P = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)} = 1 - e^{-(0.0780\times7.6\times3.67)} = 0.89$$

$$RDR = FRER \times P = 0.0514 \times 0.89 = 0.0456$$

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{RDR_{E_i}}{RDR_{Cs-137}}$$

Where:

$cpm_{Cs\text{-}137}$	Reported detector response to ^{137}Cs 662 keV gamma energy, equal to 2,300 cpm/µR/hr per the users manual.

Table 5
Instrument Count Rate to Exposure Rate Ratio, 3x3 NaI

$Energy_{\gamma}$ (keV)	RDR_{Ei}	Ludlum 44-20 3x3 NaI (**cpm per µR/hr**), E_i
15	0.0517	2610
20	0.0969	4894
30	0.2268	11453
40	0.3906	19729
50	0.5208	26306
60	0.5708	28828
80	0.5297	26752
100	0.4329	21865
150	0.2656	13415
200	0.1866	9422
300	0.1146	5790
400	0.0812	4103
500	0.0626	3164
600	0.0507	2560
662	0.0455	2300
800	0.0367	1853
1,000	0.0287	1452
1,500	0.0191	964
2,000	0.0146	738

Calculation of the total energy-weighted cpm/µR/hr ratio

$$weighted\left(cpm/\frac{\mu R}{hr}\right) = \sum\left(\frac{\dot{X}_{E_i}}{\dot{X}_{Total}} \times \frac{cpm}{\mu R/_{hr}}, E_i\right)$$

Table 6
Calculation of Total Energy-Weighted Count Rate to Exposure Rate Ratio, 3x3 NaI

$Energy_{\gamma}$ (keV)	MicroShield Exposure Rate (With Buildup) (µR/hr)	cpm per µR/hr, Ei	cpm per µR/hr (weighted)	Percent of NaI detector response
15	1.159E-04	2610	0	0.0%
20	0.000E+00	4894	0	0.0%
30	0.000E+00	11453	0	0.0%
40	0.000E+00	19729	0	0.0%
50	2.393E-04	26306	9	0.4%
60	0.000E+00	28828	0	0.0%
80	3.926E-03	26752	152	7.3%
100	3.551E-05	21865	1	0.1%
150	0.000E+00	13415	0	0.0%
200	8.324E-03	9422	114	5.5%
300	2.610E-02	5790	219	10.5%
400	6.605E-02	4103	392	18.9%
500	3.878E-03	3164	18	0.9%
600	1.244E-01	2560	461	22.2%
800	3.170E-02	1853	85	4.1%
1000	1.280E-01	1452	269	13.0%
1500	1.082E-01	964	151	7.3%
2000	1.899E-01	738	203	9.8%
Total	6.909E-01		2074	100.0%

Calculation of the exposure rate at the $MDCR_{Surveyor}$ and scan MDC

$$\dot{X}, MDCR_{Surveyor} = \frac{MDCR_{Surveyor}}{weighted(cpm/\frac{\mu R}{hr})} = \frac{2{,}028}{2{,}074} = 0.978\ \mu R/hr$$

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{\dot{X}, MDCR_{Surveyor}}{\dot{X}_{Total}.} = (1) \times \frac{0.978}{0.6909} = 1.42\ pCi/g$$

2.4 Additional Modeling and Results

Using the process described in Section 2.3, scan MDCs were calculated for the 3x3 NaI for the following scenarios:

- Distributed soil source, no soil cover – representative of distributed contamination in a 15.24 cm (6-inch) thick RSY pad
- Discrete ^{226}Ra object, 12.7 cm soil cover – representative of a worst-case discrete object at the bottom of a 15.24 cm (6-inch) thick RSY pad
- Distributed soil source, 15.24 cm (6-inch) soil cover – representative of worst-case distributed contamination in a 30.48 cm (12-inch) thick RSY pad
- Discrete ^{226}Ra object, 27.94 cm soil cover – representative of a worst-case discrete object at the bottom of a 30.48 cm (12-inch) thick RSY pad
- Distributed soil source, 7.62 cm (3-inch) soil cover – representative of worst-case distributed contamination in a 22.86 cm (9-inch) thick RSY pad
- Discrete ^{226}Ra object, 20.32 cm soil cover – representative of a worst-case discrete object at the bottom of a 22.86 cm (9-inch) thick RSY pad
- Distributed soil source, 15.24 cm (6-inch) concrete cover – representative of upper 15.24 cm (6 inches) of soil below areas with concrete surface covering
- Discrete ^{226}Ra object, 15.24 cm (6-inch) concrete cover, and 12.7 cm (5-inch) soil cover – representative of a worst-case discrete object at the bottom of upper 15.24 cm (6 inches) of soil below area with concrete surface covering

2.5 Summary of Calculations

The results of the calculations described in Section 2.4 are listed in Table 7. The Microshield output files and supporting calculation spreadsheets are provided in Appendix A. The calculations support the following conclusions:

- The scan MDC for ^{226}Ra in a distributed soil source ranges from 1.42 pCi/g for a 6-inch soil lift to 9.51 pCi/g for a 12-inch soil lift. The scan MDC for soil under a 6-inch concrete cover is 10.4 pCi/g.

- The scan minimum detectable activity for a discrete object containing ^{226}Ra ranges from 0.108 µCi for an object at the bottom of a 6-inch soil lift to 0.890 µCi for an object at the bottom of a 12-inch soil lift. The scan minimum detectable activity for an object in the upper soil layer under a 6-inch concrete cover is 0.975 µCi. These calculated values compare favorably with the estimated activities of actual radiological objects recovered at NSTI using a 3x3 NaI.

Table 7
Summary of Scan MDC Calculations, 3x3 NaI

Description	Source Type	Filename	Scan MDC[a]	Units[b]
RSY pads - 6 inch (15.24 cm) thickness	Distributed	TI1AD	1.42	pCi/g
RSY pads - 6 inch (15.24 cm) thickness, 12.7 cm cover above source	Object	TI1AO	0.108	µCi
RSY pads - 12 inch (30.48 cm)thickness, 15.24 cm cover above source	Distributed	TI2AD	9.51	pCi/g
RSY pads - 12 inch (30.48 cm) thickness, 27.94 cm cover above source	Object	TI2AO	0.89	µCi
RSY pads - 9 inch (22.86 cm) thickness, 7.62 cm cover above source	Distributed	TI3AD	3.59	pCi/g
RSY pads - 9 inch (22.86 cm) thickness, 20.32 cm cover above source	Object	TI3AO	0.322	µCi
Concrete-covered surface soil (15.24 cm concrete above source)	Distributed	TI5AD	10.4	pCi/g
Concrete-covered surface soil (15.24 cm concrete and 12.7 cm soil above source)	Object	TI5AO	0.975	µCi

Notes:

[a] Scan MDC = scan minimum detectable concentration. For source types modeled as Objects, the minimum detectable object activity is reported.

[b] pCi/g = picocuries per gram; µCi = microcuries.

These calculations demonstrate that the scanning sensitivity for the 3x3 NaI for a 6-inch thickness is consistent with the NSTI ^{226}Ra screening criterion of 1.69 pCi/g; therefore, additional soil sampling is not required to supplement the scanning measurements in a 6-inch soil layer. The calculations for the scan of concrete-covered surface soil for the 3x3 NaI are consistent with the observed objects recovered using that instrument at NSTI to date.

One potential source of error is the use of the manufacturer's reported detector response of 2,300 cpm/µR/hr. It is worth noting that the observed NSTI background count rate of 18,000 cpm corresponds to an observed background exposure rate of approximately 5 µR/hr. These observed values result in a detector response of 3,600 cpm/µR/hr. Use of a 3,600 cpm/µR/hr detector

response results in a calculated scan MDC of 0.90 pCi/g for distributed ^{226}Ra in soil. The use of the manufacturer's reported detector response is conservative, and actual conditions are likely to result in higher detector sensitivity.

3.0 Gamma Surveys with RS-700 256-Cubic Inch NaI

As noted in Section 1, surveys to be performed with the RSI include characterization, remediation support, and final status scanning surveys that may be logged and position-correlated with an external GPS unit.

3.1 Instrument Setup

Per the Sitewide RPP and CB&I procedures, instruments to be used will be calibrated annually. Prior to use in the field, the instrument will be used to collect reference area data which will be used to determine an instrument- and media-specific investigation level. The specific instrument setup parameters for the RS-700 are detailed in the RS-700 Users Manual (RSI, 2014) and work instructions.

3.2 General Calculation Assumptions

The general assumptions and modeling inputs for the RS-700 are as follows:

- Average background count rate of 3,767 counts per second (the per-detector average), equal to 226,018 cpm, based on the observed average count rate for RS-700 at the Area 7 soil reference area at NSTI.
- Estimated count rate to exposure rate ratio of 42,483 cpm per μR/hr for ^{137}Cs (based on observation of 226,018 cpm in a 5.32 μR/hr field)
- Length of the detector parallel to the surveyed surface is equal to 4 inches (10.16 cm).
- For scans using the RS-700, level of performance (d') is equal to 3.28, corresponding to 95% true positive detection rate and 5% false positive detection rate - for the RS-700 a lower false positive detection rate is desired as the size and mobility of the system will limit the technician's ability to investigate anomalous measurements in real time.
- The thickness of the carbon fiber and foam casing of the detector is modeled as a 0.125 inch (0.318 cm) carbon layer with a density of 2.27 g/cm^3. The aluminum covering for the NaI crystal is 0.02 inches (0.051 cm), with a density of 2.7 g/cm^3.
- The bottom of the detector is mounted 15.24 cm (6 inches) above the ground surface.
- The scan speed for the RS-700 is 0.25 meters per second, resulting in an observation interval of 2 seconds
- Surveyor efficiency of 0.9, increased from a default of 0.5 based on the constant surveyor speed, datalogging, mapping, and spectral analysis features of the RS-700 system.

3.3 Example Calculation

The example calculation for the RS-700 presented in this section is for the measurement of the NUREG-1507 default distributed soil source term, following the process described in Section 1.5.

Calculation of MDCR and $MDCR_{Surveyor}$

$$s_i = d'\sqrt{b_i}$$

$$MDCR = s_i \times (60/i)$$

$$MDCR_{Surveyor} = \frac{MDCR}{\sqrt{p}}$$

Where:

d'	measurement performance parameter, determined from desired true positive and false positive rates from MARSSIM Table 6.5, unitless, equal to 3.28
b_i	number of background counts observed during observation interval *i*, in counts, equal to: $\frac{226{,}018\ counts}{minute} \times \frac{1\ minute}{60\ seconds} \times 2\ seconds = 7{,}533.9\ counts$ assuming a background count rate of 226,018cpm and an observation interval, *i*, of 2 seconds
s_i	number of source counts required for a specified level of measurement performance and observation interval *i*, in counts: $s_i = 3.28\sqrt{7533.9} = 284.7\ counts$
MDCR	minimum detectable count rate, in cpm $MDCR = 284.7 \times (60/2) = 8540.9\ cpm$
$MDCR_{Surveyor}$	minimum detectable count rate accounting for surveyor efficiency, in cpm
p	surveyor efficiency, equal to 0.9

$$MDCR_{Surveyor} = \frac{8540.9\ cpm}{\sqrt{0.9}} = 9{,}003\ cpm$$

Calculation of the FRER

$$Fluence\ Rate\ to\ Exposure\ Rate\ \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Table 8
Calculation of FRER, RS-700

Gamma Energy (keV)	$(\mu_{en}/\rho)_{air}$ (cm^2/g)	FRER
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Calculation of probability of interaction through the detector

$$Probabilty\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

Where

x	Length of detector parallel to surveyed surface, equal to 10.16 cm
ρ_{NaI}	Density of NaI, equal to 3.67 grams per cubic centimeter (g/cm^3)

Table 9
Probability of Interaction with Detector, RS-700

Energy$_\gamma$ (keV)	$(\mu/\rho)_{NaI}$, (cm^2/g)	P
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	1.00
400	0.117	0.99
500	0.0955	0.97
600	0.0826	0.95
800	0.0676	0.92
1,000	0.0586	0.89
1,500	0.0469	0.83
2,000	0.0413	0.79

Calculation of RDR

$$RDR = FRER \times P$$

Table 10
Relative Detector Response, RS-700

$Energy_{\gamma}$ (keV)	FRER	P	RDR
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	1.00	0.1155
400	0.0845	0.99	0.0834
500	0.0673	0.97	0.0654
600	0.0563	0.95	0.0537
800	0.0433	0.92	0.0398
1,000	0.0357	0.89	0.0317
1,500	0.0261	0.83	0.0216
2,000	0.0214	0.79	0.0168

Calculation of the FRER, P, and RDR for 662 keV gamma emission from ^{137}Cs, and detector response relative to ^{137}Cs

At 662 keV, $(\mu_{en}/\rho)_{air}$ is equal to 0.0294 cm^2/g, and $(\mu/\rho)_{NaI}$ is equal to 0.0780 cm^2/g.

$$FRER \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}} = \frac{1}{(662)(0.0294)} = 0.0514$$

$$P = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)} = 1 - e^{-(0.0780\times10.16\times3.67)} = 0.95$$

$$RDR = FRER \times P = 0.0514 \times 0.95 = 0.0486$$

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{RDR_{E_i}}{RDR_{Cs-137}}$$

Where:

$cpm_{Cs\text{-}137}$	Estimated detector response to ^{137}Cs 662 keV gamma energy, equal to 42,483 cpm/µR/hr based on the observed background count rate at a background exposure rate of 5.32 µR/hr.

Table 11
Instrument Count Rate to Exposure Rate Ratio, RS-700

$Energy_{\gamma}$ (keV)	RDR_{Ei}	RS-700 NaI (**cpm per µR/hr**), E_i
15	0.0517	45202
20	0.0969	84753
30	0.2268	198333
40	0.3906	341660
50	0.5208	455547
60	0.5708	499230
80	0.5297	463268
100	0.4329	378637
150	0.2656	232311
200	0.1866	163180
300	0.1155	101033
400	0.0834	72931
500	0.0654	57226
600	0.0537	46985
662	0.0486	42483
800	0.0398	34789
1,000	0.0317	27724
1,500	0.0216	18888
2,000	0.0168	14682

Calculation of the total energy-weighted cpm/µR/hr ratio

$$weighted\left(cpm/\frac{\mu R}{hr}\right) = \sum\left(\frac{\dot{X}_{E_i}}{\dot{X}_{Total}} \times \frac{cpm}{\mu R/_{hr}}, E_i\right)$$

Table 12
Calculation of Total Energy-Weighted Count Rate to Exposure Rate Ratio, RS-700

$Energy_{\gamma}$ (keV)	MicroShield Exposure Rate (With Buildup) (µR/hr)	cpm per µR/hr, Ei	cpm per µR/hr (weighted)	Percent of NaI detector response
15	9.731E-05	45202	7	0.0%
20	0.000E+00	84753	0	0.0%
30	0.000E+00	198333	0	0.0%
40	0.000E+00	341660	0	0.0%
50	4.085E-04	455547	299	0.7%
60	0.000E+00	499230	0	0.0%
80	5.319E-03	463268	3964	9.9%
100	4.411E-05	378637	27	0.1%
150	0.000E+00	232311	0	0.0%
200	8.408E-03	163180	2207	5.5%
300	2.478E-02	101033	4027	10.1%
400	6.117E-02	72931	7176	17.9%
500	3.532E-03	57226	325	0.8%
600	1.125E-01	46985	8503	21.2%
800	2.835E-02	34789	1587	4.0%
1000	1.139E-01	27724	5080	12.7%
1500	9.573E-02	18888	2909	7.3%
2000	1.674E-01	14682	3954	9.9%
Total	6.216E-01		40065	100.0%

Calculation of the exposure rate at the $MDCR_{Surveyor}$ and scan MDC

$$\dot{X}, MDCR_{Surveyor} = \frac{MDCR_{Surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)} = \frac{9003}{40065} = 0.225\ \mu R/hr$$

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{\dot{X}, MDCR_{Surveyor}}{\dot{X}_{Total}.} = (1) \times \frac{0.225}{0.6216} = 0.36\ pCi/g$$

3.4 Additional Modeling and Results

Using the process described in Section 3.3, scan MDCs were calculated for the RS-700 for the following scenarios:

- Distributed soil source, no soil cover – representative of distributed contamination in a 15.24 cm (6-inch) thick RSY pad
- Discrete ^{226}Ra object, 12.7 cm soil cover – representative of a worst-case discrete object at the bottom of a 15.24 cm (6-inch) thick RSY pad
- Distributed soil source, 15.24 cm (6-inch) soil cover – representative of worst-case distributed contamination in a 30.48 cm (12-inch) thick RSY pad
- Discrete ^{226}Ra object, 27.94 cm soil cover – representative of a worst-case discrete object at the bottom of a 30.48 cm (12-inch) thick RSY pad
- Distributed soil source, 7.62 cm (3-inch) soil cover – representative of worst-case distributed contamination in a 22.86 cm (9-inch) thick RSY pad
- Discrete ^{226}Ra object, 20.32 cm soil cover – representative of a worst-case discrete object at the bottom of a 22.86 cm (9-inch) thick RSY pad
- Distributed soil source, 15.24 cm (6-inch) concrete cover – representative of upper 15.24 cm (6 inches) of soil below areas with concrete surface covering
- Discrete ^{226}Ra object, 15.24 cm (6-inch) concrete cover, and 12.7 cm (5-inch) soil cover – representative of a worst-case discrete object at the bottom of upper 15.24 cm (6 inches) of soil below area with concrete surface covering

3.5 Summary of Calculations

The results of the calculations described in Section 3.4 are listed in Table 13. The Microshield output files and supporting calculation spreadsheets are provided in Appendix B. The calculations support the following conclusions:

- The scan MDC for ^{226}Ra in a distributed soil source ranges from 0.36 pCi/g for a 6-inch soil lift to 2.32 pCi/g for a 12-inch soil lift. The scan MDC for soil under a 6-inch concrete cover is 2.53 pCi/g.
- The scan minimum detectable activity for a discrete object containing ^{226}Ra ranges from 0.032 µCi for an object at the bottom of a 6-inch soil lift to 0.230 µCi for an object at the bottom of a 12-inch soil lift. The scan minimum detectable activity for an object in the upper soil layer under a 6-inch concrete cover is 0.251 µCi.

Table 13
Summary of Scan MDC Calculations, RS-700

Description	Source Type	Filename	Scan MDC[a]	Units[b]
RSY pads - 6 inch (15.24 cm) thickness	Distributed	TI1BD	0.36	pCi/g
RSY pads - 6 inch (15.24 cm) thickness, 12.7 cm cover above source	Object	TI1BO	0.032	µCi
RSY pads - 12 inch (30.48 cm) thickness, 15.24 cm cover above source	Distributed	TI2BD	2.32	pCi/g
RSY pads - 12 inch (30.48 cm) thickness, 27.94 cm cover above source	Object	TI2BO	0.0.230	µCi
RSY pads - 9 inch (22.86 cm) thickness, 7.62 cm cover above source	Distributed	TI3BD	0.91	pCi/g
RSY pads - 9 inch (22.86 cm) thickness, 20.32 cm cover above source	Object	TI3BO	0.087	µCi
Concrete-covered surface soil (15.24 cm concrete above source)	Distributed	TI5BD	2.53	pCi/g
Concrete-covered surface soil (15.24 cm concrete and 12.7 cm soil above source)	Object	TI5BO	0.251	µCi

Notes:

[a] Scan MDC = scan minimum detectable concentration. For source types modeled as Objects, the minimum detectable object activity is reported.

[b] pCi/g = picocuries per gram; µCi = microcuries.

These calculations demonstrate that the scanning sensitivity for the RS-700 for a 9-inch thickness is consistent with the NSTI ^{226}Ra screening criterion of 1.69 pCi/g; therefore, additional soil sampling would not be required to supplement the scanning measurements if a 9-inch RSY layer were to be used. In the calculation of the minimum activity object detectable under a concrete layer, the result for the RS-700 is more sensitive than the 3x3 NaI by an approximate factor of 4. Both systems are calculated to be able to detect a typical ^{226}Ra object within the top 6 inches of soil below a 6-inch concrete cover.

4.0 Summary and Conclusion

Using the NUREG-1507 methodology, MDCs for gamma scanning surveys were calculated for the 3x3 NaI and RS-700 gamma detectors used under specific conditions (i.e., maximum scan speed of 0.5 meters per second, detector height of 10 cm) for multiple projects at NSTI. The results from calculations performed for distributed ^{226}Ra in soil demonstrate that the sensitivity calculated for the RS-700 for a soil thickness of 9 inches (22.86 cm), equal to 0.91 pCi/g, is similar to the sensitivity calculated for the 3x3 NaI for a soil thickness of 6 inches (15.24 cm), equal to 1.42 pCi/g. Therefore, should an increase in RSY pad thickness from 6 inches to 9 inches be implemented, additional soil sampling would not be required to compensate for reduced scan sensitivity. If an increase in RSY pad thickness beyond 9 inches is desired, additional soil sampling required to meet project data quality objectives would be addressed in the project-specific work plan or task-specific plan.

The calculations assessed the ability of the two systems to detect discrete objects in various configurations, including soil and concrete. The results for the values calculated for the 3x3 NaI are consistent with the observed objects recovered using that instrument at NSTI to date. The calculated results for the RS-700 are more sensitive by an approximate factor of 3. Both systems are calculated to be able to detect a typical ^{226}Ra object within the top 6 inches of soil below a 6-inch concrete cover.

One variable to both sets of calculations is the assumed background count rates. Gamma background levels are variable and are specific to both the instrument and local environment being surveyed. As additional work is performed, the assumptions with respect to background will be evaluated to verify that they are still valid. Additional calculations will be performed during and after data collection for each project to confirm that the initial assumptions are still appropriate.

RSY soil layer depths in excess of 6 inches will only be implemented with concurrence by the Navy's Radiological Affairs Support Office.

5.0 References

CB&I, 2014, *Sitewide Radiation Protection Plan, Naval Station Treasure Island, San Francisco, California*.

Grove Software, Inc., 2009, *Microshield*, Version 8.02.

Radiation Solutions, Inc. (RSI), 2014, *RS-700 Carborne System Gamma/Neutron Users Manual*, Revision 7.01, March.

Shaw Environmental, Inc., 2012a, Internal Memorandum from Steve Adams, Certified Health Physicist, to Christine Donahue, Project Radiation Safety Officer, *Analysis of Gamma Survey and Radium-226 Soil Concentration Data at the NSTI Site-Wide Background Areas and the Area 7 Background Reference Area*, April 23.

Shaw Environmental, Inc., 2012b, Internal Memorandum from Steve Adams, Certified Health Physicist, to Christine Donahue, Project Radiation Safety Officer, *Analysis of the Treasure Island Asphalt Background Areas – Gamma Survey and Radium-226 Concentration Data*, May 16.

Shaw Environmental, Inc., 2012c, *Operation and Use of Portable Instruments at Treasure Island*, Work Instruction TIWI-12-01, October.

U.S. Department of Health, Education, and Welfare, 1970, *Radiological Health Handbook*, Revised Edition, January.

U.S. Environmental Protection Agency, 1993, *External Exposure to Radionuclides in Air, Water, and Soil*, Federal Guidance Report No. 12, EPA-402-R-93-081, September.

U.S. Nuclear Regulatory Commission (NRC), U.S. Environmental Protection Agency, and U.S. Department of Energy, 2000, *Multi-Agency Radiation Survey and Site Investigation Manual*, NUREG-1575, EPA 402-R-97-016, DOE/EH-0624, Revision 1, Washington, D.C.

NRC, 1998, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, NUREG-1507, June.

Appendix A
3x3 NaI Microshield Modeling and MDC Calculations

MicroShield 8.02
CB&I Federal Services (8.02-0000)

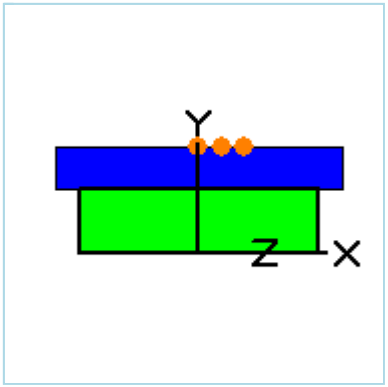
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI1AD 20141104.msd	November 4, 2014	1:41:28 PM	00:00:00

Project Info	
Case Title	TI1AD
Description	3x3 Soil Distributed Source, no cover
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	0.0 cm (0 in)	25.051 cm (9.9 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	25.051 cm (9.9 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	25.051 cm (9.9 in)	30.48 cm (1 ft)



Shields			
Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	FGR 12 Soil	1.6
Shield 1	10.0 cm	Air	0.00122
Shield 2	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	3.5579e-008	1.3164e+003	9.6302e-007	3.5632e-002
Bi-214	5.8338e-008	2.1585e+003	1.5790e-006	5.8424e-002
Pb-210	3.5593e-008	1.3169e+003	9.6340e-007	3.5646e-002
Pb-214	5.8338e-008	2.1585e+003	1.5790e-006	5.8424e-002
Po-210	3.5185e-008	1.3018e+003	9.5235e-007	3.5237e-002
Po-214	5.8325e-008	2.1580e+003	1.5787e-006	5.8412e-002
Po-218	5.8349e-008	2.1589e+003	1.5794e-006	5.8436e-002
Ra-226	5.8349e-008	2.1589e+003	1.5793e-006	5.8436e-002
Rn-222	5.8349e-008	2.1589e+003	1.5794e-006	5.8436e-002

Buildup: The material reference is Source Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,25.051,0) cm					
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	6.404e+02	1.678e-06	1.849e-06	1.439e-07	1.586e-07
0.05	7.720e+01	6.054e-05	1.556e-04	1.613e-07	4.145e-07
0.08	4.976e+02	1.047e-03	3.755e-03	1.657e-06	5.942e-06
0.1	2.930e+00	8.776e-06	3.221e-05	1.343e-08	4.928e-08
0.2	2.325e+02	1.795e-03	5.354e-03	3.168e-06	9.450e-06
0.3	4.454e+02	5.845e-03	1.474e-02	1.109e-05	2.796e-05
0.4	8.260e+02	1.581e-02	3.550e-02	3.081e-05	6.916e-05
0.5	3.856e+01	9.896e-04	2.037e-03	1.942e-06	3.999e-06
0.6	1.041e+03	3.393e-02	6.533e-02	6.624e-05	1.275e-04
0.8	2.040e+02	9.701e-03	1.691e-02	1.845e-05	3.216e-05
1.0	6.758e+02	4.303e-02	7.017e-02	7.932e-05	1.293e-04
1.5	4.109e+02	4.425e-02	6.464e-02	7.445e-05	1.088e-04
2.0	5.777e+02	8.959e-02	1.230e-01	1.385e-04	1.902e-04
Totals	**5.670e+03**	**2.461e-01**	**4.016e-01**	**4.260e-04**	**7.051e-04**

Results - Dose Point # 2 - (0,25.051,15.24) cm					
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	6.404e+02	7.995e-07	9.012e-07	6.858e-08	7.730e-08
0.05	7.720e+01	5.352e-05	1.362e-04	1.426e-07	3.629e-07
0.08	4.976e+02	9.173e-04	3.240e-03	1.452e-06	5.127e-06
0.1	2.930e+00	7.672e-06	2.772e-05	1.174e-08	4.240e-08
0.2	2.325e+02	1.562e-03	4.615e-03	2.757e-06	8.145e-06
0.3	4.454e+02	5.078e-03	1.273e-02	9.633e-06	2.414e-05
0.4	8.260e+02	1.372e-02	3.070e-02	2.674e-05	5.982e-05
0.5	3.856e+01	8.583e-04	1.764e-03	1.685e-06	3.462e-06
0.6	1.041e+03	2.942e-02	5.661e-02	5.743e-05	1.105e-04
0.8	2.040e+02	8.408e-03	1.467e-02	1.599e-05	2.791e-05
1.0	6.758e+02	3.730e-02	6.095e-02	6.875e-05	1.123e-04
1.5	4.109e+02	3.837e-02	5.624e-02	6.456e-05	9.463e-05
2.0	5.777e+02	7.774e-02	1.072e-01	1.202e-04	1.657e-04
Totals	**5.670e+03**	**2.134e-01**	**3.489e-01**	**3.694e-04**	**6.123e-04**

Results - Dose Point # 3 - (0,25.051,30.48) cm					
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	6.404e+02	2.264e-07	2.562e-07	1.942e-08	2.198e-08
0.05	7.720e+01	2.547e-05	6.647e-05	6.786e-08	1.771e-07
0.08	4.976e+02	4.476e-04	1.658e-03	7.083e-07	2.623e-06
0.1	2.930e+00	3.772e-06	1.446e-05	5.771e-09	2.212e-08
0.2	2.325e+02	7.819e-04	2.498e-03	1.380e-06	4.409e-06
0.3	4.454e+02	2.569e-03	6.979e-03	4.874e-06	1.324e-05
0.4	8.260e+02	7.005e-03	1.696e-02	1.365e-05	3.305e-05
0.5	3.856e+01	4.414e-04	9.797e-04	8.664e-07	1.923e-06
0.6	1.041e+03	1.523e-02	3.157e-02	2.973e-05	6.162e-05
0.8	2.040e+02	4.401e-03	8.237e-03	8.371e-06	1.567e-05
1.0	6.758e+02	1.971e-02	3.438e-02	3.632e-05	6.337e-05
1.5	4.109e+02	2.064e-02	3.204e-02	3.473e-05	5.390e-05
2.0	5.777e+02	4.236e-02	6.148e-02	6.551e-05	9.507e-05
Totals	**5.670e+03**	**1.136e-01**	**1.969e-01**	**1.962e-04**	**3.451e-04**

TI 3x3 NaI Scan for Ra-226 @ 1pCi/g, 0 inches of soil cover, 15 cm thick x 28 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u_{en}/ρ)air

File	TI1AD 20141104

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

Assumptions

Detector is 3 in (7.6 cm) height by 3 in (7.6 cm) diameter

15 x 28 source at 1.6 g/cm3 (dry soil) - Buildup reference
No soil cover
0.020 inch (0.051 cm) aluminum detector casing @ 2.7 g/cm3
2300 cpm/uR/hr
Assume average background count rate of 18,000 cpm based on observed soil reference area data

