OAK RIDGE INSTITUTE
FOR SCIENCE AND EDUCATION
Shaping the Future of Science

January 17, 2020

Mr. John Hickman
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Division of Decommissioning, Uranium Recovery, and Waste Programs
Materials Decommissioning Branch
TWFN Mail Stop: T-8F5
Rockville, MD 20852

**SUBJECT:** **DOE Contract No. DE-SC0014664**
**INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR REMAINING LAND AREAS AND SELECT BUILDINGS AT THE HUMBOLDT BAY POWER PLANT, EUREKA, CALIFORNIA**
**DOCKET NO.05000133; RFTA NO. 18-005;**
**DCN 5272-SR-04-0**

Dear Mr. Hickman:

The Oak Ridge Institute for Science and Education (ORISE) is pleased to provide the enclosed report, which describes the procedures and results of the independent confirmatory survey for remaining land areas and select buildings at the Humboldt Bay Power Plant in Eureka, California that ORISE performed during the period of August 26-29, 2019. NRC's comments on the draft report have been addressed in this final version.

You may contact me at 865.576.6659 or Kaitlin Engel at 865.574.7008 if you have any questions or require additional information.

Sincerely,

Erika N. Bailey
Survey and Technical Projects Group Manager
ORISE

KME:tb

electronic distribution: K. Conway, NRC; R. Evans, NRC; K. Engel, ORISE; D. Hagemeyer, ORISE; File/5272

OAK RIDGE INSTITUTE
FOR SCIENCE AND EDUCATION

*Shaping the Future of Science*

# INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR REMAINING LAND AREAS AND SELECT BUILDINGS AT THE HUMBOLDT BAY POWER PLANT EUREKA, CALIFORNIA

**K. M. Engel**
**ORISE**

**FINAL REPORT**

**Prepared for the**
**U.S. Nuclear Regulatory Commission**

**January 2020**

**INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR REMAINING LAND AREAS AND SELECT BUILDINGS AT THE HUMBOLDT BAY POWER PLANT EUREKA, CALIFORNIA**

**FINAL REPORT**


**Prepared by**

**K. M. Engel**
**ORISE**


**January 2020**

**Prepared for the**
**U.S. Nuclear Regulatory Commission**


This document was prepared for U.S. Nuclear Regulatory Commission by the Oak Ridge Institute for Science and Education (ORISE) through interagency agreement number 31310018N0014 with the U.S. Department of Energy (DOE). ORISE is managed by Oak Ridge Associated Universities under DOE contract number DE-SC0014664.

OAK RIDGE INSTITUTE
FOR SCIENCE AND EDUCATION

**INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR REMAINING LAND AREAS AND SELECT BUILDINGS FOR THE HUMBOLDT BAY POWER PLANT EUREKA, CALIFORNIA**

Prepared by: ______________________ Date: 1/17/2020
K. M. Engel, Health Physicist
ORISE

Reviewed by: ______________________ Date: 1/17/2020
P. H. Benton, Quality Manager
ORISE

Reviewed by: ______________________ Date: 1/17/2020
N. A. Altic, CHP, Health Physicist
ORISE

Reviewed by: ______________________ Date: 1/17/2020
W. F. Smith, Senior Chemist
ORISE

Reviewed and approved for release by: ______________________ Date: 1/17/2020
E. N. Bailey, Survey and Technical Projects Group Manager
ORISE

**FINAL REPORT**

**January 2020**

# CONTENTS

## FIGURES



## TABLES

# ACRONYMS

| | |
|---|---|
| AA | alternative action |
| AEC | Atomic Energy Commission |
| cm | centimeter |
| cpm | counts per minute |
| $DCGL_W$ | derived concentration guideline levels |
| dpm/100 $cm^2$ | disintegrations per minute per 100 square centimeters |
| DQO | data quality objective |
| FSS | final status survey |
| GPS | global positioning system |
| HBPP | Humboldt Bay Power Plant |
| HTD | hard-to-detect |
| MDC | minimum detectable concentration |
| mg/$cm^2$ | milligram per square centimeter |
| mrem/yr | millirem per year |
| NaI[Tl] | thallium-doped sodium iodide |
| NORM | naturally occurring radioactive material |
| NRC | U.S. Nuclear Regulatory Commission |
| ORISE | Oak Ridge Institute for Science and Education |
| pCi/g | picocurie per gram |
| PG&E | Pacific Gas & Electric |
| PSQ | principal study question |
| Q-Q | quantile-quantile |
| ROC | radionuclide of concern |
| SAFSTOR | safe storage |
| SOF | sum-of-fractions |
| SU | survey unit |
| VSP | Visual Sample Plan |
| WMF | waste management facility |

# INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR REMAINING LAND AREAS AND SELECT BUILDINGS AT THE HUMBOLDT BAY POWER PLANT EUREKA, CALIFORNIA

## EXECUTIVE SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) requested that the Oak Ridge Institute for Science and Education (ORISE) perform an independent confirmatory survey of the remaining land areas and select buildings at the Humboldt Bay Power Plant in Eureka, California. ORISE performed independent assessment activities during the period of August 26-29, 2019. Confirmatory survey activities included gamma surface scans, gamma direct measurements, alpha-plus-beta scans, alpha-only and beta-only direct measurements, smear sampling, and soil sampling within the land areas and select buildings, as applicable.

No elevated direct gamma radiation levels distinguishable from background were identified in any of the land areas surveyed. In total, 20 surface soil samples were collected for analysis: eight random and two judgmental samples from areas believed to be mostly native soil and ten of the licensee's archived final status survey (FSS) surface soil samples from areas where the site's staff had confirmed backfill material had been applied. The radionuclide concentrations in the soil samples were compared to the NRC-approved derived concentration guidelines ($DCGL_W$s) established for the site. All radionuclide concentrations were below the $DCGL_W$s and all sum-of-fractions were less than 1. Additionally, all radionuclide concentrations were less than 50% of the respective gamma-emitting $DCGL_W$s, thus confirming the licensee's FSS classification.

Limited confirmatory survey activities were conducted in three buildings during this survey: the security building (Building 7), the Waste Management Facility (WMF), and the soil lab (Building 13). Gamma and alpha-plus-beta scans were performed in interior portions of all three buildings. Additionally, the roof of the security building and the asphalt/concrete pad north and east of the WMF were scanned for gamma radiation. Elevated gamma radiation was identified within the soil lab, where the site's radiological sources were stored. Judgmental direct measurements and smear samples were collected behind the "push walls" in the WMF. Total activities measured in the WMF did not exceed the $DCGL_W$s and the removable activity was less than ten percent of the total activity. Therefore, confirmatory direct measurements support the licensee's Class 2 FSS SU designation.

The confirmatory results indicate that the residual radioactivity concentrations in the remaining land areas and structural surfaces were below the applicable release criteria, and the confirmatory results support the licensee's classification of the FSS SUs. The confirmatory survey results indicate that the areas surveyed meet the NRC-approved criteria for release for unrestricted use. Such conclusions cannot be drawn about the soil lab at this time as radioactive materials (i.e., sources) were still present during the confirmatory survey.

# INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR REMAINING LAND AREAS AND SELECT BUILDINGS AT THE HUMBOLDT BAY POWER PLANT EUREKA, CALIFORNIA

## 1. INTRODUCTION

The Pacific Gas & Electric Company (PG&E) operated the Humboldt Bay Power Plant (HBPP) Unit 3 nuclear reactor near Eureka, California under the Atomic Energy Commission (AEC) provisional license number DPR-7. HBPP Unit 3 achieved initial criticality in February 1963 and began commercial operations in August 1963. Unit 3 was a natural circulation boiling water reactor with a direct-cycle design. Stainless steel fuel claddings were used from reactor startup until cladding failures resulted in plant system contamination – zircaloy-clad fuel was used exclusively starting in 1965, eliminating cladding-related contamination. A number of spill and gaseous releases were reported during operations, resulting in a range of mitigation activities (ESI 2008).

In July 1973, Unit 3 was shut down for annual refueling and seismic modification. However, by December 1980, it was concluded that completing the required upgrades and restarting Unit 3 would be cost prohibitive. PG&E decided in June of 1983 to decommission Unit 3, received a possession-only license amendment, and placed the unit into cold shutdown and safe storage (SAFSTOR). The impacted areas associated with Unit 3 have gone through decommissioning. As part of the Humboldt Bay Repowering Project, PG&E has built ten new fossil fuel units, 16.3 megawatt electric each, on the site in the vicinity of Unit 3. Decommissioning activities have also been completed on the adjacent fossil fuel Units 1 and 2, with all structures removed to ground level (Bartlett 2011).