Centerpoint of detector has no offset from center of source

TABLE 1		
Energy$_\gamma$, keV	**(u_{en}/ρ)$_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For Ludlum 3x3 Model 44-20: 7.6 cm dia x 7.6 cm thick NaI crystal

Aluminum housing for 44-20 is 0.020 inches (0.051 cm)

x = 7.6 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
Energy$_\gamma$, keV	**(μ/ρ)$_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	0.99
400	0.117	0.96
500	0.0955	0.93
600	0.0826	0.90
800	0.0676	0.85
1,000	0.0586	0.80
1,500	0.0469	0.73
2,000	0.0413	0.68

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
Energy$_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	0.99	0.1146
400	0.0845	0.96	0.0812
500	0.0673	0.93	0.0626
600	0.0563	0.90	0.0507
800	0.0433	0.85	0.0367
1,000	0.0357	0.80	0.0287
1,500	0.0261	0.73	0.0191
2,000	0.0214	0.68	0.0146

Estimated Ludlum 44-20 7.6 cm dia x 7.6 cm thick NaI response for Cs-137 is **2300** cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

Energy$_\gamma$, keV	(u_{en}/ρ)$_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
Energy$_\gamma$, keV	**(μ/ρ)$_{NaI}$, cm^2/g**		
662	0.0780	Probability =	0.89
		RDR =	0.0455

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
Energy$_\gamma$, keV	**RDR$_{Ei}$**	**Ludlum 44-20 3x3 NaI cpm per μR/hr, E_i**
15	0.0517	2610
20	0.0969	4894
30	0.2268	11453
40	0.3906	19729
50	0.5208	26306
60	0.5708	28828
80	0.5297	26752
100	0.4329	21865
150	0.2656	13415
200	0.1866	9422
300	0.1146	5790
400	0.0812	4103
500	0.0626	3164
600	0.0507	2560
662	0.0455	2300
800	0.0367	1853
1,000	0.0287	1452
1,500	0.0191	964
2,000	0.0146	738

MDCR$_{surveyor}$ for Cs-137 energy

2300 cpm/μR/hr

Bkgd = 18000 cpm

Observation Interval, i =	1	second
b_i =	300	counts
d' =	1.38	from Table 6.1 of NUREG-1507
MDCR =	1434.14	cpm
MDCR$_{surveyor}$ =	2028	cpm

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\,(60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.50

minimum detectable exposure rate, Cs-137 = 0.88 μR/hr

Table 5				
Energy$_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	1.159E-04	2610	0	0.0%
20	0.000E+00	4894	0	0.0%
30	0.000E+00	11453	0	0.0%
40	0.000E+00	19729	0	0.0%
50	2.393E-04	26306	9	0.4%
60	0.000E+00	28828	0	0.0%
80	3.926E-03	26752	152	7.3%
100	3.551E-05	21865	1	0.1%
150	0.000E+00	13415	0	0.0%
200	8.324E-03	9422	114	5.5%
300	2.610E-02	5790	219	10.5%
400	6.605E-02	4103	392	18.9%
500	3.878E-03	3164	18	0.9%
600	1.244E-01	2560	461	22.2%
800	3.170E-02	1853	85	4.1%
1000	1.280E-01	1452	269	13.0%
1500	1.082E-01	964	151	7.3%
2000	1.899E-01	738	203	9.8%
Total	6.909E-01		2074	100.0%

	mR/hr, from MS
15	1.16E-07
20	
30	
40	
50	2.39E-07
60	
80	3.93E-06
100	3.55E-08
150	
200	8.32E-06
300	2.61E-05
400	6.61E-05
500	3.88E-06
600	1.24E-04
800	3.17E-05
1000	1.28E-04
1500	1.08E-04
2000	1.90E-04
	6.909E-04

Microshield Output

0.015	6.40E+02	1.68E-06	1.85E-06	1.44E-07	1.59E-07
0.05	7.72E+01	6.05E-05	1.56E-04	1.61E-07	4.15E-07
0.08	4.98E+02	1.05E-03	3.76E-03	1.66E-06	5.94E-06
0.1	2.93E+00	8.78E-06	3.22E-05	1.34E-08	4.93E-08
0.2	2.33E+02	1.80E-03	5.35E-03	3.17E-06	9.45E-06
0.3	4.45E+02	5.85E-03	1.47E-02	1.11E-05	2.80E-05
0.4	8.26E+02	1.58E-02	3.55E-02	3.08E-05	6.92E-05
0.5	3.86E+01	9.90E-04	2.04E-03	1.94E-06	4.00E-06
0.6	1.04E+03	3.39E-02	6.53E-02	6.62E-05	1.28E-04
0.8	2.04E+02	9.70E-03	1.69E-02	1.85E-05	3.22E-05
1	6.76E+02	4.30E-02	7.02E-02	7.93E-05	1.29E-04
1.5	4.11E+02	4.43E-02	6.46E-02	7.45E-05	1.09E-04
2	5.78E+02	8.96E-02	1.23E-01	1.39E-04	1.90E-04

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
0.978 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6 g/cm3

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate,\ MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **1.42** pCi/g
5.24E+01 Bq/kg

MicroShield 8.02
CB&I Federal Services (8.02-0000)

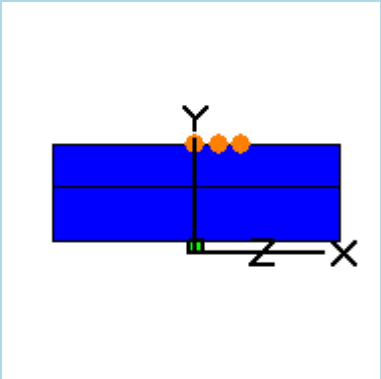
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI1AO 20141104.msd	November 4, 2014	2:36:03 PM	00:00:00

Project Info	
Case Title	TI1AO
Description	3x3 Soil Object, 12.7 cm cover (6-inch lift)
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	2.54 cm (1.0 in)
Radius	1.5 cm (0.6 in)

Dose Points			
A	X	Y	Z
#1	0.0 cm (0 in)	25.291 cm (10.0 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	25.291 cm (10.0 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	25.291 cm (10.0 in)	30.48 cm (1 ft)



Shields			
Shield N	Dimension	Material	Density
Source	17.954 cm³	Concrete	1.6
Shield 1	12.7 cm	FGR 12 Soil	1.6
Shield 2	10.0 cm	Air	0.00122
Shield 3	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	1.7290e-011	6.3974e-001	9.6302e-007	3.5632e-002
Bi-214	2.8350e-011	1.0490e+000	1.5790e-006	5.8424e-002
Pb-210	1.7297e-011	6.3999e-001	9.6340e-007	3.5646e-002
Pb-214	2.8350e-011	1.0490e+000	1.5790e-006	5.8424e-002
Po-210	1.7099e-011	6.3265e-001	9.5235e-007	3.5237e-002
Po-214	2.8344e-011	1.0487e+000	1.5787e-006	5.8412e-002
Po-218	2.8356e-011	1.0492e+000	1.5794e-006	5.8436e-002
Ra-226	2.8356e-011	1.0492e+000	1.5793e-006	5.8436e-002
Rn-222	2.8356e-011	1.0492e+000	1.5794e-006	5.8436e-002

Buildup: The material reference is Shield 1 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,25.291,0) cm					
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	3.112e-01	3.322e-64	7.344e-33	2.849e-65	6.299e-34
0.05	3.751e-02	1.965e-10	1.981e-09	5.235e-13	5.276e-12
0.08	2.418e-01	3.637e-08	5.682e-07	5.756e-11	8.991e-10
0.1	1.424e-03	4.652e-10	7.216e-09	7.118e-13	1.104e-11
0.2	1.130e-01	1.848e-07	1.785e-06	3.262e-10	3.150e-09
0.3	2.165e-01	7.840e-07	5.273e-06	1.487e-09	1.000e-08
0.4	4.014e-01	2.510e-06	1.308e-05	4.891e-09	2.549e-08
0.5	1.874e-02	1.772e-07	7.652e-07	3.477e-10	1.502e-09
0.6	5.058e-01	6.658e-06	2.480e-05	1.300e-08	4.840e-08
0.8	9.913e-02	2.174e-06	6.543e-06	4.136e-09	1.245e-08
1.0	3.284e-01	1.059e-05	2.748e-05	1.953e-08	5.065e-08
1.5	1.997e-01	1.263e-05	2.601e-05	2.125e-08	4.376e-08
2.0	2.807e-01	2.787e-05	5.041e-05	4.310e-08	7.796e-08
Totals	**2.755e+00**	**6.362e-05**	**1.567e-04**	**1.081e-07**	**2.743e-07**

Results - Dose Point # 2 - (0,25.291,15.24) cm					
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	3.112e-01	3.616e-73	5.274e-33	3.101e-74	4.523e-34
0.05	3.751e-02	4.440e-11	5.081e-10	1.183e-13	1.354e-12
0.08	2.418e-01	1.298e-08	2.451e-07	2.053e-11	3.879e-10
0.1	1.424e-03	1.813e-10	3.471e-09	2.773e-13	5.311e-12
0.2	1.130e-01	8.353e-08	1.006e-06	1.474e-10	1.776e-09
0.3	2.165e-01	3.776e-07	3.110e-06	7.162e-10	5.899e-09
0.4	4.014e-01	1.261e-06	7.902e-06	2.458e-09	1.540e-08
0.5	1.874e-02	9.184e-08	4.689e-07	1.803e-10	9.204e-10
0.6	5.058e-01	3.537e-06	1.536e-05	6.904e-09	2.998e-08
0.8	9.913e-02	1.198e-06	4.124e-06	2.279e-09	7.844e-09
1.0	3.284e-01	5.995e-06	1.752e-05	1.105e-08	3.229e-08
1.5	1.997e-01	7.472e-06	1.690e-05	1.257e-08	2.844e-08
2.0	2.807e-01	1.693e-05	3.319e-05	2.619e-08	5.132e-08
Totals	**2.755e+00**	**3.696e-05**	**9.983e-05**	**6.251e-08**	**1.743e-07**

Results - Dose Point # 3 - (0,25.291,30.48) cm					
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	3.112e-01	3.408e-95	2.833e-33	2.923e-96	2.430e-34
0.05	3.751e-02	1.458e-12	2.173e-11	3.883e-15	5.787e-14
0.08	2.418e-01	1.294e-09	3.610e-08	2.047e-12	5.713e-11
0.1	1.424e-03	2.238e-11	6.587e-10	3.424e-14	1.008e-12
0.2	1.130e-01	1.476e-08	2.811e-07	2.604e-11	4.961e-10
0.3	2.165e-01	7.772e-08	9.740e-07	1.474e-10	1.848e-09
0.4	4.014e-01	2.875e-07	2.652e-06	5.602e-10	5.167e-09
0.5	1.874e-02	2.257e-08	1.641e-07	4.430e-11	3.222e-10
0.6	5.058e-01	9.217e-07	5.568e-06	1.799e-09	1.087e-08
0.8	9.913e-02	3.409e-07	1.564e-06	6.484e-10	2.975e-09
1.0	3.284e-01	1.819e-06	6.857e-06	3.353e-09	1.264e-08
1.5	1.997e-01	2.520e-06	6.971e-06	4.240e-09	1.173e-08
2.0	2.807e-01	6.091e-06	1.417e-05	9.419e-09	2.191e-08
Totals	**2.755e+00**	**1.210e-05**	**3.924e-05**	**2.024e-08**	**6.801e-08**

TI 3x3 NaI Scan for Ra-226 @ 1pCi/g, 12.7 cm of soil cover, 2.54 cm thick x 1.5 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u_{en}/ρ)air

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
$Energy_\gamma$, keV	**$(u_{en}/\rho)_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For Ludlum 3x3 Model 44-20: 7.6 cm dia x 7.6 cm thick NaI crystal

Aluminum housing for 44-20 is 0.020 inches (0.051 cm)

x = 7.6 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
$Energy_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	0.99
400	0.117	0.96
500	0.0955	0.93
600	0.0826	0.90
800	0.0676	0.85
1,000	0.0586	0.80
1,500	0.0469	0.73
2,000	0.0413	0.68

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
$Energy_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	0.99	0.1146
400	0.0845	0.96	0.0812
500	0.0673	0.93	0.0626
600	0.0563	0.90	0.0507
800	0.0433	0.85	0.0367
1,000	0.0357	0.80	0.0287
1,500	0.0261	0.73	0.0191
2,000	0.0214	0.68	0.0146

Estimated Ludlum 44-20 7.6 cm dia x 7.6 cm thick NaI response for Cs-137 is **2300** cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

$Energy_\gamma$, keV	$(u_{en}/\rho)_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
$Energy_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**		
662	0.0780	Probability =	0.89
		RDR =	0.0455

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/hr}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
$Energy_\gamma$, keV	**RDR_{Ei}**	**Ludlum 44-20 3x3 NaI cpm per μR/hr, E_i**
15	0.0517	2610
20	0.0969	4894
30	0.2268	11453
40	0.3906	19729
50	0.5208	26306
60	0.5708	28828
80	0.5297	26752
100	0.4329	21865
150	0.2656	13415
200	0.1866	9422
300	0.1146	5790
400	0.0812	4103
500	0.0626	3164
600	0.0507	2560
662	0.0455	2300
800	0.0367	1853
1,000	0.0287	1452
1,500	0.0191	964
2,000	0.0146	738

$MDCR_{surveyor}$ for Cs-137 energy

			Observation Interval, i =	1	second
2300	cpm/μR/hr		b_i =	300	counts
Bkgd = 18000	cpm		d' =	1.38	from Table 6.1 of NUREG-1507
			MDCR =	1434.14	cpm
			$MDCR_{surveyor}$ =	2028	cpm

minimum detectable exposure rate, Cs-137 = 0.88 μR/hr

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\,(60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.50

Table 5				
$Energy_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	6.299E-31	2610	0	0.0%
20	0.000E+00	4894	0	0.0%
30	0.000E+00	11453	0	0.0%
40	0.000E+00	19729	0	0.0%
50	5.276E-09	26306	1	0.0%
60	0.000E+00	28828	0	0.0%
80	8.991E-07	26752	88	4.4%
100	1.104E-08	21865	1	0.0%
150	0.000E+00	13415	0	0.0%
200	3.150E-06	9422	108	5.5%
300	1.000E-05	5790	211	10.7%
400	2.549E-05	4103	381	19.3%
500	1.502E-06	3164	17	0.9%
600	4.840E-05	2560	452	22.9%
800	1.245E-05	1853	84	4.3%
1000	5.065E-05	1452	268	13.6%
1500	4.376E-05	964	154	7.8%
2000	7.796E-05	738	210	10.6%
Total	2.743E-04		1975	100.0%

	mR/hr, from MS
15	6.30E-34
20	
30	
40	
50	5.28E-12
60	
80	8.99E-10
100	1.10E-11
150	
200	3.15E-09
300	1.00E-08
400	2.55E-08
500	1.50E-09
600	4.84E-08
800	1.25E-08
1000	5.07E-08
1500	4.38E-08
2000	7.80E-08
	2.743E-07

Microshield Output

0.015	3.11E-01	3.32E-64	7.34E-33	2.85E-65	6.30E-34
0.05	3.75E-02	1.97E-10	1.98E-09	5.24E-13	5.28E-12
0.08	2.42E-01	3.64E-08	5.68E-07	5.76E-11	8.99E-10
0.1	1.42E-03	4.65E-10	7.22E-09	7.12E-13	1.10E-11
0.2	1.13E-01	1.85E-07	1.79E-06	3.26E-10	3.15E-09
0.3	2.17E-01	7.84E-07	5.27E-06	1.49E-09	1.00E-08
0.4	4.01E-01	2.51E-06	1.31E-05	4.89E-09	2.55E-08
0.5	1.87E-02	1.77E-07	7.65E-07	3.48E-10	1.50E-09
0.6	5.06E-01	6.66E-06	2.48E-05	1.30E-08	4.84E-08
0.8	9.91E-02	2.17E-06	6.54E-06	4.14E-09	1.25E-08
1	3.28E-01	1.06E-05	2.75E-05	1.95E-08	5.07E-08
1.5	2.00E-01	1.26E-05	2.60E-05	2.13E-08	4.38E-08
2	2.81E-01	2.79E-05	5.04E-05	4.31E-08	7.80E-08

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
1.027 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6 g/cm3

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate, MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **3745.05** pCi/g
1.39E+05 Bq/kg

Source Vol. 17.95 cm3
Density 1.6 g/cm3
Source mass 28.72 g

Total activity 107558 pCi
0.108 uCi

File	TI1AO 20141104

Assumptions

Detector is 3 in (7.6 cm) height by 3 in (7.6 cm) diameter
2.54 cm height by 3 diameter cm radium source at 1.6 g/cm3 (soil hockey puck)
10 cm detector height
Soil cover of (15.24-2.54) = 12.70 cm (worst case for 6 inches of soil on RSY pad)
0.020 inch (0.051 cm) aluminum detector casing @ 2.7 g/cm3
2300 cpm/uR/hr
Assume average background count rate of 18,000 cpm based on observed soil reference area data

Centerpoint of detector has no offset from center of source

MicroShield 8.02
CB&I Federal Services (8.02-0000)

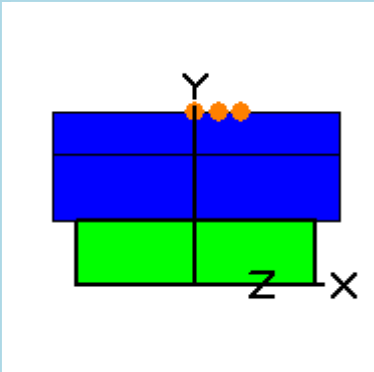
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI2AD 20141104.msd	November 4, 2014	2:56:01 PM	00:00:00

Project Info	
Case Title	TI2AD
Description	3x3 Soil Distributed Source, 15.24 cm soil cover
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	0.0 cm (0 in)	40.291 cm (1 ft 3.9 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	40.291 cm (1 ft 3.9 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	40.291 cm (1 ft 3.9 in)	30.48 cm (1 ft)



Shields			
Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	FGR 12 Soil	1.6
Shield 1	15.24 cm	FGR 12 Soil	1.6
Shield 2	10.0 cm	Air	0.00122
Shield 3	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	3.5579e-008	1.3164e+003	9.6302e-007	3.5632e-002
Bi-214	5.8338e-008	2.1585e+003	1.5790e-006	5.8424e-002
Pb-210	3.5593e-008	1.3169e+003	9.6340e-007	3.5646e-002
Pb-214	5.8338e-008	2.1585e+003	1.5790e-006	5.8424e-002
Po-210	3.5185e-008	1.3018e+003	9.5235e-007	3.5237e-002
Po-214	5.8325e-008	2.1580e+003	1.5787e-006	5.8412e-002
Po-218	5.8349e-008	2.1589e+003	1.5794e-006	5.8436e-002
Ra-226	5.8349e-008	2.1589e+003	1.5793e-006	5.8436e-002
Rn-222	5.8349e-008	2.1589e+003	1.5794e-006	5.8436e-002

Buildup: The material reference is Shield 1 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,40.291,0) cm					
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	6.404e+02	1.273e-74	6.369e-30	1.092e-75	5.463e-31
0.05	7.720e+01	4.062e-09	5.346e-08	1.082e-11	1.424e-10
0.08	4.976e+02	2.274e-06	5.891e-05	3.599e-09	9.322e-08
0.1	2.930e+00	3.744e-08	1.052e-06	5.728e-11	1.609e-09
0.2	2.325e+02	2.378e-05	4.620e-04	4.196e-08	8.154e-07
0.3	4.454e+02	1.257e-04	1.650e-03	2.384e-07	3.130e-06
0.4	8.260e+02	4.693e-04	4.584e-03	9.143e-07	8.931e-06
0.5	3.856e+01	3.721e-05	2.887e-04	7.304e-08	5.666e-07
0.6	1.041e+03	1.535e-03	9.928e-03	2.997e-06	1.938e-05
0.8	2.040e+02	5.787e-04	2.851e-03	1.101e-06	5.422e-06
1.0	6.758e+02	3.139e-03	1.270e-02	5.786e-06	2.341e-05
1.5	4.109e+02	4.495e-03	1.328e-02	7.562e-06	2.235e-05
2.0	5.777e+02	1.112e-02	2.748e-02	1.720e-05	4.250e-05
Totals	**5.670e+03**	**2.153e-02**	**7.329e-02**	**3.592e-05**	**1.266e-04**

Results - Dose Point # 2 - (0,40.291,15.24) cm					
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	6.404e+02	6.587e-75	5.720e-30	5.650e-76	4.906e-31
0.05	7.720e+01	3.649e-09	4.742e-08	9.722e-12	1.263e-10
0.08	4.976e+02	1.934e-06	4.933e-05	3.061e-09	7.807e-08
0.1	2.930e+00	3.156e-08	8.755e-07	4.829e-11	1.339e-09
0.2	2.325e+02	1.985e-05	3.850e-04	3.503e-08	6.795e-07
0.3	4.454e+02	1.048e-04	1.381e-03	1.988e-07	2.620e-06
0.4	8.260e+02	3.914e-04	3.852e-03	7.627e-07	7.506e-06
0.5	3.856e+01	3.107e-05	2.434e-04	6.100e-08	4.778e-07
0.6	1.041e+03	1.284e-03	8.397e-03	2.506e-06	1.639e-05
0.8	2.040e+02	4.855e-04	2.422e-03	9.234e-07	4.607e-06
1.0	6.758e+02	2.641e-03	1.084e-02	4.869e-06	1.997e-05
1.5	4.109e+02	3.807e-03	1.141e-02	6.405e-06	1.919e-05
2.0	5.777e+02	9.470e-03	2.371e-02	1.464e-05	3.666e-05
Totals	**5.670e+03**	**1.824e-02**	**6.268e-02**	**3.041e-05**	**1.082e-04**

Results - Dose Point # 3 - (0,40.291,30.48) cm					
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	6.404e+02	6.326e-77	4.294e-30	5.426e-78	3.683e-31
0.05	7.720e+01	1.469e-09	1.943e-08	3.914e-12	5.175e-11
0.08	4.976e+02	8.563e-07	2.286e-05	1.355e-09	3.617e-08
0.1	2.930e+00	1.436e-08	4.234e-07	2.197e-11	6.477e-10
0.2	2.325e+02	9.591e-06	2.036e-04	1.693e-08	3.593e-07
0.3	4.454e+02	5.234e-05	7.592e-04	9.928e-08	1.440e-06
0.4	8.260e+02	2.005e-04	2.171e-03	3.907e-07	4.231e-06
0.5	3.856e+01	1.625e-05	1.398e-04	3.189e-08	2.745e-07
0.6	1.041e+03	6.830e-04	4.899e-03	1.333e-06	9.562e-06
0.8	2.040e+02	2.656e-04	1.447e-03	5.052e-07	2.752e-06
1.0	6.758e+02	1.478e-03	6.587e-03	2.724e-06	1.214e-05
1.5	4.109e+02	2.219e-03	7.153e-03	3.733e-06	1.204e-05
2.0	5.777e+02	5.673e-03	1.516e-02	8.773e-06	2.345e-05
Totals	**5.670e+03**	**1.060e-02**	**3.855e-02**	**1.761e-05**	**6.628e-05**

TI 3x3 NaI Scan for Ra-226 @ 1pCi/g, 15.24 cm of soil cover, 15 cm thick x 28 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u_{en}/ρ)air

File	TI2AD20141104

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
$Energy_\gamma$, keV	**$(u_{en}/\rho)_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Assumptions

Detector is 3 in (7.6 cm) height by 3 in (7.6 cm) diameter
10 cm detector height
15 x 28 source at 1.6 g/cm3 (dry soil) - Buildup reference
15.24 cm of soil cover (12-inch RSY pad with source in bottom half)
0.020 inch (0.051 cm) aluminum detector casing @ 2.7 g/cm3
2300 cpm/uR/hr
Assume average background count rate of 18,000 cpm based on observed soil reference area data

Centerpoint of detector has no offset from center of source

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For Ludlum 3x3 Model 44-20: 7.6 cm dia x 7.6 cm thick NaI crystal

Aluminum housing for 44-20 is 0.020 inches (0.051 cm)

x = 7.6 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
$Energy_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	0.99
400	0.117	0.96
500	0.0955	0.93
600	0.0826	0.90
800	0.0676	0.85
1,000	0.0586	0.80
1,500	0.0469	0.73
2,000	0.0413	0.68

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
$Energy_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	0.99	0.1146
400	0.0845	0.96	0.0812
500	0.0673	0.93	0.0626
600	0.0563	0.90	0.0507
800	0.0433	0.85	0.0367
1,000	0.0357	0.80	0.0287
1,500	0.0261	0.73	0.0191
2,000	0.0214	0.68	0.0146

Estimated Ludlum 44-20 7.6 cm dia x 7.6 cm thick NaI response for Cs-137 is **2300** cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

$Energy_\gamma$, keV	$(u_{en}/\rho)_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
$Energy_\gamma$, keV	$(\mu/\rho)_{NaI}$, cm^2/g		
662	0.0780	Probability =	0.89
		RDR =	0.0455

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
$Energy_\gamma$, keV	**RDR_{Ei}**	**Ludlum 44-20 3x3 NaI cpm per μR/hr, E_i**
15	0.0517	2610
20	0.0969	4894
30	0.2268	11453
40	0.3906	19729
50	0.5208	26306
60	0.5708	28828
80	0.5297	26752
100	0.4329	21865
150	0.2656	13415
200	0.1866	9422
300	0.1146	5790
400	0.0812	4103
500	0.0626	3164
600	0.0507	2560
662	0.0455	2300
800	0.0367	1853
1,000	0.0287	1452
1,500	0.0191	964
2,000	0.0146	738

$MDCR_{surveyor}$ for Cs-137 energy

2300 cpm/μR/hr

Bkgd = 18000 cpm

Observation Interval, i =	1	second
b_i =	300	counts
d' =	1.38	from Table 6.1 of NUREG-1507
MDCR =	1434.14	cpm
$MDCR_{surveyor}$ =	2028	cpm

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\,(60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.50

minimum detectable exposure rate, Cs-137 = 0.88 μR/hr

Table 5				
$Energy_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	5.463E-28	2610	0	0.0%
20	0.000E+00	4894	0	0.0%
30	0.000E+00	11453	0	0.0%
40	0.000E+00	19729	0	0.0%
50	1.424E-07	26306	0	0.0%
60	0.000E+00	28828	0	0.0%
80	9.322E-05	26752	20	1.2%
100	1.609E-06	21865	0	0.0%
150	0.000E+00	13415	0	0.0%
200	8.154E-04	9422	61	3.6%
300	3.130E-03	5790	143	8.5%
400	8.931E-03	4103	289	17.2%
500	5.666E-04	3164	14	0.8%
600	1.938E-02	2560	392	23.3%
800	5.422E-03	1853	79	4.7%
1000	2.341E-02	1452	268	15.9%
1500	2.235E-02	964	170	10.1%
2000	4.250E-02	738	248	14.7%
Total	1.266E-01		1685	100.0%

	mR/hr, from MS
15	5.46E-31
20	
30	
40	
50	1.42E-10
60	
80	9.32E-08
100	1.61E-09
150	
200	8.15E-07
300	3.13E-06
400	8.93E-06
500	5.67E-07
600	1.94E-05
800	5.42E-06
1000	2.34E-05
1500	2.24E-05
2000	4.25E-05
	1.266E-04

Microshield Output

0.015	6.40E+02	1.27E-74	6.37E-30	1.09E-75	5.46E-31
0.05	7.72E+01	4.06E-09	5.35E-08	1.08E-11	1.42E-10
0.08	4.98E+02	2.27E-06	5.89E-05	3.60E-09	9.32E-08
0.1	2.93E+00	3.74E-08	1.05E-06	5.73E-11	1.61E-09
0.2	2.33E+02	2.38E-05	4.62E-04	4.20E-08	8.15E-07
0.3	4.45E+02	1.26E-04	1.65E-03	2.38E-07	3.13E-06
0.4	8.26E+02	4.69E-04	4.58E-03	9.14E-07	8.93E-06
0.5	3.86E+01	3.72E-05	2.89E-04	7.30E-08	5.67E-07
0.6	1.04E+03	1.54E-03	9.93E-03	3.00E-06	1.94E-05
0.8	2.04E+02	5.79E-04	2.85E-03	1.10E-06	5.42E-06
1	6.76E+02	3.14E-03	1.27E-02	5.79E-06	2.34E-05
1.5	4.11E+02	4.50E-03	1.33E-02	7.56E-06	2.24E-05
2	5.78E+02	1.11E-02	2.75E-02	1.72E-05	4.25E-05

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
1.204 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6 g/cm3

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate,\ MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **9.51** pCi/g
3.52E+02 Bq/kg

MicroShield 8.02
CB&I Federal Services (8.02-0000)

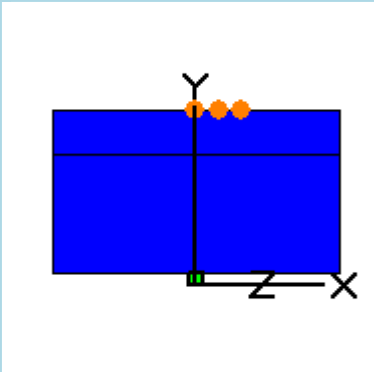
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI2AO 20141104.msd	November 4, 2014	3:22:04 PM	00:00:00

Project Info	
Case Title	TI2AO
Description	3x3 Soil Object, 27.94 cm cover (12-inch lift)
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	2.54 cm (1.0 in)
Radius	1.5 cm (0.6 in)

Dose Points			
A	X	Y	Z
#1	0.0 cm (0 in)	40.531 cm (1 ft 4.0 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	40.531 cm (1 ft 4.0 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	40.531 cm (1 ft 4.0 in)	30.48 cm (1 ft)