The U.S. Nuclear Regulatory Commission (NRC) requested that the Oak Ridge Institute for Science and Education (ORISE) perform confirmatory survey activities of the HBPP. The focus of this survey effort—as determined by NRC staff—was on the remaining land areas and three buildings: the security building (Building 7), soil lab (Building 13), and the Waste Management Facility (WMF).

## 2. SITE DESCRIPTION

The HBPP site, owned by PG&E consists of 58 hectares on the southern edge of Humboldt Bay, 6 kilometers southwest of the town of Eureka in Humboldt County, California. Figure 2.1 provides a recent aerial view of the HBPP.

**Figure 2.1. HBPP Aerial View**

Most buildings have been demolished and many roadways and parking lots have been removed. The survey units (SUs) were backfilled anywhere from 1 to 100% with onsite recycled soil from all three final status survey (FSS) classifications of material (MARSSIM class 1, 2, or 3). After backfilling with onsite soils was complete, the SUs were then covered with off-site material or engineered materials to various depths (ORAU 2019c). Figure 2.2 indicates the SUs that received some amount of backfill materials—either from onsite or offsite borrow—and Figure 2.3 shows the final status survey (FSS) classification of the SUs.

The three buildings selected for confirmatory surveys were the WMF, security building (Building 7), and soil lab (Building 13). The WMF was undergoing FSS during the onsite confirmatory survey activities while the security building and soil lab had not yet received FSS.