Shields			
Shield N	Dimension	Material	Density
Source	17.954 cm³	Concrete	1.6
Shield 1	27.94 cm	FGR 12 Soil	1.6
Shield 2	10.0 cm	Air	0.00122
Shield 3	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	1.7290e-011	6.3974e-001	9.6302e-007	3.5632e-002
Bi-214	2.8350e-011	1.0490e+000	1.5790e-006	5.8424e-002
Pb-210	1.7297e-011	6.3999e-001	9.6340e-007	3.5646e-002
Pb-214	2.8350e-011	1.0490e+000	1.5790e-006	5.8424e-002
Po-210	1.7099e-011	6.3265e-001	9.5235e-007	3.5237e-002
Po-214	2.8344e-011	1.0487e+000	1.5787e-006	5.8412e-002
Po-218	2.8356e-011	1.0492e+000	1.5794e-006	5.8436e-002
Ra-226	2.8356e-011	1.0492e+000	1.5793e-006	5.8436e-002
Rn-222	2.8356e-011	1.0492e+000	1.5794e-006	5.8436e-002

Buildup: The material reference is Shield 1 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,40.531,0) cm					
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	3.112e-01	5.531e-131	2.797e-33	4.744e-132	2.399e-34
0.05	3.751e-02	3.014e-14	5.998e-13	8.028e-17	1.598e-15
0.08	2.418e-01	1.279e-10	5.501e-09	2.025e-13	8.705e-12
0.1	1.424e-03	2.978e-12	1.420e-10	4.555e-15	2.172e-13
0.2	1.130e-01	3.217e-09	1.023e-07	5.678e-12	1.805e-10
0.3	2.165e-01	2.090e-08	4.219e-07	3.965e-11	8.003e-10
0.4	4.014e-01	8.889e-08	1.264e-06	1.732e-10	2.464e-09
0.5	1.874e-02	7.729e-09	8.391e-08	1.517e-11	1.647e-10
0.6	5.058e-01	3.419e-07	3.000e-06	6.674e-10	5.856e-09
0.8	9.913e-02	1.426e-07	9.083e-07	2.712e-10	1.728e-09
1.0	3.284e-01	8.298e-07	4.195e-06	1.530e-09	7.733e-09
1.5	1.997e-01	1.327e-06	4.640e-06	2.233e-09	7.807e-09
2.0	2.807e-01	3.501e-06	9.915e-06	5.414e-09	1.533e-08
Totals	**2.755e+00**	**6.263e-06**	**2.454e-05**	**1.035e-08**	**4.208e-08**

Results - Dose Point # 2 - (0,40.531,15.24) cm					
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	3.112e-01	6.883e-139	2.405e-33	5.904e-140	2.063e-34
0.05	3.751e-02	9.674e-15	2.049e-13	2.577e-17	5.457e-16
0.08	2.418e-01	6.072e-11	2.875e-09	9.608e-14	4.549e-12
0.1	1.424e-03	1.523e-12	8.101e-11	2.330e-15	1.239e-13
0.2	1.130e-01	1.867e-09	6.679e-08	3.296e-12	1.179e-10
0.3	2.165e-01	1.281e-08	2.883e-07	2.430e-11	5.469e-10
0.4	4.014e-01	5.647e-08	8.882e-07	1.100e-10	1.731e-09
0.5	1.874e-02	5.042e-09	6.006e-08	9.896e-12	1.179e-10
0.6	5.058e-01	2.277e-07	2.178e-06	4.445e-10	4.251e-09
0.8	9.913e-02	9.794e-08	6.733e-07	1.863e-10	1.281e-09
1.0	3.284e-01	5.832e-07	3.158e-06	1.075e-09	5.821e-09
1.5	1.997e-01	9.684e-07	3.579e-06	1.629e-09	6.022e-09
2.0	2.807e-01	2.613e-06	7.756e-06	4.041e-09	1.199e-08
Totals	**2.755e+00**	**4.567e-06**	**1.865e-05**	**7.524e-09**	**3.189e-08**

Results - Dose Point # 3 - (0,40.531,30.48) cm					
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	3.112e-01	1.202e-160	1.727e-33	1.031e-161	1.481e-34
0.05	3.751e-02	4.476e-16	1.110e-14	1.192e-18	2.957e-17
0.08	2.418e-01	8.359e-12	5.063e-10	1.323e-14	8.012e-13
0.1	1.424e-03	2.586e-13	1.816e-11	3.956e-16	2.778e-14
0.2	1.130e-01	4.505e-10	2.173e-08	7.951e-13	3.834e-11
0.3	2.165e-01	3.591e-09	1.067e-07	6.811e-12	2.024e-10
0.4	4.014e-01	1.750e-08	3.562e-07	3.409e-11	6.940e-10
0.5	1.874e-02	1.681e-09	2.541e-08	3.300e-12	4.988e-11
0.6	5.058e-01	8.045e-08	9.600e-07	1.570e-10	1.874e-09
0.8	9.913e-02	3.772e-08	3.153e-07	7.174e-11	5.998e-10
1.0	3.284e-01	2.391e-07	1.545e-06	4.408e-10	2.848e-09
1.5	1.997e-01	4.405e-07	1.880e-06	7.411e-10	3.162e-09
2.0	2.807e-01	1.266e-06	4.245e-06	1.958e-09	6.564e-09
Totals	**2.755e+00**	**2.087e-06**	**9.455e-06**	**3.414e-09**	**1.603e-08**

TI 3x3 NaI Scan for Ra-226 @ 1pCi/g, 27.94 cm of soil cover, 2.54 cm thick X 1.5 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u$_{en}$/ρ)air

File TI2AO 20141104

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
Energy$_\gamma$, keV	**(u$_{en}$/ρ)$_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Assumptions

Detector is 3 in (7.6 cm) height by 3 in (7.6 cm) diameter
2.54 cm height by 3 diameter cm radium source at 1.6 g/cm3 (soil hockey puck)
10 cm detector height
Soil cover of (15.24-2.54) = 12.70 cm + 15.24 cm = 27.94 cm (worst case for 12 inches of soil on RSY pad)
0.020 inch (0.051 cm) aluminum detector casing @ 2.7 g/cm3
2300 cpm/uR/hr
Assume average background count rate of 18,000 cpm based on observed soil reference area data

Centerpoint of detector has no offset from center of source

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For Ludlum 3x3 Model 44-20: 7.6 cm dia x 7.6 cm thick NaI crystal

Aluminum housing for 44-20 is 0.020 inches (0.051 cm)

x = 7.6 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
Energy$_\gamma$, keV	**(μ/ρ)$_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	0.99
400	0.117	0.96
500	0.0955	0.93
600	0.0826	0.90
800	0.0676	0.85
1,000	0.0586	0.80
1,500	0.0469	0.73
2,000	0.0413	0.68

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
Energy$_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	0.99	0.1146
400	0.0845	0.96	0.0812
500	0.0673	0.93	0.0626
600	0.0563	0.90	0.0507
800	0.0433	0.85	0.0367
1,000	0.0357	0.80	0.0287
1,500	0.0261	0.73	0.0191
2,000	0.0214	0.68	0.0146

Estimated Ludlum 44-20 7.6 cm dia x 7.6 cm thick NaI response for Cs-137 is **2300** cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

Energy$_\gamma$, keV	(u$_{en}$/ρ)$_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
Energy$_\gamma$, keV	**(μ/ρ)$_{NaI}$, cm^2/g**		
662	0.0780	Probability =	0.89
		RDR =	0.0455

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/hr}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
Energy$_\gamma$, keV	**RDR$_{Ei}$**	**Ludlum 44-20 3x3 NaI cpm per μR/hr, E$_i$**
15	0.0517	2610
20	0.0969	4894
30	0.2268	11453
40	0.3906	19729
50	0.5208	26306
60	0.5708	28828
80	0.5297	26752
100	0.4329	21865
150	0.2656	13415
200	0.1866	9422
300	0.1146	5790
400	0.0812	4103
500	0.0626	3164
600	0.0507	2560
662	0.0455	2300
800	0.0367	1853
1,000	0.0287	1452
1,500	0.0191	964
2,000	0.0146	738

MDCR$_{surveyor}$ for Cs-137 energy

2300 cpm/μR/hr
Bkgd = 18000 cpm

Observation Interval, i =	1	second
b$_i$ =	300	counts
d' =	1.38	from Table 6.1 of NUREG-1507
MDCR =	1434.14	cpm
MDCR$_{surveyor}$ =	2028	cpm

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\,(60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.50

minimum detectable exposure rate, Cs-137 = 0.88 μR/hr

Table 5				
Energy$_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	2.399E-31	2610	0	0.0%
20	0.000E+00	4894	0	0.0%
30	0.000E+00	11453	0	0.0%
40	0.000E+00	19729	0	0.0%
50	1.598E-12	26306	0	0.0%
60	0.000E+00	28828	0	0.0%
80	8.705E-09	26752	6	0.4%
100	2.172E-10	21865	0	0.0%
150	0.000E+00	13415	0	0.0%
200	1.805E-07	9422	40	2.6%
300	8.003E-07	5790	110	7.1%
400	2.464E-06	4103	240	15.4%
500	1.647E-07	3164	12	0.8%
600	5.856E-06	2560	356	22.9%
800	1.728E-06	1853	76	4.9%
1000	7.733E-06	1452	267	17.2%
1500	7.807E-06	964	179	11.5%
2000	1.533E-05	738	269	17.3%
Total	4.207E-05		1556	100.0%

	mR/hr, from MS
15	2.40E-34
20	
30	
40	
50	1.60E-15
60	
80	8.71E-12
100	2.17E-13
150	
200	1.81E-10
300	8.00E-10
400	2.46E-09
500	1.65E-10
600	5.86E-09
800	1.73E-09
1000	7.73E-09
1500	7.81E-09
2000	1.53E-08
	4.207E-08

Microshield Output

0.015	3.11E-01	5.53E-131	2.80E-33	4.74E-132	2.40E-34
0.05	3.75E-02	3.01E-14	6.00E-13	8.03E-17	1.60E-15
0.08	2.42E-01	1.28E-10	5.50E-09	2.03E-13	8.71E-12
0.1	1.42E-03	2.98E-12	1.42E-10	4.56E-15	2.17E-13
0.2	1.13E-01	3.22E-09	1.02E-07	5.68E-12	1.81E-10
0.3	2.17E-01	2.09E-08	4.22E-07	3.97E-11	8.00E-10
0.4	4.01E-01	8.89E-08	1.26E-06	1.73E-10	2.46E-09
0.5	1.87E-02	7.73E-09	8.39E-08	1.52E-11	1.65E-10
0.6	5.06E-01	3.42E-07	3.00E-06	6.67E-10	5.86E-09
0.8	9.91E-02	1.43E-07	9.08E-07	2.71E-10	1.73E-09
1	3.28E-01	8.30E-07	4.20E-06	1.53E-09	7.73E-09
1.5	2.00E-01	1.33E-06	4.64E-06	2.23E-09	7.81E-09
2	2.81E-01	3.50E-06	9.92E-06	5.41E-09	1.53E-08

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
1.304 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6 g/cm3

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate, MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **30983.00** pCi/g
1.15E+06 Bq/kg

Source Vol. 17.95 cm3
Density 1.6 g/cm3
Source mass 28.72 g

Total activity 889832 pCi
0.890 uCi

MicroShield 8.02
CB&I Federal Services (8.02-0000)

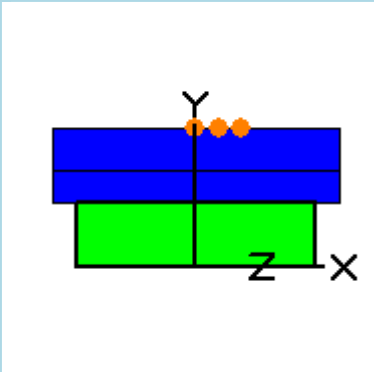
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI3AD 20141104.msd	November 4, 2014	4:01:00 PM	00:00:00

Project Info	
Case Title	TI3AD
Description	3x3 Soil Distributed Source, 7.62 cm soil cover
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	0.0 cm (0 in)	32.671 cm (1 ft 0.9 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	32.671 cm (1 ft 0.9 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	32.671 cm (1 ft 0.9 in)	30.48 cm (1 ft)



Shields			
Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	FGR 12 Soil	1.6
Shield 1	7.62 cm	FGR 12 Soil	1.6
Shield 2	10.0 cm	Air	0.00122
Shield 3	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	3.5579e-008	1.3164e+003	9.6302e-007	3.5632e-002
Bi-214	5.8338e-008	2.1585e+003	1.5790e-006	5.8424e-002
Pb-210	3.5593e-008	1.3169e+003	9.6340e-007	3.5646e-002
Pb-214	5.8338e-008	2.1585e+003	1.5790e-006	5.8424e-002
Po-210	3.5185e-008	1.3018e+003	9.5235e-007	3.5237e-002
Po-214	5.8325e-008	2.1580e+003	1.5787e-006	5.8412e-002
Po-218	5.8349e-008	2.1589e+003	1.5794e-006	5.8436e-002
Ra-226	5.8349e-008	2.1589e+003	1.5793e-006	5.8436e-002
Rn-222	5.8349e-008	2.1589e+003	1.5794e-006	5.8436e-002

Buildup: The material reference is Shield 1 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,32.671,0) cm					
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	6.404e+02	3.723e-41	9.433e-30	3.194e-42	8.091e-31
0.05	7.720e+01	3.416e-07	2.839e-06	9.100e-10	7.564e-09
0.08	4.976e+02	3.819e-05	5.282e-04	6.043e-08	8.359e-07
0.1	2.930e+00	4.610e-07	6.583e-06	7.053e-10	1.007e-08
0.2	2.325e+02	1.741e-04	1.712e-03	3.073e-07	3.022e-06
0.3	4.454e+02	7.372e-04	5.226e-03	1.398e-06	9.914e-06
0.4	8.260e+02	2.375e-03	1.327e-02	4.627e-06	2.586e-05
0.5	3.856e+01	1.689e-04	7.881e-04	3.316e-07	1.547e-06
0.6	1.041e+03	6.404e-03	2.589e-02	1.250e-05	5.053e-05
0.8	2.040e+02	2.126e-03	6.961e-03	4.044e-06	1.324e-05
1.0	6.758e+02	1.052e-02	2.965e-02	1.938e-05	5.465e-05
1.5	4.109e+02	1.293e-02	2.876e-02	2.175e-05	4.838e-05
2.0	5.777e+02	2.917e-02	5.672e-02	4.511e-05	8.771e-05
Totals	**5.670e+03**	**6.464e-02**	**1.695e-01**	**1.095e-04**	**2.957e-04**

Results - Dose Point # 2 - (0,32.671,15.24) cm					
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	6.404e+02	1.857e-41	8.341e-30	1.592e-42	7.154e-31
0.05	7.720e+01	3.113e-07	2.544e-06	8.292e-10	6.776e-09
0.08	4.976e+02	3.308e-05	4.473e-04	5.234e-08	7.078e-07
0.1	2.930e+00	3.957e-07	5.534e-06	6.054e-10	8.466e-09
0.2	2.325e+02	1.476e-04	1.439e-03	2.605e-07	2.539e-06
0.3	4.454e+02	6.230e-04	4.405e-03	1.182e-06	8.355e-06
0.4	8.260e+02	2.004e-03	1.122e-02	3.905e-06	2.186e-05
0.5	3.856e+01	1.425e-04	6.675e-04	2.798e-07	1.310e-06
0.6	1.041e+03	5.404e-03	2.197e-02	1.055e-05	4.289e-05
0.8	2.040e+02	1.796e-03	5.926e-03	3.416e-06	1.127e-05
1.0	6.758e+02	8.893e-03	2.530e-02	1.639e-05	4.664e-05
1.5	4.109e+02	1.097e-02	2.465e-02	1.846e-05	4.147e-05
2.0	5.777e+02	2.483e-02	4.876e-02	3.839e-05	7.541e-05
Totals	**5.670e+03**	**5.484e-02**	**1.448e-01**	**9.289e-05**	**2.525e-04**

Results - Dose Point # 3 - (0,32.671,30.48) cm					
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	6.404e+02	1.608e-43	5.781e-30	1.380e-44	4.959e-31
0.05	7.720e+01	1.243e-07	1.041e-06	3.312e-10	2.772e-09
0.08	4.976e+02	1.440e-05	2.065e-04	2.278e-08	3.268e-07
0.1	2.930e+00	1.765e-07	2.664e-06	2.700e-10	4.076e-09
0.2	2.325e+02	6.940e-05	7.528e-04	1.225e-07	1.329e-06
0.3	4.454e+02	3.014e-04	2.381e-03	5.718e-07	4.517e-06
0.4	8.260e+02	9.912e-04	6.191e-03	1.931e-06	1.206e-05
0.5	3.856e+01	7.176e-05	3.738e-04	1.409e-07	7.338e-07
0.6	1.041e+03	2.762e-03	1.245e-02	5.390e-06	2.431e-05
0.8	2.040e+02	9.404e-04	3.420e-03	1.789e-06	6.506e-06
1.0	6.758e+02	4.749e-03	1.480e-02	8.754e-06	2.728e-05
1.5	4.109e+02	6.072e-03	1.476e-02	1.022e-05	2.483e-05
2.0	5.777e+02	1.408e-02	2.966e-02	2.177e-05	4.587e-05
Totals	**5.670e+03**	**3.005e-02**	**8.500e-02**	**5.071e-05**	**1.478e-04**

TI 3x3 NaI Scan for Ra-226 @ 1pCi/g, 7.62 cm of soil cover, 15 cm thick x 28 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u_{en}/ρ)air

File TI3AD20141104

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
$Energy_\gamma$, keV	**$(u_{en}/\rho)_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Assumptions

Detector is 3 in (7.6 cm) height by 3 in (7.6 cm) diameter
10 cm detector height
15 x 28 source at 1.6 g/cm3 (dry soil) - Buildup reference
7.62 cm of soil cover (9-inch RSY pad with source at bottom)
0.020 inch (0.051 cm) aluminum detector casing @ 2.7 g/cm3
2300 cpm/uR/hr
Assume average background count rate of 18,000 cpm based on observed soil reference area data

Centerpoint of detector has no offset from center of source

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For Ludlum 3x3 Model 44-20: 7.6 cm dia x 7.6 cm thick NaI crystal

Aluminum housing for 44-20 is 0.020 inches (0.051 cm)

x = 7.6 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
$Energy_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	0.99
400	0.117	0.96
500	0.0955	0.93
600	0.0826	0.90
800	0.0676	0.85
1,000	0.0586	0.80
1,500	0.0469	0.73
2,000	0.0413	0.68

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
$Energy_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	0.99	0.1146
400	0.0845	0.96	0.0812
500	0.0673	0.93	0.0626
600	0.0563	0.90	0.0507
800	0.0433	0.85	0.0367
1,000	0.0357	0.80	0.0287
1,500	0.0261	0.73	0.0191
2,000	0.0214	0.68	0.0146

Estimated Ludlum 44-20 7.6 cm dia x 7.6 cm thick NaI response for Cs-137 is **2300** cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

$Energy_\gamma$, keV	$(u_{en}/\rho)_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
$Energy_\gamma$, keV	$(\mu/\rho)_{NaI}$, cm^2/g		
662	0.0780	Probability =	0.89
		RDR =	0.0455

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
$Energy_\gamma$, keV	**RDR_{Ei}**	**Ludlum 44-20 3x3 NaI cpm per μR/hr, E_i**
15	0.0517	2610
20	0.0969	4894
30	0.2268	11453
40	0.3906	19729
50	0.5208	26306
60	0.5708	28828
80	0.5297	26752
100	0.4329	21865
150	0.2656	13415
200	0.1866	9422
300	0.1146	5790
400	0.0812	4103
500	0.0626	3164
600	0.0507	2560
662	0.0455	2300
800	0.0367	1853
1,000	0.0287	1452
1,500	0.0191	964
2,000	0.0146	738

$MDCR_{surveyor}$ for Cs-137 energy

2300 cpm/μR/hr

Bkgd = 18000 cpm

Observation Interval, i = **1** second
b_i = 300 counts
d' = 1.38 from Table 6.1 of NUREG-1507
MDCR = 1434.14 cpm
$MDCR_{surveyor}$ = 2028 cpm

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\,(60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.50

minimum detectable exposure rate, Cs-137 = 0.88 μR/hr

Table 5				
$Energy_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	8.091E-28	2610	0	0.0%
20	0.000E+00	4894	0	0.0%
30	0.000E+00	11453	0	0.0%
40	0.000E+00	19729	0	0.0%
50	7.564E-06	26306	1	0.0%
60	0.000E+00	28828	0	0.0%
80	8.359E-04	26752	76	4.0%
100	1.007E-05	21865	1	0.0%
150	0.000E+00	13415	0	0.0%
200	3.022E-03	9422	96	5.0%
300	9.914E-03	5790	194	10.2%
400	2.586E-02	4103	359	18.8%
500	1.547E-03	3164	17	0.9%
600	5.053E-02	2560	437	22.9%
800	1.324E-02	1853	83	4.3%
1000	5.465E-02	1452	268	14.1%
1500	4.838E-02	964	158	8.3%
2000	8.771E-02	738	219	11.5%
Total	2.957E-01		1908	100.0%

	mR/hr, from MS
15	8.09E-31
20	
30	
40	
50	7.56E-09
60	
80	8.36E-07
100	1.01E-08
150	
200	3.02E-06
300	9.91E-06
400	2.59E-05
500	1.55E-06
600	5.05E-05
800	1.32E-05
1000	5.47E-05
1500	4.84E-05
2000	8.77E-05
	2.957E-04

Microshield Output

0.015	6.40E+02	3.72E-41	9.43E-30	3.19E-42	8.09E-31
0.05	7.72E+01	3.42E-07	2.84E-06	9.10E-10	7.56E-09
0.08	4.98E+02	3.82E-05	5.28E-04	6.04E-08	8.36E-07
0.1	2.93E+00	4.61E-07	6.58E-06	7.05E-10	1.01E-08
0.2	2.33E+02	1.74E-04	1.71E-03	3.07E-07	3.02E-06
0.3	4.45E+02	7.37E-04	5.23E-03	1.40E-06	9.91E-06
0.4	8.26E+02	2.38E-03	1.33E-02	4.63E-06	2.59E-05
0.5	3.86E+01	1.69E-04	7.88E-04	3.32E-07	1.55E-06
0.6	1.04E+03	6.40E-03	2.59E-02	1.25E-05	5.05E-05
0.8	2.04E+02	2.13E-03	6.96E-03	4.04E-06	1.32E-05
1	6.76E+02	1.05E-02	2.97E-02	1.94E-05	5.47E-05
1.5	4.11E+02	1.29E-02	2.88E-02	2.18E-05	4.84E-05
2	5.78E+02	2.92E-02	5.67E-02	4.51E-05	8.77E-05

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
1.063 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6 g/cm3

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate,\ MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **3.59** pCi/g
1.33E+02 Bq/kg

MicroShield 8.02
CB&I Federal Services (8.02-0000)

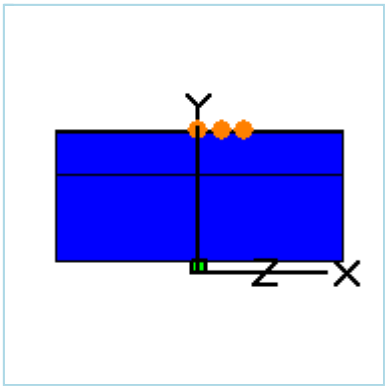
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI3AO 20141106.msd	November 6, 2014	1:35:35 PM	00:00:00

Project Info	
Case Title	TI3AO
Description	3x3 Soil Object, 20.32 cm cover (9-inch lift)
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	2.54 cm (1.0 in)
Radius	1.5 cm (0.6 in)

Dose Points			
A	X	Y	Z
#1	0.0 cm (0 in)	32.911 cm (1 ft 1.0 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	32.911 cm (1 ft 1.0 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	32.911 cm (1 ft 1.0 in)	30.48 cm (1 ft)



Shields			
Shield N	Dimension	Material	Density
Source	17.954 cm³	Concrete	1.6
Shield 1	20.32 cm	FGR 12 Soil	1.6
Shield 2	10.0 cm	Air	0.00122
Shield 3	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	1.7290e-011	6.3974e-001	9.6302e-007	3.5632e-002
Bi-214	2.8350e-011	1.0490e+000	1.5790e-006	5.8424e-002
Pb-210	1.7297e-011	6.3999e-001	9.6340e-007	3.5646e-002
Pb-214	2.8350e-011	1.0490e+000	1.5790e-006	5.8424e-002
Po-210	1.7099e-011	6.3265e-001	9.5235e-007	3.5237e-002
Po-214	2.8344e-011	1.0487e+000	1.5787e-006	5.8412e-002
Po-218	2.8356e-011	1.0492e+000	1.5794e-006	5.8436e-002
Ra-226	2.8356e-011	1.0492e+000	1.5793e-006	5.8436e-002
Rn-222	2.8356e-011	1.0492e+000	1.5794e-006	5.8436e-002

Buildup: The material reference is Shield 1 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,32.911,0) cm					
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	3.112e-01	1.271e-97	4.276e-33	1.090e-98	3.668e-34
0.05	3.751e-02	2.294e-12	3.423e-11	6.111e-15	9.117e-14
0.08	2.418e-01	2.035e-09	5.651e-08	3.220e-12	8.943e-11
0.1	1.424e-03	3.511e-11	1.026e-09	5.371e-14	1.570e-12
0.2	1.130e-01	2.301e-08	4.341e-07	4.060e-11	7.662e-10
0.3	2.165e-01	1.208e-07	1.499e-06	2.291e-10	2.843e-09
0.4	4.014e-01	4.457e-07	4.073e-06	8.684e-10	7.935e-09
0.5	1.874e-02	3.491e-08	2.517e-07	6.853e-11	4.940e-10
0.6	5.058e-01	1.424e-06	8.527e-06	2.779e-09	1.664e-08
0.8	9.913e-02	5.253e-07	2.392e-06	9.992e-10	4.550e-09
1.0	3.284e-01	2.797e-06	1.047e-05	5.157e-09	1.931e-08
1.5	1.997e-01	3.864e-06	1.063e-05	6.500e-09	1.788e-08
2.0	2.807e-01	9.321e-06	2.157e-05	1.441e-08	3.336e-08
Totals	**2.755e+00**	**1.856e-05**	**5.991e-05**	**3.106e-08**	**1.039e-07**

Results - Dose Point # 2 - (0,32.911,15.24) cm					
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	3.112e-01	3.121e-106	3.459e-33	2.677e-107	2.967e-34
0.05	3.751e-02	6.220e-13	1.014e-11	1.657e-15	2.700e-14
0.08	2.418e-01	8.504e-10	2.697e-08	1.346e-12	4.267e-11
0.1	1.424e-03	1.595e-11	5.409e-10	2.440e-14	8.275e-13
0.2	1.130e-01	1.202e-08	2.656e-07	2.122e-11	4.688e-10
0.3	2.165e-01	6.703e-08	9.634e-07	1.271e-10	1.827e-09
0.4	4.014e-01	2.574e-07	2.691e-06	5.016e-10	5.242e-09
0.5	1.874e-02	2.077e-08	1.695e-07	4.077e-11	3.328e-10
0.6	5.058e-01	8.667e-07	5.833e-06	1.692e-09	1.139e-08
0.8	9.913e-02	3.311e-07	1.669e-06	6.297e-10	3.175e-09
1.0	3.284e-01	1.808e-06	7.412e-06	3.333e-09	1.366e-08
1.5	1.997e-01	2.603e-06	7.693e-06	4.380e-09	1.294e-08
2.0	2.807e-01	6.441e-06	1.584e-05	9.960e-09	2.450e-08
Totals	**2.755e+00**	**1.241e-05**	**4.257e-05**	**2.069e-08**	**7.358e-08**

Results - Dose Point # 3 - (0,32.911,30.48) cm					
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	3.112e-01	5.546e-129	2.210e-33	4.757e-130	1.896e-34
0.05	3.751e-02	2.232e-14	4.447e-13	5.946e-17	1.185e-15
0.08	2.418e-01	9.584e-11	4.147e-09	1.517e-13	6.562e-12
0.1	1.424e-03	2.240e-12	1.077e-10	3.427e-15	1.647e-13
0.2	1.130e-01	2.442e-09	7.848e-08	4.311e-12	1.385e-10
0.3	2.165e-01	1.594e-08	3.251e-07	3.024e-11	6.167e-10
0.4	4.014e-01	6.802e-08	9.770e-07	1.325e-10	1.904e-09
0.5	1.874e-02	5.929e-09	6.496e-08	1.164e-11	1.275e-10
0.6	5.058e-01	2.628e-07	2.326e-06	5.130e-10	4.540e-09
0.8	9.913e-02	1.099e-07	7.058e-07	2.090e-10	1.342e-09
1.0	3.284e-01	6.412e-07	3.265e-06	1.182e-09	6.019e-09
1.5	1.997e-01	1.030e-06	3.621e-06	1.732e-09	6.093e-09
2.0	2.807e-01	2.722e-06	7.750e-06	4.210e-09	1.198e-08
Totals	**2.755e+00**	**4.858e-06**	**1.912e-05**	**8.025e-09**	**3.277e-08**

TI 3x3 NaI Scan for Ra-226 @ 1pCi/g, 20.32 cm of soil cover, 2.54 cm thick X 1.5 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u$_{en}$/ρ)air

File TI3AO 20141106

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
Energy$_\gamma$, keV	**(u$_{en}$/ρ)$_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Assumptions

Detector is 3 in (7.6 cm) height by 3 in (7.6 cm) diameter
2.54 cm height by 3 diameter cm radium source at 1.6 g/cm3 (soil hockey puck)
10 cm detector height
Soil cover of (15.24-2.54) = 12.70 cm + 7.62 cm = 20.32 cm (worst case for 9 inches of soil on RSY pad)
0.020 inch (0.051 cm) aluminum detector casing @ 2.7 g/cm3
2300 cpm/uR/hr
Assume average background count rate of 18,000 cpm based on observed soil reference area data

Centerpoint of detector has no offset from center of source

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For Ludlum 3x3 Model 44-20: 7.6 cm dia x 7.6 cm thick NaI crystal

Aluminum housing for 44-20 is 0.020 inches (0.051 cm)

x = 7.6 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
Energy$_\gamma$, keV	**(μ/ρ)$_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	0.99
400	0.117	0.96
500	0.0955	0.93
600	0.0826	0.90
800	0.0676	0.85
1,000	0.0586	0.80
1,500	0.0469	0.73
2,000	0.0413	0.68