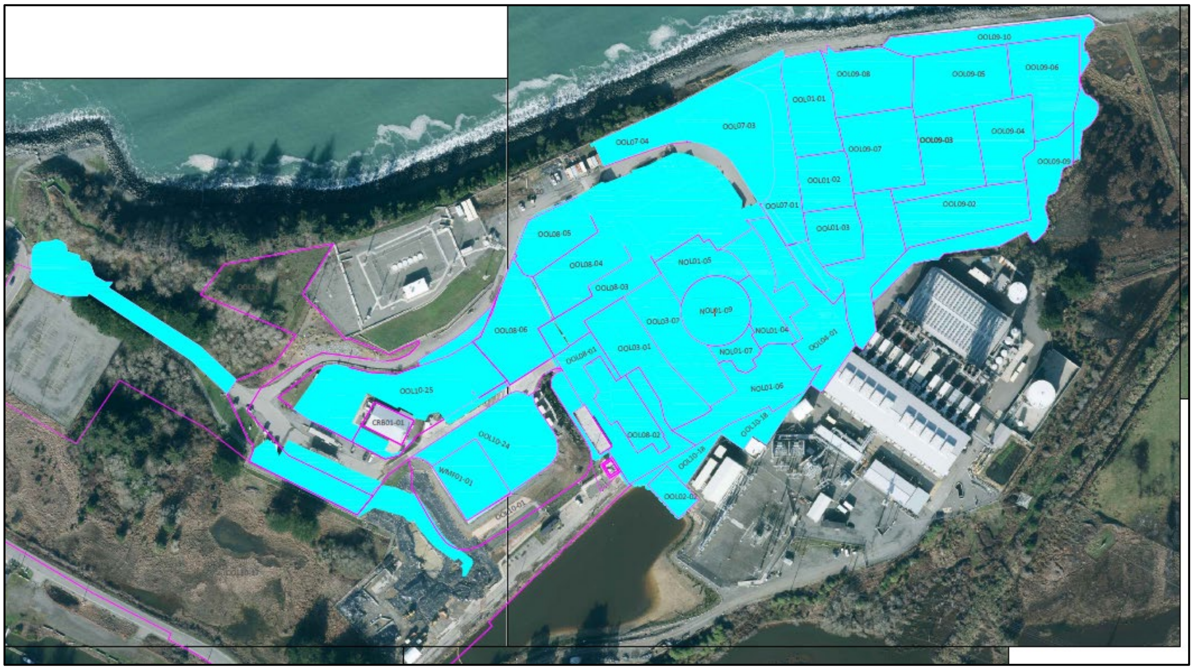

**Figure 2.2. Backfilled Survey Units**

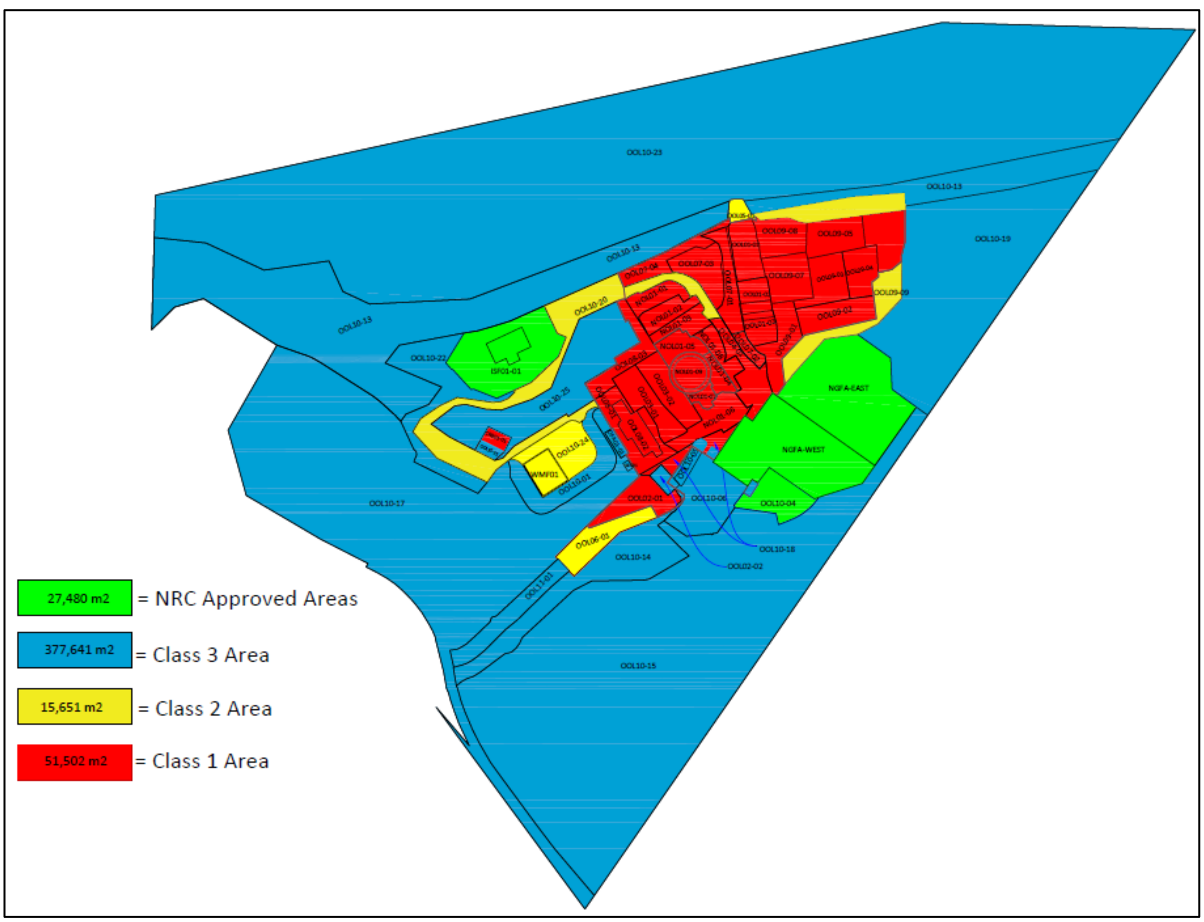


**Figure 2.3. Survey Units FSS Classification**

# 3. DATA QUALITY OBJECTIVES

The data quality objectives (DQOs) described herein are consistent with the *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA 2006) and provide a formalized method for planning radiation surveys, improving survey efficiency and effectiveness, and ensuring that the type, quality, and quantity of data collected are adequate for the intended decision applications. The seven steps in the DQO process are as follows:

1. State the problem
2. Identify the decision
3. Identify inputs to the decision
4. Define the study boundaries
5. Develop a decision rule
6. Specify limits on decision errors
7. Optimize the design for obtaining data

## 3.1 STATE THE PROBLEM

The first step in the DQO process defined the problem that necessitated the study, identified the planning team, and examined the project budget and schedule. The planning team, project budget, and schedule are presented in the project-specific plan and are not repeated here (ORISE 2016). NRC staff requested that ORISE perform confirmatory survey activities at the HBPP. The objective of the confirmatory activities was to generate independent radiological data to assist NRC staff in evaluating the licensee's FSS results. The problem statement was as follows:

> Confirmatory surveys are necessary to generate independent radiological data to assist the NRC staff with their assessment and determination of the adequacy of the FSS design, implementation, and results for demonstrating compliance with the release criteria.

## 3.2 IDENTIFY THE DECISION

The second step in the DQO process identified the principal study questions (PSQs) and alternative actions (AAs), developed decision statements (DSs), and organized multiple decisions, as

appropriate. This was done by specifying AAs that could result from a "yes" response to the PSQs and combining the PSQs and AAs into DSs. Table 3.1 presents the PSQs, AAs, and DSs.

**Table 3.1. HBPP Confirmatory Survey Decision Process**

| Principal Study Questions | Alternative Actions |
|---|---|
| **PSQ1:** Are residual radioactivity concentrations in the remaining land areas or structural surfaces below applicable release criteria? | **Yes:**<br>Compile confirmatory data and report results to NRC staff for their decision making. Provide independent interpretation that confirmatory field surveys did not identify anomalous areas of residual radioactivity and that quantative field and laboratory data satisfied the NRC-approved decommissioning criteria.<br><br>**No:**<br>Compile confirmatory data and report results to NRC staff for their decision making. Provide independent interpretation of confirmatory survey results identifying any anomalous field or laboratory data for NRC staff's determination of the adequacy and accuracy of the FSS data. |
| **PSQ2:** Do the confirmatory results support the MARSSIM classification of the FSS SUs? | **Yes:**<br>Confirmatory results support the classification of the FSS SUs. Compile confirmatory survey data and present results to NRC staff for their decision making.<br><br>**No:**<br>Confirmatory results do not support the classification of the FSS SUs. Summarize the discrepancies and provide technical comments to NRC staff for their decision making. |
| **Decision Statements** | |
| Determine if anomalous confirmatory survey results (i.e., volumetric concentrations and/or surface activity levels) exceed the NRC-approved decommissioning criteria.<br><br>Determine if confirmatory survey results support the FSS SU classification as outlined in MARSSIM guidance classification. | |

### 3.3 IDENTIFY INPUTS TO THE DECISION

The third step in the DQO process identified both the information needed and the sources of this information, determined the basis for action levels, and identified sampling and analytical methods to meet data requirements. For this effort, information inputs included the following:

- HBPP characterization data
- HBPP Geographic Information System and Visual Sample Plan (VSP) files, for SU boundaries
- HBPP's FSS data and supporting documentation (Note that, at the time of the confirmatory survey, the FSS was still in progress for the WMF and FSS had not started for the security building or soil lab)
- ORISE gamma walkover surveys
- ORISE volumetric sample analytical results for soil
- ORISE static direct measurements and removable activity results
- Radionuclides of concern (ROCs) and their associated limits (discussed in Section 3.3.1)

#### 3.3.1 Radionuclides of Concern and Release Criteria

The primary ROCs identified for the HBPP are beta-gamma emitters—fission and activation products resulting from reactor operation. The HBPP derived concentration guideline levels ($DCGL_W$s) for soils and structural surfaces are presented in Table 3.2 and Table 3.3, respectively (PG&E 2014).

| Table 3.2. HBPP Soil $DCGL_W$s | | | | | |
|---|---|---|---|---|---|
| ROC | $DCGL_W$ (pCi/g)[a] | ROC | $DCGL_W$ (pCi/g) | ROC | $DCGL_W$ (pCi/g) |
| Am-241 | 25 | Cs-137 | 7.9 | Np-237 | 1.1 |
| C-14 | 6.3 | Eu-152 | 10 | Pu-238 | 29 |
| Cm-243 | 29 | Eu-154 | 9.4 | Pu-239 | 26 |
| Cm-244 | 48 | H-3 | 680 | Pu-240 | 26 |
| Cm-245 | 17 | Nb-94 | 7.1 | Pu-241 | 860 |
| Cm-246 | 25 | Ni-59 | 1,900 | Sr-90 | 1.5 |
| Co-60 | 3.8 | Ni-63 | 720 | Tc-99 | 12 |