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
Energy$_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	0.99	0.1146
400	0.0845	0.96	0.0812
500	0.0673	0.93	0.0626
600	0.0563	0.90	0.0507
800	0.0433	0.85	0.0367
1,000	0.0357	0.80	0.0287
1,500	0.0261	0.73	0.0191
2,000	0.0214	0.68	0.0146

Estimated Ludlum 44-20 7.6 cm dia x 7.6 cm thick NaI response for Cs-137 is **2300** cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

Energy$_\gamma$, keV	(u$_{en}$/ρ)$_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
Energy$_\gamma$, keV	**(μ/ρ)$_{NaI}$, cm^2/g**		
662	0.0780	Probability =	0.89
		RDR =	0.0455

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/hr}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
Energy$_\gamma$, keV	**RDR$_{Ei}$**	**Ludlum 44-20 3x3 NaI cpm per μR/hr, E$_i$**
15	0.0517	2610
20	0.0969	4894
30	0.2268	11453
40	0.3906	19729
50	0.5208	26306
60	0.5708	28828
80	0.5297	26752
100	0.4329	21865
150	0.2656	13415
200	0.1866	9422
300	0.1146	5790
400	0.0812	4103
500	0.0626	3164
600	0.0507	2560
662	0.0455	2300
800	0.0367	1853
1,000	0.0287	1452
1,500	0.0191	964
2,000	0.0146	738

MDCR$_{surveyor}$ for Cs-137 energy

2300 cpm/μR/hr

Bkgd = 18000 cpm

Observation Interval, i = **1** second
b_i = 300 counts
d' = 1.38 from Table 6.1 of NUREG-1507
MDCR = 1434.14 cpm
MDCR$_{surveyor}$ = 2028 cpm

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\,(60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.50

minimum detectable exposure rate, Cs-137 = 0.88 μR/hr

Table 5				
Energy$_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	3.668E-31	2610	0	0.0%
20	0.000E+00	4894	0	0.0%
30	0.000E+00	11453	0	0.0%
40	0.000E+00	19729	0	0.0%
50	9.117E-11	26306	0	0.0%
60	0.000E+00	28828	0	0.0%
80	8.943E-08	26752	23	1.3%
100	1.570E-09	21865	0	0.0%
150	0.000E+00	13415	0	0.0%
200	7.662E-07	9422	70	4.0%
300	2.843E-06	5790	158	9.1%
400	7.935E-06	4103	313	18.0%
500	4.940E-07	3164	15	0.9%
600	1.664E-05	2560	410	23.5%
800	4.550E-06	1853	81	4.7%
1000	1.931E-05	1452	270	15.5%
1500	1.788E-05	964	166	9.5%
2000	3.336E-05	738	237	13.6%
Total	1.039E-04		1744	100.0%

	mR/hr, from MS
15	3.67E-34
20	
30	
40	
50	9.12E-14
60	
80	8.94E-11
100	1.57E-12
150	
200	7.66E-10
300	2.84E-09
400	7.94E-09
500	4.94E-10
600	1.66E-08
800	4.55E-09
1000	1.93E-08
1500	1.79E-08
2000	3.34E-08
	1.039E-07

Microshield Output

0.015	3.11E-01	1.27E-97	4.28E-33	1.09E-98	3.67E-34
0.05	3.75E-02	2.29E-12	3.42E-11	6.11E-15	9.12E-14
0.08	2.42E-01	2.04E-09	5.65E-08	3.22E-12	8.94E-11
0.1	1.42E-03	3.51E-11	1.03E-09	5.37E-14	1.57E-12
0.2	1.13E-01	2.30E-08	4.34E-07	4.06E-11	7.66E-10
0.3	2.17E-01	1.21E-07	1.50E-06	2.29E-10	2.84E-09
0.4	4.01E-01	4.46E-07	4.07E-06	8.68E-10	7.94E-09
0.5	1.87E-02	3.49E-08	2.52E-07	6.85E-11	4.94E-10
0.6	5.06E-01	1.42E-06	8.53E-06	2.78E-09	1.66E-08
0.8	9.91E-02	5.25E-07	2.39E-06	9.99E-10	4.55E-09
1	3.28E-01	2.80E-06	1.05E-05	5.16E-09	1.93E-08
1.5	2.00E-01	3.86E-06	1.06E-05	6.50E-09	1.79E-08
2	2.81E-01	9.32E-06	2.16E-05	1.44E-08	3.34E-08

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
1.163 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6 g/cm3

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate, MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **11196.45** pCi/g
4.14E+05 Bq/kg

Source Vol. 17.95 cm3
Density 1.6 g/cm3
Source mass 28.72 g

Total activity 321562 pCi
0.322 uCi

MicroShield 8.02
CB&I Federal Services (8.02-0000)

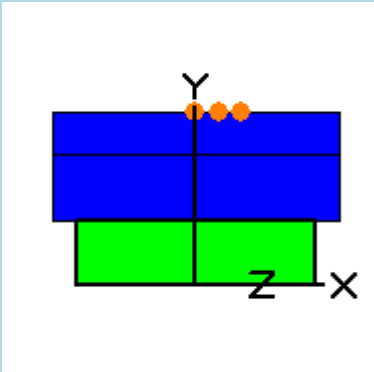
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI5AD 20141106.msd	November 6, 2014	2:17:14 PM	00:00:00

Project Info	
Case Title	TI5AD
Description	3x3 Soil Distributed Source, 15.24 cm conc cover
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	0.0 cm (0 in)	40.291 cm (1 ft 3.9 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	40.291 cm (1 ft 3.9 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	40.291 cm (1 ft 3.9 in)	30.48 cm (1 ft)



Shields			
Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	FGR 12 Soil	1.6
Shield 1	15.24 cm	Concrete	1.6
Shield 2	10.0 cm	Air	0.00122
Shield 3	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	3.5579e-008	1.3164e+003	9.6302e-007	3.5632e-002
Bi-214	5.8338e-008	2.1585e+003	1.5790e-006	5.8424e-002
Pb-210	3.5593e-008	1.3169e+003	9.6340e-007	3.5646e-002
Pb-214	5.8338e-008	2.1585e+003	1.5790e-006	5.8424e-002
Po-210	3.5185e-008	1.3018e+003	9.5235e-007	3.5237e-002
Po-214	5.8325e-008	2.1580e+003	1.5787e-006	5.8412e-002
Po-218	5.8349e-008	2.1589e+003	1.5794e-006	5.8436e-002
Ra-226	5.8349e-008	2.1589e+003	1.5793e-006	5.8436e-002
Rn-222	5.8349e-008	2.1589e+003	1.5794e-006	5.8436e-002

Buildup: The material reference is Shield 1 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,40.291,0) cm					
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	6.404e+02	6.768e-94	5.392e-30	5.805e-95	4.625e-31
0.05	7.720e+01	1.220e-09	5.702e-09	3.251e-12	1.519e-11
0.08	4.976e+02	1.804e-06	1.842e-05	2.855e-09	2.915e-08
0.1	2.930e+00	3.444e-08	4.389e-07	5.269e-11	6.715e-10
0.2	2.325e+02	2.469e-05	3.246e-04	4.357e-08	5.729e-07
0.3	4.454e+02	1.314e-04	1.344e-03	2.493e-07	2.550e-06
0.4	8.260e+02	4.889e-04	3.994e-03	9.526e-07	7.782e-06
0.5	3.856e+01	3.867e-05	2.612e-04	7.590e-08	5.128e-07
0.6	1.041e+03	1.591e-03	9.185e-03	3.106e-06	1.793e-05
0.8	2.040e+02	5.974e-04	2.711e-03	1.136e-06	5.156e-06
1.0	6.758e+02	3.231e-03	1.228e-02	5.955e-06	2.263e-05
1.5	4.109e+02	4.600e-03	1.307e-02	7.739e-06	2.198e-05
2.0	5.777e+02	1.133e-02	2.718e-02	1.752e-05	4.202e-05
Totals	**5.670e+03**	**2.204e-02**	**7.036e-02**	**3.679e-05**	**1.212e-04**

Results - Dose Point # 2 - (0,40.291,15.24) cm					
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	6.404e+02	2.827e-94	4.842e-30	2.425e-95	4.154e-31
0.05	7.720e+01	1.114e-09	5.169e-09	2.967e-12	1.377e-11
0.08	4.976e+02	1.539e-06	1.553e-05	2.435e-09	2.457e-08
0.1	2.930e+00	2.906e-08	3.665e-07	4.445e-11	5.606e-10
0.2	2.325e+02	2.061e-05	2.703e-04	3.637e-08	4.771e-07
0.3	4.454e+02	1.096e-04	1.125e-03	2.078e-07	2.134e-06
0.4	8.260e+02	4.079e-04	3.355e-03	7.947e-07	6.537e-06
0.5	3.856e+01	3.230e-05	2.202e-04	6.340e-08	4.323e-07
0.6	1.041e+03	1.331e-03	7.767e-03	2.598e-06	1.516e-05
0.8	2.040e+02	5.014e-04	2.304e-03	9.536e-07	4.381e-06
1.0	6.758e+02	2.720e-03	1.047e-02	5.013e-06	1.931e-05
1.5	4.109e+02	3.898e-03	1.122e-02	6.558e-06	1.888e-05
2.0	5.777e+02	9.652e-03	2.345e-02	1.493e-05	3.627e-05
Totals	**5.670e+03**	**1.867e-02**	**6.021e-02**	**3.115e-05**	**1.036e-04**

Results - Dose Point # 3 - (0,40.291,30.48) cm					
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	6.404e+02	8.463e-97	3.635e-30	7.259e-98	3.118e-31
0.05	7.720e+01	4.388e-10	2.054e-09	1.169e-12	5.473e-12
0.08	4.976e+02	6.760e-07	7.022e-06	1.070e-09	1.111e-08
0.1	2.930e+00	1.318e-08	1.735e-07	2.016e-11	2.654e-10
0.2	2.325e+02	9.976e-06	1.411e-04	1.761e-08	2.491e-07
0.3	4.454e+02	5.487e-05	6.137e-04	1.041e-07	1.164e-06
0.4	8.260e+02	2.095e-04	1.881e-03	4.081e-07	3.665e-06
0.5	3.856e+01	1.693e-05	1.261e-04	3.323e-08	2.474e-07
0.6	1.041e+03	7.099e-04	4.519e-03	1.386e-06	8.821e-06
0.8	2.040e+02	2.750e-04	1.374e-03	5.231e-07	2.613e-06
1.0	6.758e+02	1.525e-03	6.362e-03	2.812e-06	1.173e-05
1.5	4.109e+02	2.277e-03	7.038e-03	3.831e-06	1.184e-05
2.0	5.777e+02	5.793e-03	1.501e-02	8.959e-06	2.322e-05
Totals	**5.670e+03**	**1.087e-02**	**3.708e-02**	**1.807e-05**	**6.356e-05**

TI 3x3 NaI Scan for Ra-226 @ 1pCi/g, 15.24 cm of concrete cover, 15 cm thick x 28 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u_{en}/ρ)air

File TI5AD20141106

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
$Energy_\gamma$, keV	**$(u_{en}/\rho)_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Assumptions

Detector is 3 in (7.6 cm) height by 3 in (7.6 cm) diameter
10 cm detector height
15 x 28 source at 1.6 g/cm3 (dry soil) - Buildup reference
15.24 cm of concrete cover (6-inch concrete cover with 6-inch distributed source below)
0.020 inch (0.051 cm) aluminum detector casing @ 2.7 g/cm3
2300 cpm/uR/hr
Assume average background count rate of 18,000 cpm based on observed soil reference area data

Centerpoint of detector has no offset from center of source

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For Ludlum 3x3 Model 44-20: 7.6 cm dia x 7.6 cm thick NaI crystal

Aluminum housing for 44-20 is 0.020 inches (0.051 cm)

x = 7.6 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
$Energy_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	0.99
400	0.117	0.96
500	0.0955	0.93
600	0.0826	0.90
800	0.0676	0.85
1,000	0.0586	0.80
1,500	0.0469	0.73
2,000	0.0413	0.68

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
$Energy_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	0.99	0.1146
400	0.0845	0.96	0.0812
500	0.0673	0.93	0.0626
600	0.0563	0.90	0.0507
800	0.0433	0.85	0.0367
1,000	0.0357	0.80	0.0287
1,500	0.0261	0.73	0.0191
2,000	0.0214	0.68	0.0146

Estimated Ludlum 44-20 7.6 cm dia x 7.6 cm thick NaI response for Cs-137 is **2300** cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

$Energy_\gamma$, keV	$(u_{en}/\rho)_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
$Energy_\gamma$, keV	$(\mu/\rho)_{NaI}$, cm^2/g		
662	0.0780	Probability =	0.89
		RDR =	0.0455

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
$Energy_\gamma$, keV	**RDR_{Ei}**	**Ludlum 44-20 3x3 NaI cpm per μR/hr, E_i**
15	0.0517	2610
20	0.0969	4894
30	0.2268	11453
40	0.3906	19729
50	0.5208	26306
60	0.5708	28828
80	0.5297	26752
100	0.4329	21865
150	0.2656	13415
200	0.1866	9422
300	0.1146	5790
400	0.0812	4103
500	0.0626	3164
600	0.0507	2560
662	0.0455	2300
800	0.0367	1853
1,000	0.0287	1452
1,500	0.0191	964
2,000	0.0146	738

$MDCR_{surveyor}$ for Cs-137 energy

2300 cpm/μR/hr

Bkgd = 18000 cpm

Observation Interval, i = **1** second
b_i = 300 counts
d' = 1.38 from Table 6.1 of NUREG-1507
MDCR = 1434.14 cpm
$MDCR_{surveyor}$ = 2028 cpm

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\,(60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.50

minimum detectable exposure rate, Cs-137 = 0.88 μR/hr

Table 5				
$Energy_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	4.625E-28	2610	0	0.0%
20	0.000E+00	4894	0	0.0%
30	0.000E+00	11453	0	0.0%
40	0.000E+00	19729	0	0.0%
50	1.519E-08	26306	0	0.0%
60	0.000E+00	28828	0	0.0%
80	2.915E-05	26752	6	0.4%
100	6.715E-07	21865	0	0.0%
150	0.000E+00	13415	0	0.0%
200	5.729E-04	9422	45	2.8%
300	2.550E-03	5790	122	7.6%
400	7.782E-03	4103	263	16.4%
500	5.128E-04	3164	13	0.8%
600	1.793E-02	2560	379	23.5%
800	5.156E-03	1853	79	4.9%
1000	2.263E-02	1452	271	16.8%
1500	2.198E-02	964	175	10.9%
2000	4.202E-02	738	256	15.9%
Total	1.212E-01		1610	100.0%

	mR/hr, from MS
15	4.63E-31
20	
30	
40	
50	1.52E-11
60	
80	2.92E-08
100	6.72E-10
150	
200	5.73E-07
300	2.55E-06
400	7.78E-06
500	5.13E-07
600	1.79E-05
800	5.16E-06
1000	2.26E-05
1500	2.20E-05
2000	4.20E-05
	1.212E-04

Microshield Output

0.015	6.40E+02	6.77E-94	5.39E-30	5.81E-95	4.63E-31
0.05	7.72E+01	1.22E-09	5.70E-09	3.25E-12	1.52E-11
0.08	4.98E+02	1.80E-06	1.84E-05	2.86E-09	2.92E-08
0.1	2.93E+00	3.44E-08	4.39E-07	5.27E-11	6.72E-10
0.2	2.33E+02	2.47E-05	3.25E-04	4.36E-08	5.73E-07
0.3	4.45E+02	1.31E-04	1.34E-03	2.49E-07	2.55E-06
0.4	8.26E+02	4.89E-04	3.99E-03	9.53E-07	7.78E-06
0.5	3.86E+01	3.87E-05	2.61E-04	7.59E-08	5.13E-07
0.6	1.04E+03	1.59E-03	9.19E-03	3.11E-06	1.79E-05
0.8	2.04E+02	5.97E-04	2.71E-03	1.14E-06	5.16E-06
1	6.76E+02	3.23E-03	1.23E-02	5.96E-06	2.26E-05
1.5	4.11E+02	4.60E-03	1.31E-02	7.74E-06	2.20E-05
2	5.78E+02	1.13E-02	2.72E-02	1.75E-05	4.20E-05

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
1.260 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6 g/cm3

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate,\ MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **10.40** pCi/g
3.85E+02 Bq/kg

MicroShield 8.02
CB&I Federal Services (8.02-0000)

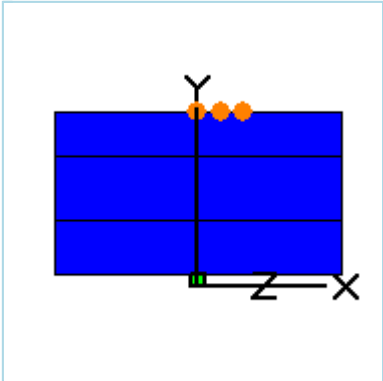
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI5AO 20141106.msd	November 6, 2014	2:51:00 PM	00:00:00

Project Info	
Case Title	TI5AO
Description	3x3 Soil Object, 15.24 cm conc, 12.7 cm soil cover
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	2.54 cm (1.0 in)
Radius	1.5 cm (0.6 in)

Dose Points			
A	X	Y	Z
#1	0.0 cm (0 in)	40.531 cm (1 ft 4.0 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	40.531 cm (1 ft 4.0 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	40.531 cm (1 ft 4.0 in)	30.48 cm (1 ft)



Shields			
Shield N	Dimension	Material	Density
Source	17.954 cm³	Concrete	1.6
Shield 1	12.7 cm	FGR 12 Soil	1.6
Shield 2	15.24 cm	Concrete	1.6
Shield 3	10.0 cm	Air	0.00122
Shield 4	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	1.7290e-011	6.3974e-001	9.6302e-007	3.5632e-002
Bi-214	2.8350e-011	1.0490e+000	1.5790e-006	5.8424e-002
Pb-210	1.7297e-011	6.3999e-001	9.6340e-007	3.5646e-002
Pb-214	2.8350e-011	1.0490e+000	1.5790e-006	5.8424e-002
Po-210	1.7099e-011	6.3265e-001	9.5235e-007	3.5237e-002
Po-214	2.8344e-011	1.0487e+000	1.5787e-006	5.8412e-002
Po-218	2.8356e-011	1.0492e+000	1.5794e-006	5.8436e-002
Ra-226	2.8356e-011	1.0492e+000	1.5793e-006	5.8436e-002
Rn-222	2.8356e-011	1.0492e+000	1.5794e-006	5.8436e-002

Buildup: The material reference is Shield 2 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,40.531,0) cm					
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	3.112e-01	3.712e-150	2.368e-33	3.184e-151	2.031e-34
0.05	3.751e-02	1.003e-14	5.789e-14	2.673e-17	1.542e-16
0.08	2.418e-01	1.041e-10	1.491e-09	1.648e-13	2.359e-12
0.1	1.424e-03	2.766e-12	5.209e-11	4.231e-15	7.969e-14
0.2	1.130e-01	3.325e-09	6.705e-08	5.868e-12	1.183e-10
0.3	2.165e-01	2.173e-08	3.302e-07	4.122e-11	6.264e-10
0.4	4.014e-01	9.212e-08	1.070e-06	1.795e-10	2.085e-09
0.5	1.874e-02	7.991e-09	7.431e-08	1.569e-11	1.459e-10
0.6	5.058e-01	3.527e-07	2.727e-06	6.885e-10	5.323e-09
0.8	9.913e-02	1.466e-07	8.535e-07	2.788e-10	1.623e-09
1.0	3.284e-01	8.507e-07	4.016e-06	1.568e-09	7.403e-09
1.5	1.997e-01	1.354e-06	4.534e-06	2.278e-09	7.629e-09
2.0	2.807e-01	3.558e-06	9.778e-06	5.502e-09	1.512e-08
Totals	**2.755e+00**	**6.387e-06**	**2.345e-05**	**1.056e-08**	**4.008e-08**

Results - Dose Point # 2 - (0,40.531,15.24) cm					
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	3.112e-01	3.261e-159	2.036e-33	2.797e-160	1.747e-34
0.05	3.751e-02	2.976e-15	1.778e-14	7.929e-18	4.736e-17
0.08	2.418e-01	4.869e-11	7.451e-10	7.705e-14	1.179e-12
0.1	1.424e-03	1.407e-12	2.873e-11	2.153e-15	4.396e-14
0.2	1.130e-01	1.934e-09	4.310e-08	3.414e-12	7.607e-11
0.3	2.165e-01	1.335e-08	2.240e-07	2.533e-11	4.249e-10
0.4	4.014e-01	5.867e-08	7.473e-07	1.143e-10	1.456e-09
0.5	1.874e-02	5.225e-09	5.302e-08	1.026e-11	1.041e-10
0.6	5.058e-01	2.355e-07	1.976e-06	4.596e-10	3.857e-09
0.8	9.913e-02	1.009e-07	6.320e-07	1.919e-10	1.202e-09
1.0	3.284e-01	5.990e-07	3.021e-06	1.104e-09	5.568e-09
1.5	1.997e-01	9.893e-07	3.498e-06	1.665e-09	5.885e-09
2.0	2.807e-01	2.659e-06	7.653e-06	4.112e-09	1.183e-08
Totals	**2.755e+00**	**4.663e-06**	**1.785e-05**	**7.685e-09**	**3.041e-08**

Results - Dose Point # 3 - (0,40.531,30.48) cm					
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	3.112e-01	2.635e-184	1.462e-33	2.260e-185	1.254e-34
0.05	3.751e-02	1.117e-16	7.278e-16	2.975e-19	1.939e-18
0.08	2.418e-01	6.443e-12	1.167e-10	1.020e-14	1.847e-13
0.1	1.424e-03	2.356e-13	5.909e-12	3.604e-16	9.041e-15
0.2	1.130e-01	4.696e-10	1.354e-08	8.289e-13	2.389e-11
0.3	2.165e-01	3.772e-09	8.133e-08	7.155e-12	1.543e-10
0.4	4.014e-01	1.830e-08	2.957e-07	3.566e-11	5.762e-10
0.5	1.874e-02	1.754e-09	2.226e-08	3.443e-12	4.370e-11
0.6	5.058e-01	8.368e-08	8.674e-07	1.633e-10	1.693e-09
0.8	9.913e-02	3.906e-08	2.954e-07	7.429e-11	5.619e-10
1.0	3.284e-01	2.468e-07	1.476e-06	4.549e-10	2.722e-09
1.5	1.997e-01	4.518e-07	1.839e-06	7.601e-10	3.095e-09
2.0	2.807e-01	1.292e-06	4.196e-06	1.999e-09	6.489e-09
Totals	**2.755e+00**	**2.138e-06**	**9.088e-06**	**3.498e-09**	**1.536e-08**

TI 3x3 NaI Scan for Ra-226 @ 1pCi/g, 15.24 cm of concrete cover, 12.7 cm soil, 2.54 cm thick X 1.5 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u_{en}/ρ)air

File TI5AO 20141106

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
$Energy_\gamma$, keV	**$(u_{en}/\rho)_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Assumptions

Detector is 3 in (7.6 cm) height by 3 in (7.6 cm) diameter
2.54 cm height by 3 diameter cm radium source at 1.6 g/cm3 (soil hockey puck)
10 cm detector height
Cover of 15.24 cm concrete (6 inches), 12.7 cm soil
0.020 inch (0.051 cm) aluminum detector casing @ 2.7 g/cm3
2300 cpm/uR/hr
Assume average background count rate of 18,000 cpm based on observed soil reference area data

Centerpoint of detector has no offset from center of source

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For Ludlum 3x3 Model 44-20: 7.6 cm dia x 7.6 cm thick NaI crystal

Aluminum housing for 44-20 is 0.020 inches (0.051 cm)

x = 7.6 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
$Energy_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	0.99
400	0.117	0.96
500	0.0955	0.93
600	0.0826	0.90
800	0.0676	0.85
1,000	0.0586	0.80
1,500	0.0469	0.73
2,000	0.0413	0.68

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
$Energy_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	0.99	0.1146
400	0.0845	0.96	0.0812
500	0.0673	0.93	0.0626
600	0.0563	0.90	0.0507
800	0.0433	0.85	0.0367
1,000	0.0357	0.80	0.0287
1,500	0.0261	0.73	0.0191
2,000	0.0214	0.68	0.0146

Estimated Ludlum 44-20 7.6 cm dia x 7.6 cm thick NaI response for Cs-137 is **2300** cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

$Energy_\gamma$, keV	$(u_{en}/\rho)_{air}$, cm^2/g		
662	0.0294	FRER =	0.0514
$Energy_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**		
662	0.0780	Probability =	0.89
		RDR =	0.0455

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/hr}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
$Energy_\gamma$, keV	**RDR_{Ei}**	**Ludlum 44-20 3x3 NaI cpm per μR/hr, E_i**
15	0.0517	2610
20	0.0969	4894
30	0.2268	11453
40	0.3906	19729
50	0.5208	26306
60	0.5708	28828
80	0.5297	26752
100	0.4329	21865
150	0.2656	13415
200	0.1866	9422
300	0.1146	5790
400	0.0812	4103
500	0.0626	3164
600	0.0507	2560
662	0.0455	2300
800	0.0367	1853
1,000	0.0287	1452
1,500	0.0191	964
2,000	0.0146	738

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\,(60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.50

$MDCR_{surveyor}$ for Cs-137 energy

			Observation Interval, i =	1	second
2300	cpm/μR/hr		b_i =	300	counts
			d' =	1.38	from Table 6.1 of NUREG-1507
Bkgd =	18000	cpm	MDCR =	1434.14	cpm
			$MDCR_{surveyor}$ =	2028	cpm

minimum detectable exposure rate, Cs-137 = 0.88 μR/hr

Table 5				
$Energy_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	2.031E-31	2610	0	0.0%
20	0.000E+00	4894	0	0.0%
30	0.000E+00	11453	0	0.0%
40	0.000E+00	19729	0	0.0%
50	1.542E-13	26306	0	0.0%
60	0.000E+00	28828	0	0.0%
80	2.359E-09	26752	2	0.1%
100	7.969E-11	21865	0	0.0%
150	0.000E+00	13415	0	0.0%
200	1.183E-07	9422	28	1.9%
300	6.264E-07	5790	91	6.1%
400	2.085E-06	4103	213	14.3%
500	1.459E-07	3164	12	0.8%
600	5.323E-06	2560	340	22.8%
800	1.623E-06	1853	75	5.0%
1000	7.403E-06	1452	268	18.0%
1500	7.629E-06	964	183	12.3%
2000	1.512E-05	738	278	18.7%
Total	4.008E-05		1490	100.0%

	mR/hr, from MS
15	2.03E-34
20	
30	
40	
50	1.54E-16
60	
80	2.36E-12
100	7.97E-14
150	
200	1.18E-10
300	6.26E-10
400	2.09E-09
500	1.46E-10
600	5.32E-09
800	1.62E-09
1000	7.40E-09
1500	7.63E-09
2000	1.51E-08
	4.008E-08

Microshield Output

0.015	3.11E-01	3.71E-150	2.37E-33	3.18E-151	2.03E-34
0.05	3.75E-02	1.00E-14	5.79E-14	2.67E-17	1.54E-16
0.08	2.42E-01	1.04E-10	1.49E-09	1.65E-13	2.36E-12
0.1	1.42E-03	2.77E-12	5.21E-11	4.23E-15	7.97E-14
0.2	1.13E-01	3.33E-09	6.71E-08	5.87E-12	1.18E-10
0.3	2.17E-01	2.17E-08	3.30E-07	4.12E-11	6.26E-10
0.4	4.01E-01	9.21E-08	1.07E-06	1.80E-10	2.09E-09
0.5	1.87E-02	7.99E-09	7.43E-08	1.57E-11	1.46E-10
0.6	5.06E-01	3.53E-07	2.73E-06	6.89E-10	5.32E-09
0.8	9.91E-02	1.47E-07	8.54E-07	2.79E-10	1.62E-09
1	3.28E-01	8.51E-07	4.02E-06	1.57E-09	7.40E-09
1.5	2.00E-01	1.35E-06	4.53E-06	2.28E-09	7.63E-09
2	2.81E-01	3.56E-06	9.78E-06	5.50E-09	1.51E-08

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
1.361 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6 g/cm3

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate, MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC =	**33963.62**	pCi/g
	1.26E+06	Bq/kg
Source Vol.	17.95	cm3
Density	1.6	g/cm3
Source mass	28.72	g
Total activity	975435	pCi
	0.975	uCi
	0.001	mCi

Appendix B
RS-700 Microshield Modeling and MDC Calculations

MicroShield 8.02
CB&I Federal Services (8.02-0000)

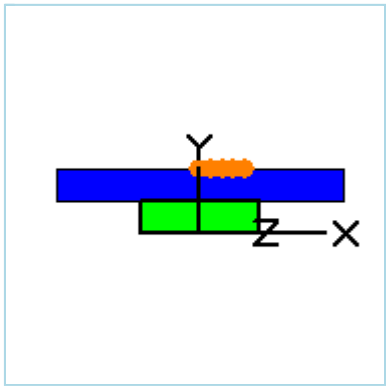
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI1BD 20150310.msd	March 10, 2015	2:28:50 PM	00:00:01

Project Info	
Case Title	TI1BD
Description	RSI Soil Distributed Source, no cover
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	0.0 cm (0 in)	30.609 cm (1 ft 0.1 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	30.609 cm (1 ft 0.1 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	30.609 cm (1 ft 0.1 in)	30.48 cm (1 ft)
#4	0.0 cm (0 in)	30.609 cm (1 ft 0.1 in)	45.72 cm (1 ft 6.0 in)
#5	0.0 cm (0 in)	30.609 cm (1 ft 0.1 in)	60.96 cm (2 ft)



Shields			
Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	FGR 12 Soil	1.6
Shield 1	15.24 cm	Air	0.00122
Shield 2	.318 cm	Carbon	2.27
Shield 3	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	5.2037e-008	1.9254e+003	1.4085e-006	5.2115e-002
Bi-214	7.2607e-008	2.6865e+003	1.9653e-006	7.2715e-002
Pb-210	5.2050e-008	1.9258e+003	1.4088e-006	5.2127e-002
Pb-214	7.2607e-008	2.6865e+003	1.9653e-006	7.2715e-002
Po-210	5.1681e-008	1.9122e+003	1.3989e-006	5.1758e-002
Po-214	7.2592e-008	2.6859e+003	1.9648e-006	7.2699e-002
Po-218	7.2621e-008	2.6870e+003	1.9657e-006	7.2729e-002
Ra-226	7.2621e-008	2.6870e+003	1.9656e-006	7.2729e-002

Rn-222	7.2621e-008	2.6870e+003	1.9657e-006	7.2729e-002

Buildup: The material reference is Source Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,30.609,0) cm

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	8.668e+02	1.018e-06	1.134e-06	8.731e-08	9.731e-08
0.05	1.077e+02	5.454e-05	1.533e-04	1.453e-07	4.085e-07
0.08	6.194e+02	8.500e-04	3.361e-03	1.345e-06	5.319e-06
0.1	3.647e+00	7.163e-06	2.883e-05	1.096e-08	4.411e-08
0.2	2.894e+02	1.493e-03	4.764e-03	2.636e-06	8.408e-06
0.3	5.544e+02	4.920e-03	1.306e-02	9.333e-06	2.478e-05
0.4	1.028e+03	1.341e-02	3.139e-02	2.613e-05	6.117e-05
0.5	4.799e+01	8.438e-04	1.799e-03	1.656e-06	3.532e-06
0.6	1.295e+03	2.905e-02	5.764e-02	5.671e-05	1.125e-04
0.8	2.539e+02	8.353e-03	1.490e-02	1.589e-05	2.835e-05
1.0	8.411e+02	3.720e-02	6.180e-02	6.856e-05	1.139e-04
1.5	5.115e+02	3.847e-02	5.690e-02	6.473e-05	9.573e-05
2.0	7.189e+02	7.814e-02	1.083e-01	1.208e-04	1.674e-04
Totals	**7.138e+03**	**2.128e-01**	**3.541e-01**	**3.681e-04**	**6.217e-04**

Results - Dose Point # 2 - (0,30.609,15.24) cm

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	8.668e+02	5.024e-07	5.694e-07	4.309e-08	4.884e-08
0.05	1.077e+02	4.681e-05	1.312e-04	1.247e-07	3.496e-07
0.08	6.194e+02	7.279e-04	2.878e-03	1.152e-06	4.555e-06
0.1	3.647e+00	6.133e-06	2.472e-05	9.382e-09	3.783e-08
0.2	2.894e+02	1.279e-03	4.107e-03	2.257e-06	7.249e-06
0.3	5.544e+02	4.216e-03	1.129e-02	7.998e-06	2.142e-05
0.4	1.028e+03	1.150e-02	2.718e-02	2.241e-05	5.296e-05
0.5	4.799e+01	7.242e-04	1.559e-03	1.422e-06	3.061e-06
0.6	1.295e+03	2.495e-02	4.999e-02	4.871e-05	9.758e-05
0.8	2.539e+02	7.184e-03	1.294e-02	1.366e-05	2.461e-05
1.0	8.411e+02	3.203e-02	5.372e-02	5.904e-05	9.903e-05
1.5	5.115e+02	3.321e-02	4.954e-02	5.588e-05	8.336e-05
2.0	7.189e+02	6.758e-02	9.439e-02	1.045e-04	1.460e-04
Totals	**7.138e+03**	**1.835e-01**	**3.078e-01**	**3.172e-04**	**5.402e-04**

Results - Dose Point # 3 - (0,30.609,30.48) cm

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	8.668e+02	1.807e-07	2.053e-07	1.550e-08	1.761e-08
0.05	1.077e+02	2.461e-05	7.133e-05	6.557e-08	1.900e-07
0.08	6.194e+02	3.925e-04	1.646e-03	6.212e-07	2.605e-06
0.1	3.647e+00	3.335e-06	1.442e-05	5.102e-09	2.207e-08
0.2	2.894e+02	7.102e-04	2.483e-03	1.254e-06	4.382e-06
0.3	5.544e+02	2.371e-03	6.904e-03	4.498e-06	1.310e-05
0.4	1.028e+03	6.532e-03	1.673e-02	1.273e-05	3.260e-05
0.5	4.799e+01	4.147e-04	9.643e-04	8.139e-07	1.893e-06
0.6	1.295e+03	1.439e-02	3.102e-02	2.808e-05	6.055e-05
0.8	2.539e+02	4.190e-03	8.076e-03	7.970e-06	1.536e-05
1.0	8.411e+02	1.886e-02	3.366e-02	3.476e-05	6.205e-05
1.5	5.115e+02	1.990e-02	3.130e-02	3.348e-05	5.266e-05
2.0	7.189e+02	4.098e-02	5.999e-02	6.338e-05	9.277e-05
Totals	**7.138e+03**	**1.088e-01**	**1.929e-01**	**1.877e-04**	**3.382e-04**

Results - Dose Point # 4 - (0,30.609,45.72) cm					
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	8.668e+02	6.903e-08	7.825e-08	5.921e-09	6.712e-09
0.05	1.077e+02	1.169e-05	3.476e-05	3.114e-08	9.261e-08
0.08	6.194e+02	1.866e-04	8.010e-04	2.952e-07	1.268e-06
0.1	3.647e+00	1.586e-06	7.051e-06	2.427e-09	1.079e-08
0.2	2.894e+02	3.401e-04	1.241e-03	6.002e-07	2.190e-06
0.3	5.544e+02	1.142e-03	3.491e-03	2.167e-06	6.621e-06
0.4	1.028e+03	3.163e-03	8.525e-03	6.163e-06	1.661e-05
0.5	4.799e+01	2.018e-04	4.942e-04	3.961e-07	9.701e-07
0.6	1.295e+03	7.032e-03	1.598e-02	1.373e-05	3.119e-05
0.8	2.539e+02	2.065e-03	4.193e-03	3.927e-06	7.975e-06
1.0	8.411e+02	9.359e-03	1.758e-02	1.725e-05	3.241e-05
1.5	5.115e+02	1.002e-02	1.653e-02	1.686e-05	2.781e-05
2.0	7.189e+02	2.087e-02	3.194e-02	3.228e-05	4.939e-05
Totals	**7.138e+03**	**5.440e-02**	**1.008e-01**	**9.371e-05**	**1.765e-04**

Results - Dose Point # 5 - (0,30.609,60.96) cm					
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	8.668e+02	2.567e-08	2.916e-08	2.202e-09	2.501e-09
0.05	1.077e+02	5.697e-06	1.777e-05	1.518e-08	4.733e-08
0.08	6.194e+02	9.313e-05	4.254e-04	1.474e-07	6.732e-07
0.1	3.647e+00	7.972e-07	3.776e-06	1.220e-09	5.777e-09
0.2	2.894e+02	1.739e-04	6.730e-04	3.070e-07	1.188e-06

0.3	5.544e+02	5.901e-04	1.903e-03	1.119e-06	3.610e-06
0.4	1.028e+03	1.646e-03	4.666e-03	3.208e-06	9.092e-06
0.5	4.799e+01	1.056e-04	2.714e-04	2.073e-07	5.327e-07
0.6	1.295e+03	3.699e-03	8.800e-03	7.220e-06	1.718e-05
0.8	2.539e+02	1.095e-03	2.320e-03	2.082e-06	4.412e-06
1.0	8.411e+02	4.994e-03	9.766e-03	9.205e-06	1.800e-05
1.5	5.115e+02	5.414e-03	9.260e-03	9.109e-06	1.558e-05
2.0	7.189e+02	1.138e-02	1.800e-02	1.760e-05	2.784e-05
Totals	**7.138e+03**	**2.920e-02**	**5.611e-02**	**5.022e-05**	**9.816e-05**

TI RSI NaI Scan for Ra-226 @ 1pCi/g, 0 inches soil, 15 cm thick x 28 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u_{en}/ρ)air

File TI1BD 20150310

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
$Energy_\gamma$, keV	**$(u_{en}/\rho)_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Assumptions

Detector is 4 in (10.16 cm) X 4 in X 16 in
15.24 cm detector height
15 x 28 source at 1.6 g/cm3 (dry soil) - Buildup reference
No soil cover

0.318 carbon casing @ 2.27 g/cm3
0.051 cm aluminum wrap @ 2.7 g/cm3

Average background count rate observed to be 3,767 cps (226,018 cpm) in 5.3 uR/hr field (ROI 10, Gross Counts)
42,483 cpm/uR/hr

Centerpoint of detector has no offset from center of source

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For RSX-1: 10.16 cm X 10.16 cm X 40.64 cm

carbon fiber case 0.318 cm thick; Al wrap 0.051 cm

x = 10.16 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
$Energy_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	1.00
400	0.117	0.99
500	0.0955	0.97
600	0.0826	0.95
800	0.0676	0.92
1,000	0.0586	0.89
1,500	0.0469	0.83
2,000	0.0413	0.79

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
$Energy_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	1.00	0.1155
400	0.0845	0.99	0.0834
500	0.0673	0.97	0.0654
600	0.0563	0.95	0.0537
800	0.0433	0.92	0.0398
1,000	0.0357	0.89	0.0317
1,500	0.0261	0.83	0.0216
2,000	0.0214	0.79	0.0168

Estimated RSI-700 4-Liter NaI total gamma response @ 662keV 42483 cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

$Energy_\gamma$, keV	$(u_{en}/\rho)_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
$Energy_\gamma$, keV	$(\mu/\rho)_{NaI}$, cm^2/g		
662	0.0780	Probability =	0.95
		RDR =	0.0486

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
$Energy_\gamma$, keV	**RDR_{Ei}**	**RSI NaI cpm per μR/hr, E_i**
15	0.0517	45202
20	0.0969	84753
30	0.2268	198333
40	0.3906	341660
50	0.5208	455547
60	0.5708	499230
80	0.5297	463268
100	0.4329	378637
150	0.2656	232311
200	0.1866	163180
300	0.1155	101033
400	0.0834	72931
500	0.0654	57226
600	0.0537	46985
662	0.0486	42483
800	0.0398	34789
1,000	0.0317	27724
1,500	0.0216	18888
2,000	0.0168	14682

$MDCR_{surveyor}$ for Cs-137 energy

42483 cpm/μR/hr

Bkgd = 226018 cpm

Observation Interval, i =	2	second
b_i =	7533.9	counts
d' =	3.28	from Table 6.1 of NUREG-1507
MDCR =	8540.9	cpm
$MDCR_{surveyor}$ =	9003	cpm

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\,(60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.90

minimum detectable exposure rate, Cs-137 = 0.21 μR/hr

Table 5				
$Energy_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	9.731E-05	45202	7	0.0%
20	0.000E+00	84753	0	0.0%
30	0.000E+00	198333	0	0.0%
40	0.000E+00	341660	0	0.0%
50	4.085E-04	455547	299	0.7%
60	0.000E+00	499230	0	0.0%
80	5.319E-03	463268	3964	9.9%
100	4.411E-05	378637	27	0.1%
150	0.000E+00	232311	0	0.0%
200	8.408E-03	163180	2207	5.5%
300	2.478E-02	101033	4027	10.1%
400	6.117E-02	72931	7176	17.9%
500	3.532E-03	57226	325	0.8%
600	1.125E-01	46985	8503	21.2%
800	2.835E-02	34789	1587	4.0%
1000	1.139E-01	27724	5080	12.7%
1500	9.573E-02	18888	2909	7.3%
2000	1.674E-01	14682	3954	9.9%
Total	6.216E-01		40065	100.0%

	mR/hr, from MS
15	9.73E-08
20	
30	
40	
50	4.09E-07
60	
80	5.32E-06
100	4.41E-08
150	
200	8.41E-06
300	2.48E-05
400	6.12E-05
500	3.53E-06
600	1.13E-04
800	2.84E-05
1000	1.14E-04
1500	9.57E-05
2000	1.67E-04
	6.216E-04

Microshield Output

0.015	#####	1.02E-06	1.13E-06	8.73E-08	9.73E-08
0.05	#####	5.45E-05	1.53E-04	1.45E-07	4.09E-07
0.08	#####	8.50E-04	3.36E-03	1.35E-06	5.32E-06
0.1	#####	7.16E-06	2.88E-05	1.10E-08	4.41E-08
0.2	#####	1.49E-03	4.76E-03	2.64E-06	8.41E-06
0.3	#####	4.92E-03	1.31E-02	9.33E-06	2.48E-05
0.4	#####	1.34E-02	3.14E-02	2.61E-05	6.12E-05
0.5	#####	8.44E-04	1.80E-03	1.66E-06	3.53E-06
0.6	#####	2.91E-02	5.76E-02	5.67E-05	1.13E-04
0.8	#####	8.35E-03	1.49E-02	1.59E-05	2.84E-05
1	#####	3.72E-02	6.18E-02	6.86E-05	1.14E-04
1.5	#####	3.85E-02	5.69E-02	6.47E-05	9.57E-05
2	#####	7.81E-02	1.08E-01	1.21E-04	1.67E-04

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
0.225 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate,\ MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **0.36** pCi/g
1.34E+01 Bq/kg

MicroShield 8.02
CB&I Federal Services (8.02-0000)

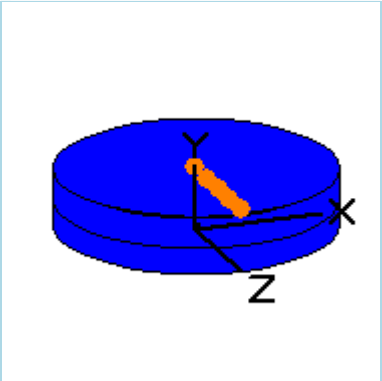
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI1BO 20150310.msd	March 10, 2015	2:36:36 PM	00:00:01

Project Info	
Case Title	TI1BO
Description	RSI Object, 12.7 cm soil cover (6-inch lift)
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	2.54 cm (1.0 in)
Radius	1.5 cm (0.6 in)

Dose Points			
A	X	Y	Z
#1	0.0 cm (0 in)	30.849 cm (1 ft 0.1 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	30.849 cm (1 ft 0.1 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	30.849 cm (1 ft 0.1 in)	30.48 cm (1 ft)
#4	0.0 cm (0 in)	30.849 cm (1 ft 0.1 in)	45.72 cm (1 ft 6.0 in)
#5	0.0 cm (0 in)	30.849 cm (1 ft 0.1 in)	60.96 cm (2 ft)



Shields			
Shield N	Dimension	Material	Density
Source	17.954 cm³	Concrete	1.6
Shield 1	12.7 cm	FGR 12 Soil	1.6
Shield 2	15.24 cm	Air	0.00122
Shield 3	.318 cm	Carbon	2.27
Shield 4	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	2.5289e-011	9.3568e-001	1.4085e-006	5.2115e-002
Bi-214	3.5285e-011	1.3055e+000	1.9653e-006	7.2715e-002
Pb-210	2.5295e-011	9.3590e-001	1.4088e-006	5.2127e-002
Pb-214	3.5285e-011	1.3055e+000	1.9653e-006	7.2715e-002
Po-210	2.5115e-011	9.2927e-001	1.3989e-006	5.1758e-002
Po-214	3.5277e-011	1.3053e+000	1.9648e-006	7.2699e-002
Po-218	3.5292e-011	1.3058e+000	1.9657e-006	7.2729e-002

Ra-226	3.5292e-011	1.3058e+000	1.9656e-006	7.2729e-002
Rn-222	3.5292e-011	1.3058e+000	1.9657e-006	7.2729e-002

Buildup: The material reference is Shield 1 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,30.849,0) cm					
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	4.212e-01	1.760e-64	6.597e-33	1.510e-65	5.658e-34
0.05	5.234e-02	1.588e-10	1.626e-09	4.230e-13	4.332e-12
0.08	3.010e-01	2.670e-08	4.315e-07	4.226e-11	6.828e-10
0.1	1.772e-03	3.438e-10	5.554e-09	5.260e-13	8.497e-12
0.2	1.406e-01	1.394e-07	1.409e-06	2.461e-10	2.486e-09
0.3	2.694e-01	5.984e-07	4.197e-06	1.135e-09	7.961e-09
0.4	4.996e-01	1.932e-06	1.046e-05	3.764e-09	2.037e-08
0.5	2.332e-02	1.372e-07	6.133e-07	2.693e-10	1.204e-09
0.6	6.295e-01	5.181e-06	1.991e-05	1.011e-08	3.886e-08
0.8	1.234e-01	1.704e-06	5.272e-06	3.242e-09	1.003e-08
1.0	4.088e-01	8.347e-06	2.219e-05	1.539e-08	4.090e-08
1.5	2.485e-01	1.004e-05	2.108e-05	1.690e-08	3.546e-08
2.0	3.494e-01	2.228e-05	4.096e-05	3.445e-08	6.334e-08
Totals	**3.469e+00**	**5.039e-05**	**1.265e-04**	**8.554e-08**	**2.213e-07**

Results - Dose Point # 2 - (0,30.849,15.24) cm					
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	4.212e-01	8.700e-71	5.216e-33	7.462e-72	4.474e-34
0.05	5.234e-02	5.733e-11	6.403e-10	1.527e-13	1.706e-12
0.08	3.010e-01	1.308e-08	2.407e-07	2.069e-11	3.808e-10
0.1	1.772e-03	1.786e-10	3.334e-09	2.733e-13	5.101e-12
0.2	1.406e-01	8.013e-08	9.425e-07	1.414e-10	1.663e-09
0.3	2.694e-01	3.593e-07	2.896e-06	6.816e-10	5.493e-09
0.4	4.996e-01	1.194e-06	7.336e-06	2.327e-09	1.429e-08
0.5	2.332e-02	8.666e-08	4.345e-07	1.701e-10	8.530e-10
0.6	6.295e-01	3.328e-06	1.421e-05	6.497e-09	2.774e-08
0.8	1.234e-01	1.123e-06	3.809e-06	2.136e-09	7.245e-09
1.0	4.088e-01	5.602e-06	1.616e-05	1.033e-08	2.979e-08
1.5	2.485e-01	6.947e-06	1.556e-05	1.169e-08	2.617e-08
2.0	3.494e-01	1.570e-05	3.050e-05	2.428e-08	4.716e-08
Totals	**3.469e+00**	**3.443e-05**	**9.209e-05**	**5.826e-08**	**1.608e-07**

Results - Dose Point # 3 - (0,30.849,30.48) cm					
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	4.212e-01	6.225e-87	3.201e-33	5.340e-88	2.746e-34
0.05	5.234e-02	4.486e-12	6.146e-11	1.195e-14	1.637e-13
0.08	3.010e-01	2.296e-09	5.717e-08	3.633e-12	9.047e-11
0.1	1.772e-03	3.666e-11	9.535e-10	5.609e-14	1.459e-12
0.2	1.406e-01	2.143e-08	3.593e-07	3.783e-11	6.342e-10
0.3	2.694e-01	1.077e-07	1.200e-06	2.043e-10	2.277e-09
0.4	4.996e-01	3.864e-07	3.198e-06	7.528e-10	6.231e-09
0.5	2.332e-02	2.965e-08	1.952e-07	5.820e-11	3.831e-10
0.6	6.295e-01	1.190e-06	6.546e-06	2.322e-09	1.278e-08
0.8	1.234e-01	4.286e-07	1.813e-06	8.153e-10	3.448e-09
1.0	4.088e-01	2.243e-06	7.868e-06	4.135e-09	1.450e-08
1.5	2.485e-01	3.011e-06	7.867e-06	5.066e-09	1.324e-08
2.0	3.494e-01	7.140e-06	1.582e-05	1.104e-08	2.447e-08
Totals	**3.469e+00**	**1.456e-05**	**4.493e-05**	**2.444e-08**	**7.805e-08**

Results - Dose Point # 4 - (0,30.849,45.72) cm					
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	4.212e-01	2.056e-108	1.947e-33	1.764e-109	1.670e-34
0.05	5.234e-02	1.859e-13	3.176e-12	4.952e-16	8.460e-15
0.08	3.010e-01	2.737e-10	9.480e-09	4.332e-13	1.500e-11
0.1	1.772e-03	5.361e-12	2.015e-10	8.202e-15	3.083e-13
0.2	1.406e-01	4.426e-09	1.098e-07	7.811e-12	1.937e-10
0.3	2.694e-01	2.581e-08	4.137e-07	4.896e-11	7.848e-10
0.4	4.996e-01	1.022e-07	1.180e-06	1.992e-10	2.299e-09
0.5	2.332e-02	8.438e-09	7.553e-08	1.656e-11	1.483e-10
0.6	6.295e-01	3.585e-07	2.630e-06	6.998e-10	5.133e-09
0.8	1.234e-01	1.407e-07	7.654e-07	2.676e-10	1.456e-09
1.0	4.088e-01	7.837e-07	3.439e-06	1.445e-09	6.339e-09
1.5	2.485e-01	1.166e-06	3.638e-06	1.962e-09	6.120e-09
2.0	3.494e-01	2.943e-06	7.578e-06	4.551e-09	1.172e-08
Totals	**3.469e+00**	**5.533e-06**	**1.984e-05**	**9.198e-09**	**3.421e-08**

Results - Dose Point # 5 - (0,30.849,60.96) cm					
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	4.212e-01	1.778e-132	1.258e-33	1.525e-133	1.079e-34
0.05	5.234e-02	6.093e-15	1.272e-13	1.623e-17	3.388e-16
0.08	3.010e-01	2.897e-11	1.368e-09	4.585e-14	2.165e-12
0.1	1.772e-03	7.116e-13	3.793e-11	1.089e-15	5.803e-14

0.2	1.406e-01	8.616e-10	3.111e-08	1.521e-12	5.490e-11
0.3	2.694e-01	5.927e-09	1.347e-07	1.124e-11	2.556e-10
0.4	4.996e-01	2.620e-08	4.162e-07	5.106e-11	8.110e-10
0.5	2.332e-02	2.345e-09	2.820e-08	4.603e-12	5.535e-11
0.6	6.295e-01	1.062e-07	1.024e-06	2.072e-10	1.999e-09
0.8	1.234e-01	4.580e-08	3.174e-07	8.712e-11	6.038e-10
1.0	4.088e-01	2.734e-07	1.492e-06	5.040e-10	2.750e-09
1.5	2.485e-01	4.560e-07	1.696e-06	7.671e-10	2.853e-09
2.0	3.494e-01	1.234e-06	3.682e-06	1.908e-09	5.694e-09
Totals	**3.469e+00**	**2.151e-06**	**8.823e-06**	**3.542e-09**	**1.508e-08**

TI RSI NaI Scan for Ra-226 @ 1pCi/g, 12.7 cm soil, 2.54 cm thick x 1.5 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u$_{en}$/ρ)air

File TI1BO 20150310

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
Energy$_\gamma$, keV	**(u$_{en}$/ρ)$_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Assumptions

Detector is 4 in (10.16 cm) X 4 in X 16 in
15.24 cm detector height
2.54 cm height by 3 diameter cm radium source at 1.6 g/cm3 (soil hockey puck)
Soil cover of (15.24-2.54) = 12.70 cm (worst case for 6 inches of soil on RSY pad)

0.318 carbon casing @ 2.27 g/cm3
0.051 cm aluminum wrap @ 2.7 g/cm3

Average background count rate observed to be 3,767 cps (226,018 cpm) in 5.3 uR/hr field (ROI 10, Gross Counts)
42,483 cpm/uR/hr

Centerpoint of detector has no offset from center of source

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For RSX-1: 10.16 cm X 10.16 cm X 40.64 cm

carbon fiber case 0.318 cm thick; Al wrap 0.051 cm

x = 10.16 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
Energy$_\gamma$, keV	**(μ/ρ)$_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	1.00
400	0.117	0.99
500	0.0955	0.97
600	0.0826	0.95
800	0.0676	0.92
1,000	0.0586	0.89
1,500	0.0469	0.83
2,000	0.0413	0.79

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
Energy$_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	1.00	0.1155
400	0.0845	0.99	0.0834
500	0.0673	0.97	0.0654
600	0.0563	0.95	0.0537
800	0.0433	0.92	0.0398
1,000	0.0357	0.89	0.0317
1,500	0.0261	0.83	0.0216
2,000	0.0214	0.79	0.0168

Estimated RSI-700 4-Liter NaI total gamma response @ 662keV 42,483 cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

Energy$_\gamma$, keV	(u$_{en}$/ρ)$_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
Energy$_\gamma$, keV	**(μ/ρ)$_{NaI}$, cm^2/g**		
662	0.0780	Probability =	0.95
		RDR =	0.0486

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
Energy$_\gamma$, keV	**RDR$_{Ei}$**	**RSI NaI cpm per μR/hr, E$_i$**
15	0.0517	45202
20	0.0969	84753
30	0.2268	198333
40	0.3906	341660
50	0.5208	455547
60	0.5708	499230
80	0.5297	463268
100	0.4329	378637
150	0.2656	232311
200	0.1866	163180
300	0.1155	101033
400	0.0834	72931
500	0.0654	57226
600	0.0537	46985
662	0.0486	42483
800	0.0398	34789
1,000	0.0317	27724
1,500	0.0216	18888
2,000	0.0168	14682

MDCR$_{surveyor}$ for Cs-137 energy

42483 cpm/μR/hr
Bkgd = 226018 cpm

Observation Interval, i = 2 second
b$_i$ = 7533.933333 counts
d' = 3.28 from Table 6.1 of NUREG-1507
MDCR = 8540.95 cpm
MDCR$_{surveyor}$ = 9003 cpm

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\,(60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.90

minimum detectable exposure rate, Cs-137 = 0.21 μR/hr

Table 5				
Energy$_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	5.658E-31	45202	0	0.0%
20	0.000E+00	84753	0	0.0%
30	0.000E+00	198333	0	0.0%
40	0.000E+00	341660	0	0.0%
50	4.332E-09	455547	9	0.0%
60	0.000E+00	499230	0	0.0%
80	6.828E-07	463268	1429	4.0%
100	8.497E-09	378637	15	0.0%
150	0.000E+00	232311	0	0.0%
200	2.486E-06	163180	1833	5.1%
300	7.961E-06	101033	3634	10.1%
400	2.037E-05	72931	6713	18.6%
500	1.204E-06	57226	311	0.9%
600	3.886E-05	46985	8250	22.8%
800	1.003E-05	34789	1577	4.4%
1000	4.090E-05	27724	5124	14.2%
1500	3.546E-05	18888	3026	8.4%
2000	6.334E-05	14682	4202	11.6%
Total	2.213E-04		36124	100.0%

	mR/hr, from MS
15	5.66E-34
20	
30	
40	
50	4.33E-12
60	
80	6.83E-10
100	8.50E-12
150	
200	2.49E-09
300	7.96E-09
400	2.04E-08
500	1.20E-09
600	3.89E-08
800	1.00E-08
1000	4.09E-08
1500	3.55E-08
2000	6.33E-08
	2.213E-07

Microshield Output

0.015	######	1.76E-64	6.60E-33	1.51E-65	5.66E-34
0.05	######	1.59E-10	1.63E-09	4.23E-13	4.33E-12
0.08	######	2.67E-08	4.32E-07	4.23E-11	6.83E-10
0.1	######	3.44E-10	5.55E-09	5.26E-13	8.50E-12
0.2	######	1.39E-07	1.41E-06	2.46E-10	2.49E-09
0.3	######	5.98E-07	4.20E-06	1.14E-09	7.96E-09
0.4	######	1.93E-06	1.05E-05	3.76E-09	2.04E-08
0.5	######	1.37E-07	6.13E-07	2.69E-10	1.20E-09
0.6	######	5.18E-06	1.99E-05	1.01E-08	3.89E-08
0.8	######	1.70E-06	5.27E-06	3.24E-09	1.00E-08
1	######	8.35E-06	2.22E-05	1.54E-08	4.09E-08
1.5	######	1.00E-05	2.11E-05	1.69E-08	3.55E-08
2	######	2.23E-05	4.10E-05	3.45E-08	6.33E-08

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
0.249 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate, MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **1126.15** pCi/g
4.17E+04 Bq/kg

Source Vol. 17.95 cm3
Density 1.6 g/cm3
Source mass 28.72 g

Total activity 32343 pCi
0.032 uCi

MicroShield 8.02
CB&I Federal Services (8.02-0000)

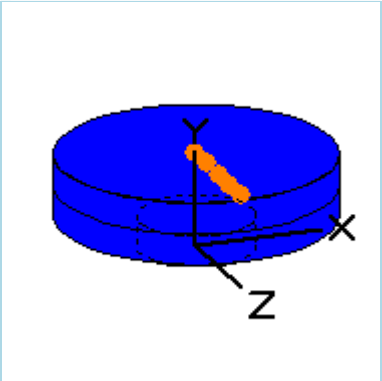
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI2BD 20150310.msd	March 10, 2015	2:59:33 PM	00:00:01

Project Info	
Case Title	TI2BD
Description	RSI Soil Distributed Source, 15.24 cm cover
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	0.0 cm (0 in)	45.849 cm (1 ft 6.1 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	45.849 cm (1 ft 6.1 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	45.849 cm (1 ft 6.1 in)	30.48 cm (1 ft)
#4	0.0 cm (0 in)	45.849 cm (1 ft 6.1 in)	45.72 cm (1 ft 6.0 in)
#5	0.0 cm (0 in)	45.849 cm (1 ft 6.1 in)	60.96 cm (2 ft)



Shields			
Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	FGR 12 Soil	1.6
Shield 1	15.24 cm	FGR 12 Soil	1.6
Shield 2	15.24 cm	Air	0.00122
Shield 3	.318 cm	Carbon	2.27
Shield 4	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	5.2037e-008	1.9254e+003	1.4085e-006	5.2115e-002
Bi-214	7.2607e-008	2.6865e+003	1.9653e-006	7.2715e-002
Pb-210	5.2050e-008	1.9258e+003	1.4088e-006	5.2127e-002
Pb-214	7.2607e-008	2.6865e+003	1.9653e-006	7.2715e-002
Po-210	5.1681e-008	1.9122e+003	1.3989e-006	5.1758e-002
Po-214	7.2592e-008	2.6859e+003	1.9648e-006	7.2699e-002
Po-218	7.2621e-008	2.6870e+003	1.9657e-006	7.2729e-002