[a] pCi/g = picocurie per gram

| Table 3.3. HBPP Surface Activity $DCGL_W$s | | | | | |
|---|---|---|---|---|---|
| ROC | $DCGL_W$ (dpm/100 $cm^2$)[a] | ROC | $DCGL_W$ (dpm/100 $cm^2$) | ROC | $DCGL_W$ (dpm/100 $cm^2$) |
| Am-241 | 3.00E+03 | Cs-137 | 4.60E+04 | Np-237 | 2.40E+03 |
| C-14 | 7.00E+06 | Eu-152 | 2.70E+04 | Pu-238 | 3.40E+03 |
| Cm-243 | 4.30E+03 | Eu-154 | 2.50E+04 | Pu-239 | 3.10E+03 |
| Cm-244 | 5.50E+03 | H-3 | 1.80E+08 | Pu-240 | 3.10E+03 |
| Cm-245 | 2.20E+03 | Nb-94 | 1.90E+04 | Pu-241 | 1.40E+05 |
| Cm-246 | 2.70E+03 | Ni-59 | 6.30E+07 | Sr-90 | 9.70E+04 |
| Co-60 | 1.30E+04 | Ni-63 | 2.40E+07 | Tc-99 | 9.60E+06 |

[a] dpm/100 $cm^2$ = disintegrations per minute per 100 square centimeters

Each radionuclide-specific $DCGL_W$ value in Tables 3.2 and 3.3 represents the surficial concentration of individual radionuclides that would be deemed in compliance with the 25 millirem per year (mrem/yr) unrestricted release dose limit to the average member of the critical group. Therefore, for sites with multiple radionuclides present, radionuclide-specific results (i.e., volumetric samples) must be evaluated using the sum-of-fractions (SOF) approach to assess the total dose and demonstrate compliance with the dose limit. SOF calculations are performed as follows:

$$SOF_{TOTAL} = \sum_{j=0}^{n} SOF_j = \sum_{j=0}^{n} \frac{C_j}{DCGL_{W,j}}$$

Where $C_j$ is the concentration of the ROC "j" and $DCGL_{W,j}$ is the $DCGL_W$ for ROC "j." Note that gross concentrations are considered for conservatism. A SU, where the average ROC concentration does not exceed 1 (unity), ensures compliance with the 25 mrem/yr unrestricted release dose limit. Elevated measurement comparisons were not necessary, and thus, not considered as part of this study.

### 3.4 DEFINE THE STUDY BOUNDARIES

The fourth step in the DQO process defined target populations and spatial boundaries, determined the timeframe for collecting data and making decisions, addressed practical constraints, and determined the smallest subpopulations, area, volume, and time for which separate decisions must be made.

The areas of focus for this survey were the safely accessible Class 1, 2, and 3 land areas depicted in Figure 2.3 as well as three buildings: WMF, security building (Building 7), and soil lab (Building 13). Temporal boundaries to complete this survey were limited to four 10-hour days on-site during the week of August 26-29, 2019.

### 3.5 DEVELOP A DECISION RULE

The fifth step in the DQO process specified appropriate parameters (e.g., mean, median), confirmed action levels were above detection limits, and developed an "if…then…" decision rule statement. Decision rules for this survey focused on independent surface scanning surveys and sample results to identify locations that could exceed the applicable $DCGL_W$s and/or analytical minimum detectable concentrations (MDCs).

The confirmatory survey design for the land areas focused on generating an unbiased estimate of the site mean ROC concentration for direct comparison against the $DCGL_W$s and scanning to identify potential hot spots. For this survey effort, the parameter of interest was the mean SOF for the land area along with the ROC concentrations of individual samples. Individual sample results were compared directly to the $DCGL_W$s. The decision rules can be stated as:

> If the mean SOF, as determined by ORISE, and individual sample results are less than the $DCGL_W$s then recommend acceptance. If results are above the $DCGL_W$s, then perform further evaluations and provide technical comments/recommendations.

SU classifications were also assessed as part of the confirmatory process based on the requirements outlined in the LTP. Confirmatory investigations were focused on Class 2 and 3 SUs, as well as non-impacted areas, because a Class 1 SU will not receive higher classification. FSS investigation levels that trigger additional evaluations were established and are presented in Section 5.3.6.2 of the LTP. These investigation levels are reproduced in Table 3.4. During the confirmatory surveys, ORISE focused on identifying locations that could potentially exceed the soil sample investigation levels. These locations were used to confirm whether the SU should have been reclassified as part of the FSS process. The decision rule related to SU classification was stated as follows:

If soil concentrations or surface activity results indicate that a Class 2 or Class 3 area should be reclassified to a higher classification, then summarize confirmatory data for NRC staff's evaluation and decision making.