Ra-226	7.2621e-008	2.6870e+003	1.9656e-006	7.2729e-002
Rn-222	7.2621e-008	2.6870e+003	1.9657e-006	7.2729e-002

Buildup: The material reference is Shield 1 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,45.849,0) cm

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	8.668e+02	9.913e-75	6.638e-30	8.503e-76	5.694e-31
0.05	1.077e+02	4.751e-09	6.285e-08	1.266e-11	1.674e-10
0.08	6.194e+02	2.291e-06	5.949e-05	3.626e-09	9.415e-08
0.1	3.647e+00	3.741e-08	1.052e-06	5.723e-11	1.610e-09
0.2	2.894e+02	2.357e-05	4.566e-04	4.160e-08	8.058e-07
0.3	5.544e+02	1.244e-04	1.624e-03	2.360e-07	3.082e-06
0.4	1.028e+03	4.638e-04	4.503e-03	9.037e-07	8.773e-06
0.5	4.799e+01	3.673e-05	2.831e-04	7.210e-08	5.556e-07
0.6	1.295e+03	1.514e-03	9.722e-03	2.955e-06	1.898e-05
0.8	2.539e+02	5.695e-04	2.786e-03	1.083e-06	5.299e-06
1.0	8.411e+02	3.084e-03	1.239e-02	5.685e-06	2.285e-05
1.5	5.115e+02	4.402e-03	1.293e-02	7.406e-06	2.175e-05
2.0	7.189e+02	1.087e-02	2.670e-02	1.681e-05	4.129e-05
Totals	**7.138e+03**	**2.109e-02**	**7.146e-02**	**3.519e-05**	**1.235e-04**

Results - Dose Point # 2 - (0,45.849,15.24) cm

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	8.668e+02	6.273e-75	6.090e-30	5.381e-76	5.224e-31
0.05	1.077e+02	4.079e-09	5.346e-08	1.087e-11	1.424e-10
0.08	6.194e+02	1.907e-06	4.930e-05	3.017e-09	7.802e-08
0.1	3.647e+00	3.106e-08	8.743e-07	4.753e-11	1.338e-09
0.2	2.894e+02	1.962e-05	3.848e-04	3.463e-08	6.791e-07
0.3	5.544e+02	1.040e-04	1.381e-03	1.972e-07	2.619e-06
0.4	1.028e+03	3.892e-04	3.849e-03	7.583e-07	7.499e-06
0.5	4.799e+01	3.093e-05	2.431e-04	6.072e-08	4.771e-07
0.6	1.295e+03	1.279e-03	8.379e-03	2.497e-06	1.635e-05
0.8	2.539e+02	4.839e-04	2.414e-03	9.205e-07	4.593e-06
1.0	8.411e+02	2.633e-03	1.079e-02	4.854e-06	1.989e-05
1.5	5.115e+02	3.793e-03	1.134e-02	6.382e-06	1.908e-05
2.0	7.189e+02	9.428e-03	2.354e-02	1.458e-05	3.640e-05
Totals	**7.138e+03**	**1.816e-02**	**6.237e-02**	**3.029e-05**	**1.077e-04**

Results - Dose Point # 3 - (0,45.849,30.48) cm					
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	8.668e+02	2.280e-76	4.778e-30	1.956e-77	4.098e-31
0.05	1.077e+02	1.752e-09	2.339e-08	4.666e-12	6.230e-11
0.08	6.194e+02	9.091e-07	2.472e-05	1.439e-09	3.912e-08
0.1	3.647e+00	1.527e-08	4.588e-07	2.336e-11	7.019e-10
0.2	2.894e+02	1.028e-05	2.211e-04	1.814e-08	3.902e-07
0.3	5.544e+02	5.636e-05	8.236e-04	1.069e-07	1.562e-06
0.4	1.028e+03	2.164e-04	2.351e-03	4.217e-07	4.582e-06
0.5	4.799e+01	1.756e-05	1.512e-04	3.446e-08	2.967e-07
0.6	1.295e+03	7.383e-04	5.286e-03	1.441e-06	1.032e-05
0.8	2.539e+02	2.870e-04	1.556e-03	5.460e-07	2.960e-06
1.0	8.411e+02	1.596e-03	7.066e-03	2.941e-06	1.303e-05
1.5	5.115e+02	2.388e-03	7.633e-03	4.017e-06	1.284e-05
2.0	7.189e+02	6.085e-03	1.612e-02	9.410e-06	2.493e-05
Totals	**7.138e+03**	**1.139e-02**	**4.123e-02**	**1.894e-05**	**7.094e-05**

Results - Dose Point # 4 - (0,45.849,45.72) cm					
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	8.668e+02	1.219e-81	3.396e-30	1.045e-82	2.913e-31
0.05	1.077e+02	3.943e-10	5.633e-09	1.050e-12	1.501e-11
0.08	6.194e+02	2.781e-07	8.407e-06	4.401e-10	1.330e-08
0.1	3.647e+00	4.985e-09	1.695e-07	7.627e-12	2.594e-10
0.2	2.894e+02	3.794e-06	9.492e-05	6.696e-09	1.675e-07
0.3	5.544e+02	2.209e-05	3.754e-04	4.189e-08	7.121e-07
0.4	1.028e+03	8.855e-05	1.114e-03	1.725e-07	2.170e-06
0.5	4.799e+01	7.431e-06	7.367e-05	1.459e-08	1.446e-07
0.6	1.295e+03	3.214e-04	2.636e-03	6.273e-07	5.146e-06
0.8	2.539e+02	1.306e-04	8.033e-04	2.484e-07	1.528e-06
1.0	8.411e+02	7.515e-04	3.744e-03	1.385e-06	6.901e-06
1.5	5.115e+02	1.196e-03	4.230e-03	2.012e-06	7.116e-06
2.0	7.189e+02	3.172e-03	9.189e-03	4.906e-06	1.421e-05
Totals	**7.138e+03**	**5.693e-03**	**2.227e-02**	**9.414e-06**	**3.811e-05**

Results - Dose Point # 5 - (0,45.849,60.96) cm					
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	8.668e+02	1.357e-92	2.365e-30	1.164e-93	2.028e-31
0.05	1.077e+02	4.941e-11	7.912e-10	1.316e-13	2.108e-12
0.08	6.194e+02	6.024e-08	2.149e-06	9.533e-11	3.400e-09
0.1	3.647e+00	1.205e-09	4.934e-08	1.843e-12	7.548e-11

0.2	2.894e+02	1.112e-06	3.421e-05	1.963e-09	6.038e-08
0.3	5.544e+02	7.077e-06	1.467e-04	1.342e-08	2.783e-07
0.4	1.028e+03	3.019e-05	4.580e-04	5.883e-08	8.925e-07
0.5	4.799e+01	2.657e-06	3.145e-05	5.215e-09	6.172e-08
0.6	1.295e+03	1.194e-04	1.160e-03	2.331e-07	2.265e-06
0.8	2.539e+02	5.153e-05	3.697e-04	9.802e-08	7.033e-07
1.0	8.411e+02	3.105e-04	1.784e-03	5.723e-07	3.288e-06
1.5	5.115e+02	5.353e-04	2.137e-03	9.006e-07	3.596e-06
2.0	7.189e+02	1.496e-03	4.819e-03	2.314e-06	7.452e-06
Totals	**7.138e+03**	**2.554e-03**	**1.094e-02**	**4.197e-06**	**1.860e-05**

TI RSI NaI Scan for Ra-226 @ 1pCi/g, 15.24 cm soil cover, 15 cm thick x 28 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u_{en}/ρ)air

File TI2BD 20150310

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
$Energy_\gamma$, keV	**$(u_{en}/\rho)_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Assumptions

Detector is 4 in (10.16 cm) X 4 in X 16 in
15.24 cm Detector Height
15 x 28 source at 1.6 g/cm3 (dry soil) - Buildup reference
15.24 cm of soil cover (12-inch RSY pad with source in bottom half)

0.318 carbon casing @ 2.27 g/cm3
0.051 cm aluminum wrap @ 2.7 g/cm3

Average background count rate observed to be 3,767 cps (226,018 cpm) in 5.3 uR/hr field (ROI 10, Gross Counts)
42,483 cpm/uR/hr

Centerpoint of detector has no offset from center of source

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For RSX-1: 10.16 cm X 10.16 cm X 40.64 cm

carbon fiber case 0.318 cm thick; Al wrap 0.051 cm

x = 10.16 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
$Energy_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	1.00
400	0.117	0.99
500	0.0955	0.97
600	0.0826	0.95
800	0.0676	0.92
1,000	0.0586	0.89
1,500	0.0469	0.83
2,000	0.0413	0.79

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
$Energy_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	1.00	0.1155
400	0.0845	0.99	0.0834
500	0.0673	0.97	0.0654
600	0.0563	0.95	0.0537
800	0.0433	0.92	0.0398
1,000	0.0357	0.89	0.0317
1,500	0.0261	0.83	0.0216
2,000	0.0214	0.79	0.0168

Estimated RSI-700 4-Liter NaI total gamma response @ 662keV 42,483 cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

$Energy_\gamma$, keV	$(u_{en}/\rho)_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
$Energy_\gamma$, keV	$(\mu/\rho)_{NaI}$, cm^2/g		
662	0.0780	Probability =	0.95
		RDR =	0.0486

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
$Energy_\gamma$, keV	**RDR_{Ei}**	**RSI NaI cpm per μR/hr, E_i**
15	0.0517	45202
20	0.0969	84753
30	0.2268	198333
40	0.3906	341660
50	0.5208	455547
60	0.5708	499230
80	0.5297	463268
100	0.4329	378637
150	0.2656	232311
200	0.1866	163180
300	0.1155	101033
400	0.0834	72931
500	0.0654	57226
600	0.0537	46985
662	0.0486	42483
800	0.0398	34789
1,000	0.0317	27724
1,500	0.0216	18888
2,000	0.0168	14682

$MDCR_{surveyor}$ for Cs-137 energy

42,483 cpm/μR/hr

Bkgd = 226018 cpm

Observation Interval, i = 2 second
b_i = 7533.933333 counts
d' = 3.28 from Table 6.1 of NUREG-1507
MDCR = 8540.95 cpm
$MDCR_{surveyor}$ = 9003 cpm

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\,(60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.90

minimum detectable exposure rate, Cs-137 = 0.21 μR/hr

Table 5				
$Energy_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	5.694E-28	45202	0	0.0%
20	0.000E+00	84753	0	0.0%
30	0.000E+00	198333	0	0.0%
40	0.000E+00	341660	0	0.0%
50	1.674E-07	455547	1	0.0%
60	0.000E+00	499230	0	0.0%
80	9.415E-05	463268	353	1.1%
100	1.610E-06	378637	5	0.0%
150	0.000E+00	232311	0	0.0%
200	8.058E-04	163180	1065	3.4%
300	3.082E-03	101033	2522	8.0%
400	8.773E-03	72931	5182	16.5%
500	5.556E-04	57226	257	0.8%
600	1.898E-02	46985	7222	23.0%
800	5.299E-03	34789	1493	4.7%
1000	2.285E-02	27724	5130	16.3%
1500	2.175E-02	18888	3327	10.6%
2000	4.129E-02	14682	4910	15.6%
Total	1.235E-01		31466	100.0%

	mR/hr, from MS
15	5.69E-31
20	
30	
40	
50	1.67E-10
60	
80	9.42E-08
100	1.61E-09
150	
200	8.06E-07
300	3.08E-06
400	8.77E-06
500	5.56E-07
600	1.90E-05
800	5.30E-06
1000	2.29E-05
1500	2.18E-05
2000	4.13E-05
	1.235E-04

Microshield Output

0.015	#####	9.91E-75	6.64E-30	8.50E-76	5.69E-31
0.05	#####	4.75E-09	6.29E-08	1.27E-11	1.67E-10
0.08	#####	2.29E-06	5.95E-05	3.63E-09	9.42E-08
0.1	#####	3.74E-08	1.05E-06	5.72E-11	1.61E-09
0.2	#####	2.36E-05	4.57E-04	4.16E-08	8.06E-07
0.3	#####	1.24E-04	1.62E-03	2.36E-07	3.08E-06
0.4	#####	4.64E-04	4.50E-03	9.04E-07	8.77E-06
0.5	#####	3.67E-05	2.83E-04	7.21E-08	5.56E-07
0.6	#####	1.51E-03	9.72E-03	2.96E-06	1.90E-05
0.8	#####	5.70E-04	2.79E-03	1.08E-06	5.30E-06
1	#####	3.08E-03	1.24E-02	5.69E-06	2.29E-05
1.5	#####	4.40E-03	1.29E-02	7.41E-06	2.18E-05
2	#####	1.09E-02	2.67E-02	1.68E-05	4.13E-05

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
0.286 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate,\ MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **2.32** pCi/g
8.57E+01 Bq/kg

MicroShield 8.02
CB&I Federal Services (8.02-0000)

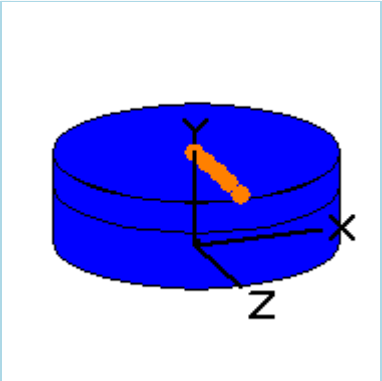
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI2BO 20150310.msd	March 10, 2015	3:05:26 PM	00:00:01

Project Info	
Case Title	TI2BO
Description	RSI Object, 27.94 cm soil cover (12-inch lift)
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	2.54 cm (1.0 in)
Radius	1.5 cm (0.6 in)

Dose Points			
A	X	Y	Z
#1	0.0 cm (0 in)	46.089 cm (1 ft 6.1 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	46.089 cm (1 ft 6.1 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	46.089 cm (1 ft 6.1 in)	30.48 cm (1 ft)
#4	0.0 cm (0 in)	46.089 cm (1 ft 6.1 in)	45.72 cm (1 ft 6.0 in)
#5	0.0 cm (0 in)	46.089 cm (1 ft 6.1 in)	60.96 cm (2 ft)



Shields			
Shield N	Dimension	Material	Density
Source	17.954 cm³	Concrete	1.6
Shield 1	27.94 cm	FGR 12 Soil	1.6
Shield 2	15.24 cm	Air	0.00122
Shield 3	.318 cm	Carbon	2.27
Shield 4	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	2.5289e-011	9.3568e-001	1.4085e-006	5.2115e-002
Bi-214	3.5285e-011	1.3055e+000	1.9653e-006	7.2715e-002
Pb-210	2.5295e-011	9.3590e-001	1.4088e-006	5.2127e-002
Pb-214	3.5285e-011	1.3055e+000	1.9653e-006	7.2715e-002
Po-210	2.5115e-011	9.2927e-001	1.3989e-006	5.1758e-002
Po-214	3.5277e-011	1.3053e+000	1.9648e-006	7.2699e-002
Po-218	3.5292e-011	1.3058e+000	1.9657e-006	7.2729e-002

Ra-226	3.5292e-011	1.3058e+000	1.9656e-006	7.2729e-002
Rn-222	3.5292e-011	1.3058e+000	1.9657e-006	7.2729e-002

Buildup: The material reference is Shield 1 **Integration Parameters**	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,46.089,0) cm

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	4.212e-01	3.374e-131	2.887e-33	2.894e-132	2.477e-34
0.05	5.234e-02	2.819e-14	5.658e-13	7.511e-17	1.507e-15
0.08	3.010e-01	1.084e-10	4.749e-09	1.715e-13	7.515e-12
0.1	1.772e-03	2.538e-12	1.238e-10	3.883e-15	1.895e-13
0.2	1.406e-01	2.796e-09	9.133e-08	4.935e-12	1.612e-10
0.3	2.694e-01	1.838e-08	3.804e-07	3.486e-11	7.216e-10
0.4	4.996e-01	7.877e-08	1.147e-06	1.535e-10	2.235e-09
0.5	2.332e-02	6.890e-09	7.642e-08	1.352e-11	1.500e-10
0.6	6.295e-01	3.063e-07	2.741e-06	5.978e-10	5.351e-09
0.8	1.234e-01	1.286e-07	8.338e-07	2.446e-10	1.586e-09
1.0	4.088e-01	7.524e-07	3.865e-06	1.387e-09	7.124e-09
1.5	2.485e-01	1.214e-06	4.298e-06	2.042e-09	7.232e-09
2.0	3.494e-01	3.219e-06	9.214e-06	4.977e-09	1.425e-08
Totals	**3.469e+00**	**5.727e-06**	**2.265e-05**	**9.456e-09**	**3.882e-08**

Results - Dose Point # 2 - (0,46.089,15.24) cm

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	4.212e-01	1.922e-137	2.577e-33	1.648e-138	2.210e-34
0.05	5.234e-02	1.173e-14	2.469e-13	3.124e-17	6.578e-16
0.08	3.010e-01	6.091e-11	2.876e-09	9.638e-14	4.551e-12
0.1	1.772e-03	1.511e-12	8.026e-11	2.312e-15	1.228e-13
0.2	1.406e-01	1.836e-09	6.571e-08	3.240e-12	1.160e-10
0.3	2.694e-01	1.259e-08	2.836e-07	2.388e-11	5.379e-10
0.4	4.996e-01	5.550e-08	8.737e-07	1.081e-10	1.702e-09
0.5	2.332e-02	4.956e-09	5.908e-08	9.728e-12	1.160e-10
0.6	6.295e-01	2.239e-07	2.143e-06	4.370e-10	4.182e-09
0.8	1.234e-01	9.632e-08	6.625e-07	1.832e-10	1.260e-09
1.0	4.088e-01	5.736e-07	3.108e-06	1.057e-09	5.728e-09
1.5	2.485e-01	9.528e-07	3.523e-06	1.603e-09	5.927e-09
2.0	3.494e-01	2.572e-06	7.635e-06	3.977e-09	1.181e-08
Totals	**3.469e+00**	**4.493e-06**	**1.836e-05**	**7.403e-09**	**3.138e-08**

Results - Dose Point # 3 - (0,46.089,30.48) cm					
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	4.212e-01	7.684e-155	1.965e-33	6.591e-156	1.686e-34
0.05	5.234e-02	1.001e-15	2.396e-14	2.666e-18	6.382e-17
0.08	3.010e-01	1.236e-11	7.127e-10	1.956e-14	1.128e-12
0.1	1.772e-03	3.623e-13	2.411e-11	5.542e-16	3.689e-14
0.2	1.406e-01	5.830e-10	2.661e-08	1.029e-12	4.696e-11
0.3	2.694e-01	4.510e-09	1.273e-07	8.556e-12	2.415e-10
0.4	4.996e-01	2.155e-08	4.183e-07	4.199e-11	8.151e-10
0.5	2.332e-02	2.041e-09	2.953e-08	4.007e-12	5.796e-11
0.6	6.295e-01	9.660e-08	1.106e-06	1.885e-10	2.159e-09
0.8	1.234e-01	4.454e-08	3.591e-07	8.471e-11	6.830e-10
1.0	4.088e-01	2.790e-07	1.745e-06	5.142e-10	3.216e-09
1.5	2.485e-01	5.037e-07	2.093e-06	8.475e-10	3.521e-09
2.0	3.494e-01	1.430e-06	4.687e-06	2.212e-09	7.249e-09
Totals	**3.469e+00**	**2.383e-06**	**1.059e-05**	**3.903e-09**	**1.799e-08**

Results - Dose Point # 4 - (0,46.089,45.72) cm					
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	4.212e-01	2.895e-180	1.409e-33	2.483e-181	1.208e-34
0.05	5.234e-02	3.068e-17	8.676e-16	8.173e-20	2.311e-18
0.08	3.010e-01	1.321e-12	9.867e-11	2.090e-15	1.561e-13
0.1	1.772e-03	4.923e-14	4.391e-12	7.531e-17	6.719e-15
0.2	1.406e-01	1.187e-10	7.412e-09	2.095e-13	1.308e-11
0.3	2.694e-01	1.092e-09	4.132e-08	2.072e-12	7.839e-11
0.4	4.996e-01	5.857e-09	1.488e-07	1.141e-11	2.898e-10
0.5	2.332e-02	6.040e-10	1.121e-08	1.186e-12	2.200e-11
0.6	6.295e-01	3.054e-08	4.423e-07	5.962e-11	8.633e-10
0.8	1.234e-01	1.556e-08	1.542e-07	2.959e-11	2.934e-10
1.0	4.088e-01	1.048e-07	7.894e-07	1.932e-10	1.455e-09
1.5	2.485e-01	2.133e-07	1.031e-06	3.588e-10	1.735e-09
2.0	3.494e-01	6.515e-07	2.430e-06	1.007e-09	3.758e-09
Totals	**3.469e+00**	**1.023e-06**	**5.056e-06**	**1.664e-09**	**8.508e-09**

Results - Dose Point # 5 - (0,46.089,60.96) cm					
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	4.212e-01	9.858e-211	1.008e-33	8.456e-212	8.650e-35
0.05	5.234e-02	5.250e-19	1.770e-17	1.399e-21	4.715e-20
0.08	3.010e-01	9.929e-14	9.730e-12	1.571e-16	1.540e-14
0.1	1.772e-03	4.920e-15	5.983e-13	7.527e-18	9.154e-16

0.2	1.406e-01	1.915e-11	1.668e-09	3.380e-14	2.945e-12
0.3	2.694e-01	2.164e-10	1.116e-08	4.105e-13	2.117e-11
0.4	4.996e-01	1.330e-09	4.489e-08	2.592e-12	8.747e-11
0.5	2.332e-02	1.517e-10	3.648e-09	2.978e-13	7.160e-12
0.6	6.295e-01	8.301e-09	1.539e-07	1.620e-11	3.005e-10
0.8	1.234e-01	4.757e-09	5.849e-08	9.048e-12	1.113e-10
1.0	4.088e-01	3.492e-08	3.202e-07	6.436e-11	5.903e-10
1.5	2.485e-01	8.190e-08	4.650e-07	1.378e-10	7.824e-10
2.0	3.494e-01	2.728e-07	1.168e-06	4.218e-10	1.807e-09
Totals	**3.469e+00**	**4.043e-07**	**2.227e-06**	**6.525e-10**	**3.710e-09**

TI RSI NaI Scan for Ra-226 @ 1pCi/g, 27.94 cm soil, 2.54 cm thick x 1.5 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u$_{en}$/ρ)air

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
Energy$_\gamma$, keV	**(u$_{en}$/ρ)$_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For RSX-1: 10.16 cm X 10.16 cm X 40.64 cm

carbon fiber case 0.318 cm thick; Al wrap 0.051 cm

x = 10.16 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
Energy$_\gamma$, keV	**(μ/ρ)$_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	1.00
400	0.117	0.99
500	0.0955	0.97
600	0.0826	0.95
800	0.0676	0.92
1,000	0.0586	0.89
1,500	0.0469	0.83
2,000	0.0413	0.79

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
Energy$_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	1.00	0.1155
400	0.0845	0.99	0.0834
500	0.0673	0.97	0.0654
600	0.0563	0.95	0.0537
800	0.0433	0.92	0.0398
1,000	0.0357	0.89	0.0317
1,500	0.0261	0.83	0.0216
2,000	0.0214	0.79	0.0168

Estimated RSI-700 4-Liter NaI total gamma response @ 662keV 42,483 cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

Energy$_\gamma$, keV	(u$_{en}$/ρ)$_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
Energy$_\gamma$, keV	**(μ/ρ)$_{NaI}$, cm^2/g**		
662	0.0780	Probability =	0.95
		RDR =	0.0486

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
Energy$_\gamma$, keV	**RDR$_{Ei}$**	**RSI NaI cpm per μR/hr, E$_i$**
15	0.0517	45202
20	0.0969	84753
30	0.2268	198333
40	0.3906	341660
50	0.5208	455547
60	0.5708	499230
80	0.5297	463268
100	0.4329	378637
150	0.2656	232311
200	0.1866	163180
300	0.1155	101033
400	0.0834	72931
500	0.0654	57226
600	0.0537	46985
662	0.0486	42483
800	0.0398	34789
1,000	0.0317	27724
1,500	0.0216	18888
2,000	0.0168	14682

MDCR$_{surveyor}$ for Cs-137 energy

42483 cpm/μR/hr

Bkgd = 226018 cpm

Observation Interval, i = 2 second
b$_i$ = 7533.933333 counts
d' = 3.28 from Table 6.1 of NUREG-1507
MDCR = 8540.95 cpm
MDCR$_{surveyor}$ = 9003 cpm

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\ (60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.90

minimum detectable exposure rate, Cs-137 = 0.21 μR/hr

Table 5				
Energy$_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	2.477E-31	45202	0	0.0%
20	0.000E+00	84753	0	0.0%
30	0.000E+00	198333	0	0.0%
40	0.000E+00	341660	0	0.0%
50	1.507E-12	455547	0	0.0%
60	0.000E+00	499230	0	0.0%
80	7.515E-09	463268	90	0.3%
100	1.895E-10	378637	2	0.0%
150	0.000E+00	232311	0	0.0%
200	1.612E-07	163180	678	2.3%
300	7.216E-07	101033	1878	6.5%
400	2.235E-06	72931	4199	14.5%
500	1.500E-07	57226	221	0.8%
600	5.351E-06	46985	6477	22.4%
800	1.586E-06	34789	1421	4.9%
1000	7.124E-06	27724	5088	17.6%
1500	7.232E-06	18888	3519	12.2%
2000	1.425E-05	14682	5390	18.6%
Total	3.882E-05		28962	100.0%

	mR/hr, from MS
15	2.48E-34
20	
30	
40	
50	1.51E-15
60	
80	7.52E-12
100	1.90E-13
150	
200	1.61E-10
300	7.22E-10
400	2.24E-09
500	1.50E-10
600	5.35E-09
800	1.59E-09
1000	7.12E-09
1500	7.23E-09
2000	1.43E-08
	3.882E-08

Microshield Output

0.015	######	3.37E-131	2.89E-33	2.89E-132	2.48E-34
0.05	######	2.82E-14	5.66E-13	7.51E-17	1.51E-15
0.08	######	1.08E-10	4.75E-09	1.72E-13	7.52E-12
0.1	######	2.54E-12	1.24E-10	3.88E-15	1.90E-13
0.2	######	2.80E-09	9.13E-08	4.94E-12	1.61E-10
0.3	######	1.84E-08	3.80E-07	3.49E-11	7.22E-10
0.4	######	7.88E-08	1.15E-06	1.54E-10	2.24E-09
0.5	######	6.89E-09	7.64E-08	1.35E-11	1.50E-10
0.6	######	3.06E-07	2.74E-06	5.98E-10	5.35E-09
0.8	######	1.29E-07	8.34E-07	2.45E-10	1.59E-09
1	######	7.52E-07	3.87E-06	1.39E-09	7.12E-09
1.5	######	1.21E-06	4.30E-06	2.04E-09	7.23E-09
2	######	3.22E-06	9.21E-06	4.98E-09	1.43E-08

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
0.311 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate, MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **8007.83** pCi/g
2.96E+05 Bq/kg

Source Vol. 17.95 cm3
Density 1.6 g/cm3
Source mass 28.72 g

Total activity 229985 pCi
0.230 uCi

File	TI2BO 20150310

Assumptions

Detector is 4 in (10.16 cm) X 4 in X 16 in
15.24 cm detector height
2.54 cm height by 3 diameter cm radium source at 1.6 g/cm3 (soil hockey puck)
Soil cover of (15.24-2.54) = 12.70 cm + 15.24 cm = 27.94 cm (worst case for 12 inches of soil on RSY pad)

0.318 carbon casing @ 2.27 g/cm3
0.051 cm aluminum wrap @ 2.7 g/cm3

Average background count rate observed to be 3,767 cps (226,018 cpm) in 5.3 uR/hr field (ROI 10, Gross Counts)
42,483 cpm/uR/hr

Centerpoint of detector has no offset from center of source

MicroShield 8.02
CB&I Federal Services (8.02-0000)

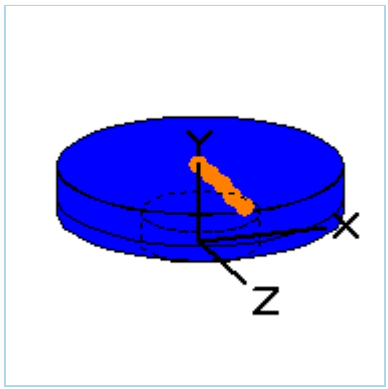
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI3BD 20150310.msd	March 10, 2015	3:14:55 PM	00:00:01

Project Info	
Case Title	TI3BD
Description	RSI Soil Distributed Source, 7.62 cm cover
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	0.0 cm (0 in)	38.229 cm (1 ft 3.1 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	38.229 cm (1 ft 3.1 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	38.229 cm (1 ft 3.1 in)	30.48 cm (1 ft)
#4	0.0 cm (0 in)	38.229 cm (1 ft 3.1 in)	45.72 cm (1 ft 6.0 in)
#5	0.0 cm (0 in)	38.229 cm (1 ft 3.1 in)	60.96 cm (2 ft)



Shields			
Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	FGR 12 Soil	1.6
Shield 1	7.62 cm	FGR 12 Soil	1.6
Shield 2	15.24 cm	Air	0.00122
Shield 3	.318 cm	Carbon	2.27
Shield 4	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	5.2037e-008	1.9254e+003	1.4085e-006	5.2115e-002
Bi-214	7.2607e-008	2.6865e+003	1.9653e-006	7.2715e-002
Pb-210	5.2050e-008	1.9258e+003	1.4088e-006	5.2127e-002
Pb-214	7.2607e-008	2.6865e+003	1.9653e-006	7.2715e-002
Po-210	5.1681e-008	1.9122e+003	1.3989e-006	5.1758e-002
Po-214	7.2592e-008	2.6859e+003	1.9648e-006	7.2699e-002
Po-218	7.2621e-008	2.6870e+003	1.9657e-006	7.2729e-002

Ra-226	7.2621e-008	2.6870e+003	1.9656e-006	7.2729e-002
Rn-222	7.2621e-008	2.6870e+003	1.9657e-006	7.2729e-002

Buildup: The material reference is Shield 1 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,38.229,0) cm