**Table 3.4. HBPP Investigation Levels [a]**

| SU Classification | Scan Investigation Levels | Direct Investigation Levels |
|---|---|---|
| Class 1 | > $DCGL_{EMC}$ [b] | > $DCGL_{EMC}$ or > $DCGL_W$ and > a statistical parameter-based value |
| Class 2 | > $DCGL_W$ or > $MDC_{Scan}$ if $MDC_{Scan}$ is greater than $DCGL_W$ [c] | > $DCGL_W$ |
| Class 3 | Detectable over background | > 0.5 * $DCGL_W$ |

[a] Recreated from PG&E 2014
[b] $DCGL_{EMC}$ = derived concentration guideline level elevated measurement comparison
[c] $MDC_{Scan}$ = scan minimum detectable concentration

### 3.6 SPECIFY LIMITS ON DECISION ERRORS

The sixth step in the DQO process established bounds of decision errors. Decision errors were controlled by optimizing the confirmatory field measurement and laboratory analytical MDCs.

One order of control was the allowable uncertainty in the estimated mean. The soil sample size was sufficient to estimate the mean SOF within 0.2 of the true mean at the 95% confidence level. The assumed standard deviation was 0.4, which is conservative, to reduce the probability of underestimating the site ROC variability. Any anomalies identified while performing surveys or following data assessment were fully investigated and discussed with NRC staff.

A second order of control was to optimize the MDCs of analyses performed by ORISE, both for field and laboratory measurements. Nominal scan and analytical MDCs for select ROCs are presented in Appendix D.

### 3.7 OPTIMIZE THE DESIGN FOR OBTAINING DATA

The seventh step in the DQO process was used to review the DQO outputs; develop data collection design alternatives, formulate mathematical expressions for each design, select the sample size to satisfy DQOs, decide on the most resource-effective design of agreed alternatives, and document

requisite details. Survey design and laboratory analyses were optimized by implementing the procedures presented in Sections 4 and 5, respectively.

# 4. PROCEDURES

The confirmatory survey activities, conducted during the period of August 26-29, 2019, were in accordance with the project-specific confirmatory survey plan, the *ORAU Radiological and Environmental Survey Procedure Manual,* and the *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORISE 2016, ORAU 2016a, 2019a). Appendices C and D provide additional information regarding survey instrumentation and related processes discussed within this section.

## 4.1 Reference System

ORISE referenced confirmatory measurement/sampling locations to global positioning system (GPS) coordinates, specifically NAD 1983 (CORS96) State Plane California Zone 1. Other prominent site features also were referenced. Measurement and sampling locations were documented on detailed survey maps.

## 4.2 Surface Scans

Surface scans of land areas were performed with Ludlum model 44-10 5.48-centimeter (cm) by 5.48-cm thallium-doped sodium iodide (NaI[Tl]) scintillation detectors coupled to Ludlum Model 2221 ratemeter-scalers with audible indicators. Detectors were also coupled to GPS data logging systems that enabled real-time gamma count rate and spatial data capture. Low- to medium-density surface scans were performed within select SUs, as time and access permitted. Total scan coverage was dependent on accessibility as many areas were impassable due to thick grass or standing water. Many areas of the site had been backfilled and covered with offsite top soil as mentioned previously in Section 2.

Surface scans of structures were performed with NaI(Tl)s and either Ludlum model 43-68 gas-flow proportional hand-held detectors or Ludlum model 43-37 gas-flow proportional floor monitors with 0.8 milligram per square centimeter ($mg/cm^2$) thick Mylar windows operated in alpha-plus-beta mode. Both detector types were coupled to Ludlum model 2221 ratemeter-scalers with audible indicators. Detectors were also coupled to data loggers to electronically record all scanning data

points. Scans with the floor monitor were qualitative (scan MDCs not calculated), but ORISE experience is that floor monitors are efficient at identifying low levels of surface contamination that can be quantitatively investigated using other hand-held instruments.