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	8.668e+02	2.889e-41	9.572e-30	2.478e-42	8.210e-31
0.05	1.077e+02	3.905e-07	3.266e-06	1.040e-09	8.701e-09
0.08	6.194e+02	3.734e-05	5.174e-04	5.908e-08	8.188e-07
0.1	3.647e+00	4.465e-07	6.377e-06	6.832e-10	9.756e-09
0.2	2.894e+02	1.672e-04	1.636e-03	2.950e-07	2.887e-06
0.3	5.544e+02	7.066e-04	4.975e-03	1.340e-06	9.436e-06
0.4	1.028e+03	2.273e-03	1.261e-02	4.429e-06	2.457e-05
0.5	4.799e+01	1.615e-04	7.476e-04	3.171e-07	1.467e-06
0.6	1.295e+03	6.117e-03	2.453e-02	1.194e-05	4.788e-05
0.8	2.539e+02	2.027e-03	6.586e-03	3.856e-06	1.253e-05
1.0	8.411e+02	1.001e-02	2.802e-02	1.845e-05	5.165e-05
1.5	5.115e+02	1.228e-02	2.713e-02	2.066e-05	4.564e-05
2.0	7.189e+02	2.765e-02	5.344e-02	4.275e-05	8.263e-05
Totals	**7.138e+03**	**6.143e-02**	**1.602e-01**	**1.041e-04**	**2.795e-04**

Results - Dose Point # 2 - (0,38.229,15.24) cm

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	8.668e+02	1.876e-41	8.522e-30	1.609e-42	7.309e-31
0.05	1.077e+02	3.364e-07	2.781e-06	8.962e-10	7.408e-09
0.08	6.194e+02	3.134e-05	4.317e-04	4.959e-08	6.831e-07
0.1	3.647e+00	3.739e-07	5.332e-06	5.721e-10	8.157e-09
0.2	2.894e+02	1.400e-04	1.383e-03	2.470e-07	2.441e-06
0.3	5.544e+02	5.929e-04	4.229e-03	1.125e-06	8.023e-06
0.4	1.028e+03	1.911e-03	1.076e-02	3.724e-06	2.096e-05
0.5	4.799e+01	1.361e-04	6.397e-04	2.672e-07	1.256e-06
0.6	1.295e+03	5.164e-03	2.104e-02	1.008e-05	4.106e-05
0.8	2.539e+02	1.717e-03	5.667e-03	3.266e-06	1.078e-05
1.0	8.411e+02	8.506e-03	2.417e-02	1.568e-05	4.455e-05
1.5	5.115e+02	1.049e-02	2.350e-02	1.765e-05	3.954e-05
2.0	7.189e+02	2.372e-02	4.643e-02	3.668e-05	7.179e-05
Totals	**7.138e+03**	**5.241e-02**	**1.383e-01**	**8.877e-05**	**2.411e-04**

Results - Dose Point # 3 - (0,38.229,30.48) cm					
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	8.668e+02	9.132e-43	6.276e-30	7.833e-44	5.383e-31
0.05	1.077e+02	1.462e-07	1.241e-06	3.896e-10	3.305e-09
0.08	6.194e+02	1.497e-05	2.200e-04	2.369e-08	3.482e-07
0.1	3.647e+00	1.834e-07	2.840e-06	2.806e-10	4.344e-09
0.2	2.894e+02	7.261e-05	7.997e-04	1.281e-07	1.411e-06
0.3	5.544e+02	3.168e-04	2.522e-03	6.009e-07	4.783e-06
0.4	1.028e+03	1.044e-03	6.538e-03	2.034e-06	1.274e-05
0.5	4.799e+01	7.566e-05	3.939e-04	1.485e-07	7.731e-07
0.6	1.295e+03	2.913e-03	1.309e-02	5.685e-06	2.555e-05
0.8	2.539e+02	9.916e-04	3.584e-03	1.886e-06	6.816e-06
1.0	8.411e+02	5.002e-03	1.546e-02	9.221e-06	2.850e-05
1.5	5.115e+02	6.375e-03	1.534e-02	1.073e-05	2.581e-05
2.0	7.189e+02	1.473e-02	3.071e-02	2.278e-05	4.749e-05
Totals	**7.138e+03**	**3.154e-02**	**8.866e-02**	**5.323e-05**	**1.542e-04**

Results - Dose Point # 4 - (0,38.229,45.72) cm					
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	8.668e+02	1.813e-46	4.098e-30	1.555e-47	3.515e-31
0.05	1.077e+02	3.840e-08	3.512e-07	1.023e-10	9.355e-10
0.08	6.194e+02	4.937e-06	8.142e-05	7.813e-09	1.288e-07
0.1	3.647e+00	6.355e-08	1.123e-06	9.722e-11	1.719e-09
0.2	2.894e+02	2.762e-05	3.563e-04	4.876e-08	6.288e-07
0.3	5.544e+02	1.263e-04	1.175e-03	2.395e-07	2.230e-06
0.4	1.028e+03	4.305e-04	3.135e-03	8.388e-07	6.109e-06
0.5	4.799e+01	3.205e-05	1.928e-04	6.290e-08	3.784e-07
0.6	1.295e+03	1.261e-03	6.515e-03	2.462e-06	1.272e-05
0.8	2.539e+02	4.449e-04	1.829e-03	8.463e-07	3.479e-06
1.0	8.411e+02	2.308e-03	8.038e-03	4.254e-06	1.482e-05
1.5	5.115e+02	3.091e-03	8.238e-03	5.201e-06	1.386e-05
2.0	7.189e+02	7.384e-03	1.685e-02	1.142e-05	2.606e-05
Totals	**7.138e+03**	**1.511e-02**	**4.641e-02**	**2.538e-05**	**8.041e-05**

Results - Dose Point # 5 - (0,38.229,60.96) cm					
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	8.668e+02	3.762e-54	2.678e-30	3.227e-55	2.297e-31
0.05	1.077e+02	6.931e-09	7.151e-08	1.846e-11	1.905e-10
0.08	6.194e+02	1.319e-06	2.584e-05	2.088e-09	4.089e-08
0.1	3.647e+00	1.840e-08	3.935e-07	2.815e-11	6.020e-10

0.2	2.894e+02	9.239e-06	1.463e-04	1.631e-08	2.582e-07
0.3	5.544e+02	4.515e-05	5.105e-04	8.565e-08	9.684e-07
0.4	1.028e+03	1.613e-04	1.410e-03	3.143e-07	2.747e-06
0.5	4.799e+01	1.245e-05	8.888e-05	2.443e-08	1.745e-07
0.6	1.295e+03	5.044e-04	3.065e-03	9.845e-07	5.982e-06
0.8	2.539e+02	1.862e-04	8.868e-04	3.541e-07	1.687e-06
1.0	8.411e+02	9.999e-04	3.987e-03	1.843e-06	7.348e-06
1.5	5.115e+02	1.424e-03	4.250e-03	2.396e-06	7.151e-06
2.0	7.189e+02	3.539e-03	8.922e-03	5.473e-06	1.380e-05
Totals	**7.138e+03**	**6.883e-03**	**2.329e-02**	**1.149e-05**	**4.015e-05**

TI RSI NaI Scan for Ra-226 @ 1pCi/g, 7.62 cm soil cover, 15 cm thick x 28 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u_{en}/ρ)air

File TI3BD 20150310

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
$Energy_\gamma$, keV	**$(u_{en}/\rho)_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Assumptions

Detector is 4 in (10.16 cm) X 4 in X 16 in
15.24 cm Detector Height
15 x 28 source at 1.6 g/cm3 (dry soil) - Buildup reference
7.62 cm of soil cover (9-inch RSY pad with source at bottom)

0.318 carbon casing @ 2.27 g/cm3
0.051 cm aluminum wrap @ 2.7 g/cm3

Average background count rate observed to be 3,767 cps (226,018 cpm) in 5.3 uR/hr field (ROI 10, Gross Counts)
42,483 cpm/uR/hr

Centerpoint of detector has no offset from center of source

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For RSX-1: 10.16 cm X 10.16 cm X 40.64 cm

carbon fiber case 0.318 cm thick; Al wrap 0.051 cm

x = 10.16 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
$Energy_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	1.00
400	0.117	0.99
500	0.0955	0.97
600	0.0826	0.95
800	0.0676	0.92
1,000	0.0586	0.89
1,500	0.0469	0.83
2,000	0.0413	0.79

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
$Energy_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	1.00	0.1155
400	0.0845	0.99	0.0834
500	0.0673	0.97	0.0654
600	0.0563	0.95	0.0537
800	0.0433	0.92	0.0398
1,000	0.0357	0.89	0.0317
1,500	0.0261	0.83	0.0216
2,000	0.0214	0.79	0.0168

Estimated RSI-700 4-Liter NaI total gamma response @ 662keV 42,483 cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

$Energy_\gamma$, keV	$(u_{en}/\rho)_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
$Energy_\gamma$, keV	$(\mu/\rho)_{NaI}$, cm^2/g		
662	0.0780	Probability =	0.95
		RDR =	0.0486

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
$Energy_\gamma$, keV	**RDR_{Ei}**	**RSI NaI cpm per μR/hr, E_i**
15	0.0517	45202
20	0.0969	84753
30	0.2268	198333
40	0.3906	341660
50	0.5208	455547
60	0.5708	499230
80	0.5297	463268
100	0.4329	378637
150	0.2656	232311
200	0.1866	163180
300	0.1155	101033
400	0.0834	72931
500	0.0654	57226
600	0.0537	46985
662	0.0486	42483
800	0.0398	34789
1,000	0.0317	27724
1,500	0.0216	18888
2,000	0.0168	14682

$MDCR_{surveyor}$ for Cs-137 energy

@5.3 uR/hr 42,483 cpm/μR/hr

Bkgd = 226018 cpm

Observation Interval, i =	2	second
b_i =	7533.933333	counts
d' =	3.28	from Table 6.1 of NUREG-1507
MDCR =	8540.95	cpm
$MDCR_{surveyor}$ =	9003	cpm

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\,(60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.9

minimum detectable exposure rate, Cs-137 = 0.21 μR/hr

Table 5				
$Energy_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	8.210E-28	45202	0	0.0%
20	0.000E+00	84753	0	0.0%
30	0.000E+00	198333	0	0.0%
40	0.000E+00	341660	0	0.0%
50	8.701E-06	455547	14	0.0%
60	0.000E+00	499230	0	0.0%
80	8.188E-04	463268	1357	3.8%
100	9.756E-06	378637	13	0.0%
150	0.000E+00	232311	0	0.0%
200	2.887E-03	163180	1685	4.8%
300	9.436E-03	101033	3411	9.6%
400	2.457E-02	72931	6411	18.1%
500	1.467E-03	57226	300	0.8%
600	4.788E-02	46985	8048	22.8%
800	1.253E-02	34789	1559	4.4%
1000	5.165E-02	27724	5123	14.5%
1500	4.564E-02	18888	3084	8.7%
2000	8.263E-02	14682	4340	12.3%
Total	2.795E-01		35346	100.0%

	mR/hr, from MS
15	8.21E-31
20	
30	
40	
50	8.70E-09
60	
80	8.19E-07
100	9.76E-09
150	
200	2.89E-06
300	9.44E-06
400	2.46E-05
500	1.47E-06
600	4.79E-05
800	1.25E-05
1000	5.17E-05
1500	4.56E-05
2000	8.26E-05
	2.795E-04

Microshield Output

0.015	#####	2.89E-41	9.57E-30	2.48E-42	8.21E-31
0.05	#####	3.91E-07	3.27E-06	1.04E-09	8.70E-09
0.08	#####	3.73E-05	5.17E-04	5.91E-08	8.19E-07
0.1	#####	4.47E-07	6.38E-06	6.83E-10	9.76E-09
0.2	#####	1.67E-04	1.64E-03	2.95E-07	2.89E-06
0.3	#####	7.07E-04	4.98E-03	1.34E-06	9.44E-06
0.4	#####	2.27E-03	1.26E-02	4.43E-06	2.46E-05
0.5	#####	1.62E-04	7.48E-04	3.17E-07	1.47E-06
0.6	#####	6.12E-03	2.45E-02	1.19E-05	4.79E-05
0.8	#####	2.03E-03	6.59E-03	3.86E-06	1.25E-05
1	#####	1.00E-02	2.80E-02	1.85E-05	5.17E-05
1.5	#####	1.23E-02	2.71E-02	2.07E-05	4.56E-05
2	#####	2.77E-02	5.34E-02	4.28E-05	8.26E-05

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
0.255 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate,\ MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **0.91** pCi/g
3.37E+01 Bq/kg

MicroShield 8.02
CB&I Federal Services (8.02-0000)

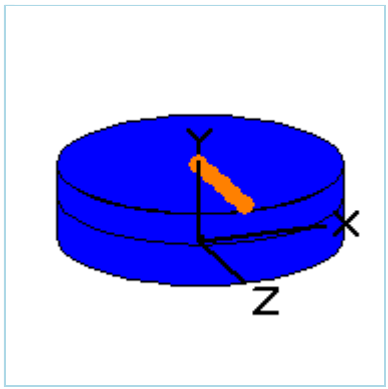
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI3BO 20150311.msd	March 11, 2015	9:59:07 AM	00:00:01

Project Info	
Case Title	TI3BO
Description	RSI Object, 20.32 cm soil cover (9-inch lift)
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	2.54 cm (1.0 in)
Radius	1.5 cm (0.6 in)

Dose Points			
A	X	Y	Z
#1	0.0 cm (0 in)	38.469 cm (1 ft 3.1 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	38.469 cm (1 ft 3.1 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	38.469 cm (1 ft 3.1 in)	30.48 cm (1 ft)
#4	0.0 cm (0 in)	38.469 cm (1 ft 3.1 in)	45.72 cm (1 ft 6.0 in)
#5	0.0 cm (0 in)	38.469 cm (1 ft 3.1 in)	60.96 cm (2 ft)



Shields			
Shield N	Dimension	Material	Density
Source	17.954 cm³	Concrete	1.6
Shield 1	20.32 cm	FGR 12 Soil	1.6
Shield 2	15.24 cm	Air	0.00122
Shield 3	.318 cm	Carbon	2.27
Shield 4	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	2.5289e-011	9.3568e-001	1.4085e-006	5.2115e-002
Bi-214	3.5285e-011	1.3055e+000	1.9653e-006	7.2715e-002
Pb-210	2.5295e-011	9.3590e-001	1.4088e-006	5.2127e-002
Pb-214	3.5285e-011	1.3055e+000	1.9653e-006	7.2715e-002
Po-210	2.5115e-011	9.2927e-001	1.3989e-006	5.1758e-002
Po-214	3.5277e-011	1.3053e+000	1.9648e-006	7.2699e-002
Po-218	3.5292e-011	1.3058e+000	1.9657e-006	7.2729e-002

Ra-226	3.5292e-011	1.3058e+000	1.9656e-006	7.2729e-002
Rn-222	3.5292e-011	1.3058e+000	1.9657e-006	7.2729e-002

Buildup: The material reference is Shield 1 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,38.469,0) cm

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	4.212e-01	7.345e-98	4.229e-33	6.300e-99	3.627e-34
0.05	5.234e-02	2.036e-12	3.072e-11	5.423e-15	8.185e-14
0.08	3.010e-01	1.641e-09	4.673e-08	2.597e-12	7.394e-11
0.1	1.772e-03	2.852e-11	8.590e-10	4.363e-14	1.314e-12
0.2	1.406e-01	1.908e-08	3.725e-07	3.367e-11	6.574e-10
0.3	2.694e-01	1.014e-07	1.299e-06	1.923e-10	2.464e-09
0.4	4.996e-01	3.772e-07	3.549e-06	7.349e-10	6.916e-09
0.5	2.332e-02	2.973e-08	2.202e-07	5.836e-11	4.323e-10
0.6	6.295e-01	1.218e-06	7.486e-06	2.378e-09	1.461e-08
0.8	1.234e-01	4.529e-07	2.109e-06	8.614e-10	4.011e-09
1.0	4.088e-01	2.425e-06	9.260e-06	4.469e-09	1.707e-08
1.5	2.485e-01	3.379e-06	9.440e-06	5.685e-09	1.588e-08
2.0	3.494e-01	8.196e-06	1.922e-05	1.267e-08	2.973e-08
Totals	**3.469e+00**	**1.620e-05**	**5.301e-05**	**2.709e-08**	**9.185e-08**

Results - Dose Point # 2 - (0,38.469,15.24) cm

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	4.212e-01	2.371e-104	3.573e-33	2.034e-105	3.065e-34
0.05	5.234e-02	7.762e-13	1.250e-11	2.068e-15	3.329e-14
0.08	3.010e-01	8.552e-10	2.683e-08	1.353e-12	4.245e-11
0.1	1.772e-03	1.578e-11	5.299e-10	2.414e-14	8.107e-13
0.2	1.406e-01	1.169e-08	2.563e-07	2.064e-11	4.523e-10
0.3	2.694e-01	6.493e-08	9.265e-07	1.232e-10	1.757e-09
0.4	4.996e-01	2.488e-07	2.583e-06	4.848e-10	5.034e-09
0.5	2.332e-02	2.004e-08	1.626e-07	3.934e-11	3.192e-10
0.6	6.295e-01	8.354e-07	5.590e-06	1.631e-09	1.091e-08
0.8	1.234e-01	3.185e-07	1.598e-06	6.059e-10	3.040e-09
1.0	4.088e-01	1.737e-06	7.091e-06	3.202e-09	1.307e-08
1.5	2.485e-01	2.496e-06	7.350e-06	4.200e-09	1.237e-08
2.0	3.494e-01	6.169e-06	1.513e-05	9.540e-09	2.339e-08
Totals	**3.469e+00**	**1.190e-05**	**4.071e-05**	**1.985e-08**	**7.039e-08**

Results - Dose Point # 3 - (0,38.469,30.48) cm					
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	4.212e-01	7.002e-122	2.497e-33	6.006e-123	2.141e-34
0.05	5.234e-02	5.885e-14	1.112e-12	1.568e-16	2.963e-15
0.08	3.010e-01	1.557e-10	6.249e-09	2.463e-13	9.888e-12
0.1	1.772e-03	3.401e-12	1.506e-10	5.203e-15	2.303e-13
0.2	1.406e-01	3.351e-09	9.881e-08	5.915e-12	1.744e-10
0.3	2.694e-01	2.104e-08	3.961e-07	3.991e-11	7.513e-10
0.4	4.996e-01	8.749e-08	1.168e-06	1.705e-10	2.276e-09
0.5	2.332e-02	7.484e-09	7.665e-08	1.469e-11	1.505e-10
0.6	6.295e-01	3.269e-07	2.718e-06	6.382e-10	5.306e-09
0.8	1.234e-01	1.338e-07	8.127e-07	2.544e-10	1.546e-09
1.0	4.088e-01	7.680e-07	3.721e-06	1.416e-09	6.858e-09
1.5	2.485e-01	1.201e-06	4.058e-06	2.021e-09	6.827e-09
2.0	3.494e-01	3.126e-06	8.602e-06	4.834e-09	1.330e-08
Totals	**3.469e+00**	**5.675e-06**	**2.166e-05**	**9.394e-09**	**3.720e-08**

Results - Dose Point # 4 - (0,38.469,45.72) cm					
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	4.212e-01	1.622e-146	1.662e-33	1.391e-147	1.426e-34
0.05	5.234e-02	1.830e-15	4.185e-14	4.876e-18	1.115e-16
0.08	3.010e-01	1.625e-11	8.768e-10	2.571e-14	1.387e-12
0.1	1.772e-03	4.482e-13	2.772e-11	6.858e-16	4.241e-14
0.2	1.406e-01	6.546e-10	2.765e-08	1.155e-12	4.880e-11
0.3	2.694e-01	4.865e-09	1.279e-07	9.229e-12	2.426e-10
0.4	4.996e-01	2.264e-08	4.114e-07	4.411e-11	8.016e-10
0.5	2.332e-02	2.104e-09	2.863e-08	4.129e-12	5.620e-11
0.6	6.295e-01	9.806e-08	1.061e-06	1.914e-10	2.071e-09
0.8	1.234e-01	4.420e-08	3.390e-07	8.408e-11	6.449e-10
1.0	4.088e-01	2.724e-07	1.629e-06	5.021e-10	3.002e-09
1.5	2.485e-01	4.788e-07	1.918e-06	8.056e-10	3.227e-09
2.0	3.494e-01	1.338e-06	4.250e-06	2.069e-09	6.573e-09
Totals	**3.469e+00**	**2.262e-06**	**9.794e-06**	**3.711e-09**	**1.667e-08**

Results - Dose Point # 5 - (0,38.469,60.96) cm					
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	4.212e-01	3.838e-175	1.132e-33	3.292e-176	9.710e-35
0.05	5.234e-02	3.691e-17	1.021e-15	9.831e-20	2.719e-18
0.08	3.010e-01	1.318e-12	9.559e-11	2.085e-15	1.513e-13
0.1	1.772e-03	4.752e-14	4.105e-12	7.271e-17	6.280e-15

0.2	1.406e-01	1.090e-10	6.588e-09	1.924e-13	1.163e-11
0.3	2.694e-01	9.839e-10	3.612e-08	1.866e-12	6.852e-11
0.4	4.996e-01	5.210e-09	1.288e-07	1.015e-11	2.509e-10
0.5	2.332e-02	5.324e-10	9.634e-09	1.045e-12	1.891e-11
0.6	6.295e-01	2.673e-08	3.780e-07	5.218e-11	7.379e-10
0.8	1.234e-01	1.347e-08	1.308e-07	2.562e-11	2.488e-10
1.0	4.088e-01	9.005e-08	6.659e-07	1.660e-10	1.227e-09
1.5	2.485e-01	1.810e-07	8.618e-07	3.045e-10	1.450e-09
2.0	3.494e-01	5.487e-07	2.021e-06	8.485e-10	3.125e-09
Totals	**3.469e+00**	**8.668e-07**	**4.238e-06**	**1.410e-09**	**7.139e-09**

TI RSI NaI Scan for Ra-226 @ 1pCi/g, 20.32 cm soil cover, 2.54 cm thick x 1.5 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u$_{en}$/ρ)air

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
Energy$_\gamma$, keV	**$(u_{en}/\rho)_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For RSX-1: 10.16 cm X 10.16 cm X 40.64 cm

carbon fiber case 0.318 cm thick; Al wrap 0.051 cm

x = 10.16 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
Energy$_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	1.00
400	0.117	0.99
500	0.0955	0.97
600	0.0826	0.95
800	0.0676	0.92
1,000	0.0586	0.89
1,500	0.0469	0.83
2,000	0.0413	0.79

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
Energy$_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	1.00	0.1155
400	0.0845	0.99	0.0834
500	0.0673	0.97	0.0654
600	0.0563	0.95	0.0537
800	0.0433	0.92	0.0398
1,000	0.0357	0.89	0.0317
1,500	0.0261	0.83	0.0216
2,000	0.0214	0.79	0.0168

Estimated RSI-700 4-Liter NaI total gamma response @ 662keV 42,483 cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

Energy$_\gamma$, keV	$(u_{en}/\rho)_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
Energy$_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**		
662	0.0780	Probability =	0.95
		RDR =	0.0486

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
Energy$_\gamma$, keV	**RDR$_{Ei}$**	**RSI NaI cpm per μR/hr, E$_i$**
15	0.0517	45202
20	0.0969	84753
30	0.2268	198333
40	0.3906	341660
50	0.5208	455547
60	0.5708	499230
80	0.5297	463268
100	0.4329	378637
150	0.2656	232311
200	0.1866	163180
300	0.1155	101033
400	0.0834	72931
500	0.0654	57226
600	0.0537	46985
662	0.0486	42483
800	0.0398	34789
1,000	0.0317	27724
1,500	0.0216	18888
2,000	0.0168	14682

MDCR$_{surveyor}$ for Cs-137 energy

42483 cpm/μR/hr

Bkgd = 226018 cpm

Observation Interval, i = 2 second
b$_i$ = 7533.933333 counts
d' = 3.28 from Table 6.1 of NUREG-1507
MDCR = 8540.95 cpm
MDCR$_{surveyor}$ = 9003 cpm

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\ (60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.90

minimum detectable exposure rate, Cs-137 = 0.21 μR/hr

Table 5				
Energy$_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	3.627E-31	45202	0	0.0%
20	0.000E+00	84753	0	0.0%
30	0.000E+00	198333	0	0.0%
40	0.000E+00	341660	0	0.0%
50	8.185E-11	455547	0	0.0%
60	0.000E+00	499230	0	0.0%
80	7.394E-08	463268	373	1.2%
100	1.314E-09	378637	5	0.0%
150	0.000E+00	232311	0	0.0%
200	6.574E-07	163180	1168	3.6%
300	2.464E-06	101033	2710	8.4%
400	6.916E-06	72931	5492	17.1%
500	4.323E-07	57226	269	0.8%
600	1.461E-05	46985	7474	23.2%
800	4.011E-06	34789	1519	4.7%
1000	1.707E-05	27724	5153	16.0%
1500	1.588E-05	18888	3266	10.1%
2000	2.973E-05	14682	4753	14.8%
Total	9.185E-05		32182	100.0%

	mR/hr, from MS
15	3.63E-34
20	
30	
40	
50	8.19E-14
60	
80	7.39E-11
100	1.31E-12
150	
200	6.57E-10
300	2.46E-09
400	6.92E-09
500	4.32E-10
600	1.46E-08
800	4.01E-09
1000	1.71E-08
1500	1.59E-08
2000	2.97E-08
	9.185E-08

Microshield Output

0.015	######	7.35E-98	4.23E-33	6.30E-99	3.63E-34
0.05	######	2.04E-12	3.07E-11	5.42E-15	8.19E-14
0.08	######	1.64E-09	4.67E-08	2.60E-12	7.39E-11
0.1	######	2.85E-11	8.59E-10	4.36E-14	1.31E-12
0.2	######	1.91E-08	3.73E-07	3.37E-11	6.57E-10
0.3	######	1.01E-07	1.30E-06	1.92E-10	2.46E-09
0.4	######	3.77E-07	3.55E-06	7.35E-10	6.92E-09
0.5	######	2.97E-08	2.20E-07	5.84E-11	4.32E-10
0.6	######	1.22E-06	7.49E-06	2.38E-09	1.46E-08
0.8	######	4.53E-07	2.11E-06	8.61E-10	4.01E-09
1	######	2.43E-06	9.26E-06	4.47E-09	1.71E-08
1.5	######	3.38E-06	9.44E-06	5.69E-09	1.59E-08
2	######	8.20E-06	1.92E-05	1.27E-08	2.97E-08

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
0.280 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate, MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **3045.83** pCi/g
1.13E+05 Bq/kg

Source Vol. 17.95 cm3
Density 1.6 g/cm3
Source mass 28.72 g

Total activity 87476 pCi
0.087 uCi

File TI3BO 20150311

Assumptions

Detector is 4 in (10.16 cm) X 4 in X 16 in
15.24 cm detector height
2.54 cm height by 3 diameter cm radium source at 1.6 g/cm3 (soil hockey puck)
Soil cover of (15.24-2.54) = 12.70 cm + 7.62 cm = 20.32 cm (worst case for 9 inches of soil on RSY pad)

0.318 carbon casing @ 2.27 g/cm3
0.051 cm aluminum wrap @ 2.7 g/cm3

Average background count rate observed to be 3,767 cps (226,018 cpm) in 5.3 uR/hr field (ROI 10, Gross Counts)
42,483 cpm/uR/hr

Centerpoint of detector has no offset from center of source

MicroShield 8.02
CB&I Federal Services (8.02-0000)

Date	By	Checked

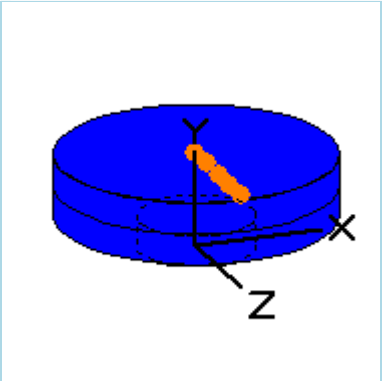
Filename	Run Date	Run Time	Duration
TI5BD 20150311.msd	March 11, 2015	10:06:31 AM	00:00:01

Project Info	
Case Title	TI5BD
Description	RSI Soil Distributed Source, 15.24 cm conc cover
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	0.0 cm (0 in)	45.849 cm (1 ft 6.1 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	45.849 cm (1 ft 6.1 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	45.849 cm (1 ft 6.1 in)	30.48 cm (1 ft)
#4	0.0 cm (0 in)	45.849 cm (1 ft 6.1 in)	45.72 cm (1 ft 6.0 in)
#5	0.0 cm (0 in)	45.849 cm (1 ft 6.1 in)	60.96 cm (2 ft)



Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	FGR 12 Soil	1.6
Shield 1	15.24 cm	Concrete	1.6
Shield 2	15.24 cm	Air	0.00122
Shield 3	.318 cm	Carbon	2.27
Shield 4	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	5.2037e-008	1.9254e+003	1.4085e-006	5.2115e-002
Bi-214	7.2607e-008	2.6865e+003	1.9653e-006	7.2715e-002
Pb-210	5.2050e-008	1.9258e+003	1.4088e-006	5.2127e-002
Pb-214	7.2607e-008	2.6865e+003	1.9653e-006	7.2715e-002
Po-210	5.1681e-008	1.9122e+003	1.3989e-006	5.1758e-002
Po-214	7.2592e-008	2.6859e+003	1.9648e-006	7.2699e-002
Po-218	7.2621e-008	2.6870e+003	1.9657e-006	7.2729e-002

Ra-226	7.2621e-008	2.6870e+003	1.9656e-006	7.2729e-002
Rn-222	7.2621e-008	2.6870e+003	1.9657e-006	7.2729e-002

Buildup: The material reference is Shield 1 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,45.849,0) cm

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	8.668e+02	5.277e-94	5.620e-30	4.526e-95	4.820e-31
0.05	1.077e+02	1.441e-09	6.756e-09	3.840e-12	1.800e-11
0.08	6.194e+02	1.825e-06	1.867e-05	2.889e-09	2.955e-08
0.1	3.647e+00	3.447e-08	4.399e-07	5.274e-11	6.730e-10
0.2	2.894e+02	2.445e-05	3.208e-04	4.315e-08	5.662e-07
0.3	5.544e+02	1.299e-04	1.323e-03	2.464e-07	2.510e-06
0.4	1.028e+03	4.826e-04	3.923e-03	9.404e-07	7.643e-06
0.5	4.799e+01	3.813e-05	2.561e-04	7.484e-08	5.027e-07
0.6	1.295e+03	1.567e-03	8.992e-03	3.059e-06	1.755e-05
0.8	2.539e+02	5.874e-04	2.648e-03	1.117e-06	5.037e-06
1.0	8.411e+02	3.171e-03	1.198e-02	5.846e-06	2.208e-05
1.5	5.115e+02	4.501e-03	1.271e-02	7.573e-06	2.139e-05
2.0	7.189e+02	1.107e-02	2.639e-02	1.712e-05	4.082e-05
Totals	**7.138e+03**	**2.157e-02**	**6.856e-02**	**3.602e-05**	**1.181e-04**

Results - Dose Point # 2 - (0,45.849,15.24) cm

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	8.668e+02	2.993e-94	5.156e-30	2.567e-95	4.422e-31
0.05	1.077e+02	1.253e-09	5.841e-09	3.338e-12	1.556e-11
0.08	6.194e+02	1.520e-06	1.549e-05	2.406e-09	2.451e-08
0.1	3.647e+00	2.863e-08	3.651e-07	4.380e-11	5.585e-10
0.2	2.894e+02	2.035e-05	2.698e-04	3.592e-08	4.761e-07
0.3	5.544e+02	1.086e-04	1.123e-03	2.060e-07	2.130e-06
0.4	1.028e+03	4.052e-04	3.349e-03	7.895e-07	6.525e-06
0.5	4.799e+01	3.213e-05	2.197e-04	6.306e-08	4.313e-07
0.6	1.295e+03	1.325e-03	7.745e-03	2.586e-06	1.512e-05
0.8	2.539e+02	4.994e-04	2.295e-03	9.499e-07	4.365e-06
1.0	8.411e+02	2.709e-03	1.042e-02	4.994e-06	1.921e-05
1.5	5.115e+02	3.881e-03	1.115e-02	6.530e-06	1.876e-05
2.0	7.189e+02	9.604e-03	2.327e-02	1.485e-05	3.598e-05
Totals	**7.138e+03**	**1.859e-02**	**5.986e-02**	**3.101e-05**	**1.030e-04**

Results - Dose Point # 3 - (0,45.849,30.48) cm					
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	8.668e+02	4.916e-96	4.045e-30	4.216e-97	3.470e-31
0.05	1.077e+02	5.261e-10	2.474e-09	1.401e-12	6.591e-12
0.08	6.194e+02	7.191e-07	7.564e-06	1.138e-09	1.197e-08
0.1	3.647e+00	1.402e-08	1.873e-07	2.145e-11	2.865e-10
0.2	2.894e+02	1.069e-05	1.530e-04	1.886e-08	2.701e-07
0.3	5.544e+02	5.904e-05	6.649e-04	1.120e-07	1.261e-06
0.4	1.028e+03	2.259e-04	2.035e-03	4.402e-07	3.965e-06
0.5	4.799e+01	1.828e-05	1.362e-04	3.588e-08	2.673e-07
0.6	1.295e+03	7.668e-04	4.873e-03	1.497e-06	9.512e-06
0.8	2.539e+02	2.969e-04	1.477e-03	5.648e-07	2.809e-06
1.0	8.411e+02	1.645e-03	6.821e-03	3.033e-06	1.257e-05
1.5	5.115e+02	2.448e-03	7.505e-03	4.118e-06	1.263e-05
2.0	7.189e+02	6.209e-03	1.595e-02	9.602e-06	2.467e-05
Totals	**7.138e+03**	**1.168e-02**	**3.963e-02**	**1.942e-05**	**6.797e-05**

Results - Dose Point # 4 - (0,45.849,45.72) cm					
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	8.668e+02	1.497e-102	2.875e-30	1.284e-103	2.466e-31
0.05	1.077e+02	1.060e-10	5.179e-10	2.824e-13	1.380e-12
0.08	6.194e+02	2.148e-07	2.427e-06	3.398e-10	3.841e-09
0.1	3.647e+00	4.537e-09	6.634e-08	6.942e-12	1.015e-10
0.2	2.894e+02	3.962e-06	6.448e-05	6.992e-09	1.138e-07
0.3	5.544e+02	2.327e-05	3.001e-04	4.413e-08	5.692e-07
0.4	1.028e+03	9.294e-05	9.575e-04	1.811e-07	1.866e-06
0.5	4.799e+01	7.779e-06	6.609e-05	1.527e-08	1.297e-07
0.6	1.295e+03	3.355e-04	2.423e-03	6.548e-07	4.730e-06
0.8	2.539e+02	1.357e-04	7.617e-04	2.582e-07	1.449e-06
1.0	8.411e+02	7.783e-04	3.613e-03	1.435e-06	6.660e-06
1.5	5.115e+02	1.230e-03	4.162e-03	2.070e-06	7.003e-06
2.0	7.189e+02	3.247e-03	9.111e-03	5.021e-06	1.409e-05
Totals	**7.138e+03**	**5.855e-03**	**2.146e-02**	**9.687e-06**	**3.661e-05**

Results - Dose Point # 5 - (0,45.849,60.96) cm					
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	8.668e+02	1.327e-116	2.002e-30	1.138e-117	1.717e-31
0.05	1.077e+02	1.093e-11	5.693e-11	2.911e-14	1.516e-13
0.08	6.194e+02	4.473e-08	5.665e-07	7.079e-11	8.964e-10
0.1	3.647e+00	1.081e-09	1.814e-08	1.653e-12	2.775e-11

0.2	2.894e+02	1.169e-06	2.270e-05	2.064e-09	4.007e-08
0.3	5.544e+02	7.518e-06	1.159e-04	1.426e-08	2.199e-07
0.4	1.028e+03	3.194e-05	3.910e-04	6.223e-08	7.618e-07
0.5	4.799e+01	2.802e-06	2.811e-05	5.501e-09	5.517e-08
0.6	1.295e+03	1.255e-04	1.064e-03	2.451e-07	2.076e-06
0.8	2.539e+02	5.392e-05	3.507e-04	1.026e-07	6.670e-07
1.0	8.411e+02	3.235e-04	1.723e-03	5.964e-07	3.176e-06
1.5	5.115e+02	5.536e-04	2.108e-03	9.315e-07	3.546e-06
2.0	7.189e+02	1.538e-03	4.792e-03	2.378e-06	7.410e-06
Totals	**7.138e+03**	**2.638e-03**	**1.059e-02**	**4.338e-06**	**1.795e-05**

TI RSI NaI Scan for Ra-226 @ 1pCi/g, 15.24 cm concrete cover, 15 cm thick x 28 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u_{en}/ρ)air

File TI5BD 20150311

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
$Energy_\gamma$, keV	**$(u_{en}/\rho)_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Assumptions

Detector is 4 in (10.16 cm) X 4 in X 16 in
15.24 cm Detector Height
15 x 28 source at 1.6 g/cm3 (dry soil) - Buildup reference
15.24 cm of concrete cover (6-inch concrete cover with 6-inch distributed source below)

0.318 carbon casing @ 2.27 g/cm3
0.051 cm aluminum wrap @ 2.7 g/cm3

Average background count rate observed to be 3,767 cps (226,018 cpm) in 5.3 uR/hr field (ROI 10, Gross Counts)
42,483 cpm/uR/hr

Centerpoint of detector has no offset from center of source

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For RSX-1: 10.16 cm X 10.16 cm X 40.64 cm

carbon fiber case 0.318 cm thick; Al wrap 0.051 cm

x = 10.16 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
$Energy_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	1.00
400	0.117	0.99
500	0.0955	0.97
600	0.0826	0.95
800	0.0676	0.92
1,000	0.0586	0.89
1,500	0.0469	0.83
2,000	0.0413	0.79

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
$Energy_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	1.00	0.1155
400	0.0845	0.99	0.0834
500	0.0673	0.97	0.0654
600	0.0563	0.95	0.0537
800	0.0433	0.92	0.0398
1,000	0.0357	0.89	0.0317
1,500	0.0261	0.83	0.0216
2,000	0.0214	0.79	0.0168

Estimated RSI-700 4-Liter NaI total gamma response @ 662keV 42,483 cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

$Energy_\gamma$, keV	$(u_{en}/\rho)_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
$Energy_\gamma$, keV	$(\mu/\rho)_{NaI}$, cm^2/g		
662	0.0780	Probability =	0.95
		RDR =	0.0486

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
$Energy_\gamma$, keV	**RDR_{Ei}**	**RSI NaI cpm per μR/hr, E_i**
15	0.0517	45202
20	0.0969	84753
30	0.2268	198333
40	0.3906	341660
50	0.5208	455547
60	0.5708	499230
80	0.5297	463268
100	0.4329	378637
150	0.2656	232311
200	0.1866	163180
300	0.1155	101033
400	0.0834	72931
500	0.0654	57226
600	0.0537	46985
662	0.0486	42483
800	0.0398	34789
1,000	0.0317	27724
1,500	0.0216	18888
2,000	0.0168	14682

$MDCR_{surveyor}$ for Cs-137 energy

42,483 cpm/μR/hr

Bkgd = 226018 cpm

Observation Interval, i = 2 second
b_i = 7533.933333 counts
d' = 3.28 from Table 6.1 of NUREG-1507
MDCR = 8540.95 cpm
$MDCR_{surveyor}$ = 9003 cpm

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\,(60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.90

minimum detectable exposure rate, Cs-137 = 0.21 μR/hr

Table 5				
$Energy_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	4.820E-28	45202	0	0.0%
20	0.000E+00	84753	0	0.0%
30	0.000E+00	198333	0	0.0%
40	0.000E+00	341660	0	0.0%
50	1.800E-08	455547	0	0.0%
60	0.000E+00	499230	0	0.0%
80	2.955E-05	463268	116	0.4%
100	6.730E-07	378637	2	0.0%
150	0.000E+00	232311	0	0.0%
200	5.662E-04	163180	782	2.6%
300	2.510E-03	101033	2147	7.1%
400	7.643E-03	72931	4719	15.7%
500	5.027E-04	57226	244	0.8%
600	1.755E-02	46985	6980	23.2%
800	5.037E-03	34789	1483	4.9%
1000	2.208E-02	27724	5182	17.2%
1500	2.139E-02	18888	3420	11.3%
2000	4.082E-02	14682	5074	16.8%
Total	1.181E-01		30149	100.0%

	mR/hr, from MS
15	4.82E-31
20	
30	
40	
50	1.80E-11
60	
80	2.96E-08
100	6.73E-10
150	
200	5.66E-07
300	2.51E-06
400	7.64E-06
500	5.03E-07
600	1.76E-05
800	5.04E-06
1000	2.21E-05
1500	2.14E-05
2000	4.08E-05
	1.181E-04

Microshield Output

0.015	8.67E+02	5.28E-94	5.62E-30	4.53E-95	4.82E-31
0.05	1.08E+02	1.44E-09	6.76E-09	3.84E-12	1.80E-11
0.08	6.19E+02	1.83E-06	1.87E-05	2.89E-09	2.96E-08
0.1	3.65E+00	3.45E-08	4.40E-07	5.27E-11	6.73E-10
0.2	2.89E+02	2.45E-05	3.21E-04	4.32E-08	5.66E-07
0.3	5.54E+02	1.30E-04	1.32E-03	2.46E-07	2.51E-06
0.4	1.03E+03	4.83E-04	3.92E-03	9.40E-07	7.64E-06
0.5	4.80E+01	3.81E-05	2.56E-04	7.48E-08	5.03E-07
0.6	1.30E+03	1.57E-03	8.99E-03	3.06E-06	1.76E-05
0.8	2.54E+02	5.87E-04	2.65E-03	1.12E-06	5.04E-06
1	8.41E+02	3.17E-03	1.20E-02	5.85E-06	2.21E-05
1.5	5.12E+02	4.50E-03	1.27E-02	7.57E-06	2.14E-05
2	7.19E+02	1.11E-02	2.64E-02	1.71E-05	4.08E-05

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
0.299 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate,\ MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **2.53** pCi/g
9.35E+01 Bq/kg

MicroShield 8.02
CB&I Federal Services (8.02-0000)

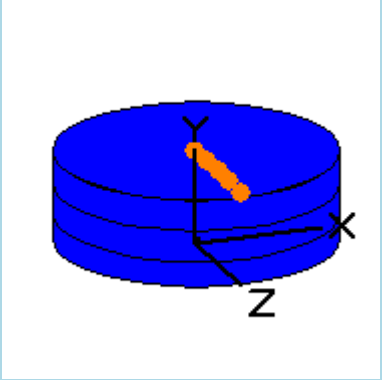
Date	By	Checked

Filename	Run Date	Run Time	Duration
TI5BO 20150311.msd	March 11, 2015	10:13:57 AM	00:00:01

Project Info	
Case Title	TI5BO
Description	RSI Object, 15.24 cm conc, 12.7 cm soil
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	2.54 cm (1.0 in)
Radius	1.5 cm (0.6 in)

Dose Points			
A	X	Y	Z
#1	0.0 cm (0 in)	46.089 cm (1 ft 6.1 in)	0.0 cm (0 in)
#2	0.0 cm (0 in)	46.089 cm (1 ft 6.1 in)	15.24 cm (6.0 in)
#3	0.0 cm (0 in)	46.089 cm (1 ft 6.1 in)	30.48 cm (1 ft)
#4	0.0 cm (0 in)	46.089 cm (1 ft 6.1 in)	45.72 cm (1 ft 6.0 in)
#5	0.0 cm (0 in)	46.089 cm (1 ft 6.1 in)	60.96 cm (2 ft)



Shields			
Shield N	Dimension	Material	Density
Source	17.954 cm³	Concrete	1.6
Shield 1	12.7 cm	FGR 12 Soil	1.6
Shield 2	15.24 cm	Concrete	1.6
Shield 3	15.24 cm	Air	0.00122
Shield 4	.318 cm	Carbon	2.27
Shield 5	.051 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		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	Ci	Bq	µCi/cm³	Bq/cm³
Bi-210	2.5289e-011	9.3568e-001	1.4085e-006	5.2115e-002
Bi-214	3.5285e-011	1.3055e+000	1.9653e-006	7.2715e-002
Pb-210	2.5295e-011	9.3590e-001	1.4088e-006	5.2127e-002
Pb-214	3.5285e-011	1.3055e+000	1.9653e-006	7.2715e-002
Po-210	2.5115e-011	9.2927e-001	1.3989e-006	5.1758e-002
Po-214	3.5277e-011	1.3053e+000	1.9648e-006	7.2699e-002

Po-218	3.5292e-011	1.3058e+000	1.9657e-006	7.2729e-002
Ra-226	3.5292e-011	1.3058e+000	1.9656e-006	7.2729e-002
Rn-222	3.5292e-011	1.3058e+000	1.9657e-006	7.2729e-002

Buildup: The material reference is Shield 2 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results - Dose Point # 1 - (0,46.089,0) cm					
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	4.212e-01	2.273e-150	2.444e-33	1.950e-151	2.097e-34
0.05	5.234e-02	9.389e-15	5.439e-14	2.501e-17	1.449e-16
0.08	3.010e-01	8.822e-11	1.279e-09	1.396e-13	2.024e-12
0.1	1.772e-03	2.357e-12	4.516e-11	3.606e-15	6.908e-14
0.2	1.406e-01	2.889e-09	5.962e-08	5.100e-12	1.052e-10
0.3	2.694e-01	1.911e-08	2.971e-07	3.624e-11	5.636e-10
0.4	4.996e-01	8.164e-08	9.688e-07	1.591e-10	1.888e-09
0.5	2.332e-02	7.124e-09	6.760e-08	1.398e-11	1.327e-10
0.6	6.295e-01	3.159e-07	2.490e-06	6.167e-10	4.860e-09
0.8	1.234e-01	1.322e-07	7.831e-07	2.514e-10	1.489e-09
1.0	4.088e-01	7.714e-07	3.698e-06	1.422e-09	6.817e-09
1.5	2.485e-01	1.238e-06	4.199e-06	2.083e-09	7.065e-09
2.0	3.494e-01	3.271e-06	9.086e-06	5.058e-09	1.405e-08
Totals	**3.469e+00**	**5.840e-06**	**2.165e-05**	**9.646e-09**	**3.697e-08**

Results - Dose Point # 2 - (0,46.089,15.24) cm					
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	4.212e-01	1.585e-157	2.181e-33	1.360e-158	1.871e-34
0.05	5.234e-02	3.673e-15	2.186e-14	9.783e-18	5.824e-17
0.08	3.010e-01	4.900e-11	7.483e-10	7.755e-14	1.184e-12
0.1	1.772e-03	1.398e-12	2.851e-11	2.138e-15	4.361e-14
0.2	1.406e-01	1.901e-09	4.238e-08	3.355e-12	7.480e-11
0.3	2.694e-01	1.312e-08	2.202e-07	2.488e-11	4.177e-10
0.4	4.996e-01	5.763e-08	7.348e-07	1.123e-10	1.432e-09
0.5	2.332e-02	5.134e-09	5.214e-08	1.008e-11	1.023e-10
0.6	6.295e-01	2.314e-07	1.943e-06	4.516e-10	3.793e-09
0.8	1.234e-01	9.917e-08	6.217e-07	1.886e-10	1.182e-09
1.0	4.088e-01	5.889e-07	2.972e-06	1.086e-09	5.478e-09
1.5	2.485e-01	9.731e-07	3.442e-06	1.637e-09	5.791e-09
2.0	3.494e-01	2.616e-06	7.532e-06	4.045e-09	1.165e-08
Totals	**3.469e+00**	**4.586e-06**	**1.756e-05**	**7.559e-09**	**2.992e-08**

Results - Dose Point # 3 - (0,46.089,30.48) cm					
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	4.212e-01	1.417e-177	1.664e-33	1.215e-178	1.427e-34
0.05	5.234e-02	2.653e-16	1.696e-15	7.068e-19	4.517e-18
0.08	3.010e-01	9.637e-12	1.688e-10	1.525e-14	2.671e-13
0.1	1.772e-03	3.314e-13	7.990e-12	5.070e-16	1.222e-14
0.2	1.406e-01	6.067e-10	1.667e-08	1.071e-12	2.942e-11
0.3	2.694e-01	4.727e-09	9.732e-08	8.967e-12	1.846e-10
0.4	4.996e-01	2.250e-08	3.479e-07	4.384e-11	6.778e-10
0.5	2.332e-02	2.126e-09	2.590e-08	4.172e-12	5.083e-11
0.6	6.295e-01	1.003e-07	1.000e-06	1.958e-10	1.952e-09
0.8	1.234e-01	4.605e-08	3.363e-07	8.759e-11	6.398e-10
1.0	4.088e-01	2.875e-07	1.666e-06	5.300e-10	3.072e-09
1.5	2.485e-01	5.160e-07	2.047e-06	8.682e-10	3.443e-09
2.0	3.494e-01	1.459e-06	4.631e-06	2.256e-09	7.162e-09
Totals	**3.469e+00**	**2.439e-06**	**1.017e-05**	**3.995e-09**	**1.721e-08**

Results - Dose Point # 4 - (0,46.089,45.72) cm					
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	4.212e-01	6.318e-207	1.192e-33	5.419e-208	1.023e-34
0.05	5.234e-02	6.414e-18	4.479e-17	1.709e-20	1.193e-19
0.08	3.010e-01	9.847e-13	2.051e-11	1.558e-15	3.245e-14
0.1	1.772e-03	4.431e-14	1.325e-12	6.779e-17	2.028e-15
0.2	1.406e-01	1.244e-10	4.493e-09	2.196e-13	7.930e-12
0.3	2.694e-01	1.154e-09	3.101e-08	2.190e-12	5.883e-11
0.4	4.996e-01	6.163e-09	1.226e-07	1.201e-11	2.388e-10
0.5	2.332e-02	6.335e-10	9.751e-09	1.244e-12	1.914e-11
0.6	6.295e-01	3.193e-08	3.968e-07	6.233e-11	7.746e-10
0.8	1.234e-01	1.618e-08	1.443e-07	3.078e-11	2.745e-10
1.0	4.088e-01	1.086e-07	7.546e-07	2.002e-10	1.391e-09
1.5	2.485e-01	2.195e-07	1.011e-06	3.692e-10	1.700e-09
2.0	3.494e-01	6.667e-07	2.407e-06	1.031e-09	3.723e-09
Totals	**3.469e+00**	**1.051e-06**	**4.881e-06**	**1.709e-09**	**8.188e-09**

Results - Dose Point # 5 - (0,46.089,60.96) cm					
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	4.212e-01	4.030e-242	8.538e-34	3.457e-243	7.323e-35
0.05	5.234e-02	8.284e-20	6.336e-19	2.207e-22	1.688e-21
0.08	3.010e-01	7.021e-14	1.747e-12	1.111e-16	2.764e-15
0.1	1.772e-03	4.345e-15	1.627e-13	6.647e-18	2.490e-16

0.2	1.406e-01	2.024e-11	9.765e-10	3.573e-14	1.723e-12
0.3	2.694e-01	2.310e-10	8.237e-09	4.382e-13	1.563e-11
0.4	4.996e-01	1.413e-09	3.670e-08	2.753e-12	7.151e-11
0.5	2.332e-02	1.605e-10	3.175e-09	3.151e-13	6.232e-12
0.6	6.295e-01	8.748e-09	1.371e-07	1.708e-11	2.677e-10
0.8	1.234e-01	4.984e-09	5.473e-08	9.480e-12	1.041e-10
1.0	4.088e-01	3.642e-08	3.066e-07	6.713e-11	5.651e-10
1.5	2.485e-01	8.471e-08	4.569e-07	1.425e-10	7.687e-10
2.0	3.494e-01	2.803e-07	1.161e-06	4.334e-10	1.795e-09
Totals	**3.469e+00**	**4.170e-07**	**2.165e-06**	**6.732e-10**	**3.596e-09**

TI RSI NaI Scan for Ra-226 @ 1pCi/g, 15.24 cm of concrete cover, 12.7 cm soil, 2.54 cm thick x 1.5 cm Radius, 0" offset
Fluence rate to exposure rate (FRER, no units) = ~ (1 uR/h)/(Eγ)(u_{en}/ρ)air

File TI5BO 20150311

$$Fluence\ Rate \approx \frac{\left(1\frac{\mu R}{hr}\right)}{E_\gamma\left(\frac{\mu_{en}}{\rho}\right)_{air}}$$

Mass energy-absorption coefficients from 1970 Rad Health Handbook

TABLE 1		
$Energy_\gamma$, keV	**$(u_{en}/\rho)_{air}$, cm^2/g**	**FRER**
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Assumptions

Detector is 4 in (10.16 cm) X 4 in X 16 in
15.24 cm detector height
2.54 cm height by 3 diameter cm radium source at 1.6 g/cm3 (soil hockey puck)
Cover of 15.24 cm concrete (6 inches), 12.7 cm soil

0.318 carbon casing @ 2.27 g/cm3
0.051 cm aluminum wrap @ 2.7 g/cm3

Average background count rate observed to be 3,767 cps (226,018 cpm) in 5.3 uR/hr field (ROI 10, Gross Counts)
42,483 cpm/uR/hr

Centerpoint of detector has no offset from center of source

Probability of interaction (P) through end of detector for given energy is

$$Probability\ of\ Interaction\ (P) = 1 - e^{-\left(\left(\frac{\mu}{\rho}\right)_{NaI}(x)(\rho_{NaI})\right)}$$

For RSX-1: 10.16 cm X 10.16 cm X 40.64 cm

carbon fiber case 0.318 cm thick; Al wrap 0.051 cm

x = 10.16 cm
ρ_{NaI} = 3.67 g/cm3

Mass attenuation coefficients from 1970 Rad Health Handbook

TABLE 2		
$Energy_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**	**P**
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	1.00
400	0.117	0.99
500	0.0955	0.97
600	0.0826	0.95
800	0.0676	0.92
1,000	0.0586	0.89
1,500	0.0469	0.83
2,000	0.0413	0.79

Relative Detector Response (RDR) = relative fluence-to-exposure rate (FRER) times probability (P) of interaction

$$Relative\ Detector\ Response = Fluence\ Rate \times Probability\ of\ Interaction$$

TABLE 3			
$Energy_\gamma$, keV	**Fluence Rate**	**P**	**RDR**
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	1.00	0.1155
400	0.0845	0.99	0.0834
500	0.0673	0.97	0.0654
600	0.0563	0.95	0.0537
800	0.0433	0.92	0.0398
1,000	0.0357	0.89	0.0317
1,500	0.0261	0.83	0.0216
2,000	0.0214	0.79	0.0168

Estimated RSI-700 4-Liter NaI total gamma response @ 662keV 42,483 cpm/μR/hr

Use same methodology and interpolating for Cs-137 response have:

$Energy_\gamma$, keV	$(u_{en}/\rho)_{air}$, cm^2/g		
662	0.0294	FRER ~	0.0514
$Energy_\gamma$, keV	**$(\mu/\rho)_{NaI}$, cm^2/g**		
662	0.0780	Probability =	0.95
		RDR =	0.0486

For this detector the response to another energy is based on the ratio of the relative detector response, RDR, to the Cs-137 energy

$$\frac{cpm}{\mu R/_{hr}}, E_i = (cpm_{Cs-137}) \times \frac{Relative\ Detector\ Response_{E_i}}{Relative\ Detector\ Response_{Cs-137}}$$

TABLE 4		
$Energy_\gamma$, keV	**RDR_{Ei}**	**RSI NaI cpm per μR/hr, E_i**
15	0.0517	45202
20	0.0969	84753
30	0.2268	198333
40	0.3906	341660
50	0.5208	455547
60	0.5708	499230
80	0.5297	463268
100	0.4329	378637
150	0.2656	232311
200	0.1866	163180
300	0.1155	101033
400	0.0834	72931
500	0.0654	57226
600	0.0537	46985
662	0.0486	42483
800	0.0398	34789
1,000	0.0317	27724
1,500	0.0216	18888
2,000	0.0168	14682

$MDCR_{surveyor}$ for Cs-137 energy

42483 cpm/μR/hr

Bkgd = 226018 cpm

Observation Interval, i = 2 second
b_i = 7533.933333 counts
d' = 3.28 from Table 6.1 of NUREG-1507
MDCR = 8540.95 cpm
$MDCR_{surveyor}$ = 9003 cpm

$$S_i = d'\sqrt{b_i}$$

$$MDCR = S_i\ (60\ /\ i)$$

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}}$$

P=0.90

minimum detectable exposure rate, Cs-137 = 0.21 μR/hr

Table 5				
$Energy_\gamma$, keV	**MicroShield Exposure Rate, μR/hr (with buildup)**	**cpm/μR/hr**	**cpm/μR/hr (weighted)**	**Percent of NaI detector response**
15	2.097E-31	45202	0	0.0%
20	0.000E+00	84753	0	0.0%
30	0.000E+00	198333	0	0.0%
40	0.000E+00	341660	0	0.0%
50	1.449E-13	455547	0	0.0%
60	0.000E+00	499230	0	0.0%
80	2.024E-09	463268	25	0.1%
100	6.908E-11	378637	1	0.0%
150	0.000E+00	232311	0	0.0%
200	1.052E-07	163180	464	1.7%
300	5.636E-07	101033	1540	5.5%
400	1.888E-06	72931	3724	13.4%
500	1.327E-07	57226	205	0.7%
600	4.860E-06	46985	6176	22.2%
800	1.489E-06	34789	1401	5.0%
1000	6.817E-06	27724	5112	18.4%
1500	7.065E-06	18888	3609	13.0%
2000	1.405E-05	14682	5579	20.0%
Total	3.697E-05		27838	100.0%

	mR/hr, from MS
15	2.10E-34
20	
30	
40	
50	1.45E-16
60	
80	2.02E-12
100	6.91E-14
150	
200	1.05E-10
300	5.64E-10
400	1.89E-09
500	1.33E-10
600	4.86E-09
800	1.49E-09
1000	6.82E-09
1500	7.07E-09
2000	1.41E-08
	3.697E-08

Microshield Output

0.015	4.21E-01	2.27E-150	2.44E-33	1.95E-151	2.10E-34
0.05	5.23E-02	9.39E-15	5.44E-14	2.50E-17	1.45E-16
0.08	3.01E-01	8.82E-11	1.28E-09	1.40E-13	2.02E-12
0.1	1.77E-03	2.36E-12	4.52E-11	3.61E-15	6.91E-14
0.2	1.41E-01	2.89E-09	5.96E-08	5.10E-12	1.05E-10
0.3	2.69E-01	1.91E-08	2.97E-07	3.62E-11	5.64E-10
0.4	5.00E-01	8.16E-08	9.69E-07	1.59E-10	1.89E-09
0.5	2.33E-02	7.12E-09	6.76E-08	1.40E-11	1.33E-10
0.6	6.30E-01	3.16E-07	2.49E-06	6.17E-10	4.86E-09
0.8	1.23E-01	1.32E-07	7.83E-07	2.51E-10	1.49E-09
1	4.09E-01	7.71E-07	3.70E-06	1.42E-09	6.82E-09
1.5	2.49E-01	1.24E-06	4.20E-06	2.08E-09	7.07E-09
2	3.49E-01	3.27E-06	9.09E-06	5.06E-09	1.41E-08

Minimum Detectable Exposure Rate =

MDCR surveyor/(cpm/μr/hr)
0.323 μr/hr

$$Exposure\ Rate, MDCR_{surveyor} = \frac{MDCR_{surveyor}}{weighted\left(cpm/\frac{\mu R}{hr}\right)}$$

and MDC for Ra-226 based on a normalized 1 pCi/g in soil with density of 1.6

$$Scan\ MDC\left(\frac{pCi}{g}\right) = Modeled\ Conc. \times \frac{Exposure\ Rate, MDCR_{surveyor}}{Exposure\ Rate,\ Modeled\ Conc.}$$

Scan MDC = **8747.23** pCi/g
3.24E+05 Bq/kg

Source Vol. 17.95 cm3
Density 1.6 g/cm3
Source mass 28.72 g

Total activity 251220 pCi
0.251 uCi