As noted in Section 6.3 of the NRC-approved 2016 Confirmatory Survey Plan (ORISE 2016), direct measurements for total beta and alpha activity would, at a minimum, be collected from judgmentally selected locations based on surface scans. The total number of direct measurements was dependent on findings as the survey progressed. No areas were marked for further investigation based on scanning results.

## 4.3 Surface Activity Measurements

Total surface activity measurements were performed with Ludlum model 43-68 gas-flow proportional hand-held detectors coupled to Ludlum model 2221 ratemeter-scalers with audible output. The Mylar thickness was 0.8 $mg/cm^2$ for alpha-only measurements, and 3.8 $mg/cm^2$ thickness for beta-only measurements.

Although scans of the floors and walls in the WMF behind the north and south push walls did not indicate elevated radiation levels of concern, nine direct measurements for total alpha and beta activity were collected from judgmentally selected areas based on the concern for accumulation potential behind the walls. No direct measurements were collected in the main area of the WMF, security building, or the soil lab based on scanning results.

Smear samples, to determine removable alpha and beta activity levels, were collected from all direct measurement locations. Smears for hard-to-detects (HTDs), H-3, C-14, and Ni-63, were judgmentally collected at two locations within the WMF, co-located with the alpha and beta smear sample.

## 4.4 Soil Sampling

Eighteen random soil samples and two judgmental soil samples were collected from the land area SUs. Visual Sample Plan (VSP) version 7.10 was used to determine the number of samples required to estimate the mean ROC concentration within the study area. For this effort, based on the allowable uncertainty in the mean, presented in Section 3.6, 18 random samples were required.

A total of 20 confirmatory soil samples were collected—18 from randomly selected locations and 2 from judgmentally selected locations. Of the eighteen random samples, eight were from areas that had not been backfilled on the eastern and western sides of the property. The other ten random samples were from the site's archived samples that were collected from native soil before backfill, as requested by the NRC. The site's sample that was closest to the ORISE randomly generated location was selected for analysis. Two judgmental samples were selected from non-backfilled areas, per the request of NRC staff.

Surface soil samples were collected from a depth of 0–15 cm using hand trowels. Gamma measurements were performed prior to and after sample collection to assess the potential for subsurface contamination. No subsurface samples were collected. Sampling equipment was rinsed and wiped after each sample to minimize the potential for cross-contamination.

## 5. SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data collected on site were transferred to the ORISE facility for analysis and interpretation. Sample custody was transferred to the Radiological and Environmental Analytical Laboratory in Oak Ridge, Tennessee. Sample analyses were performed in accordance with the *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2019b).

A wet aliquot of each soil sample was first set aside for further analyses of HTDs, if needed. The remaining portions of the soil samples were dried and homogenized before being analyzed via gamma spectrometry for gamma-emitting fission and activation products. The spectra also were reviewed for other identifiable photopeaks. Based on the results of the gamma spectroscopy and as directed by NRC staff, further analyses were not performed. Analytical results are reported in units of picocuries per gram (pCi/g).

Smear samples were analyzed for alpha and beta activity using a low-background proportional counter. Smears for HTDs, H-3 and C-14, were analyzed via liquid scintillation counting. Smear samples and direct measurement results are reported in units of disintegrations per minute per one hundred square centimeters (dpm/100 $cm^2$).

Direct measurements are gross and background contributions were not subtracted, which is consistent with the site's reporting and is conservative. Gamma radiation scan and static measurements are presented as gross counts per minute (cpm).

Scan data sets were graphed in a quantile-quantile (Q-Q) plot for assessment. The Q-Q plot is a graphical tool for assessing the distribution of a data set. For the scan data, the Y-axis represents gross gamma surface activity in units of cpm. The X-axis represents the data quantiles about the median value. Values less than the median are represented in the negative quantiles, and values greater than the median are represented in the positive quantiles. A normal distribution that is not skewed by outliers will appear as a straight line, with the slope of the line subject to the degree of variability among the data population. More than one distribution, such as background plus contamination or other outliers, will appear as a step function. Q-Q plots for the data are presented in Section 6.

## 6. FINDINGS AND RESULTS

The results of the confirmatory survey are discussed in the following subsections.

Appendix A provides the figures generated from the survey data, Appendix B provides data tables, and Appendices C and D provide additional details regarding field and laboratory instrumentation as well as additional information on calibration, quality assurance, survey and analytical procedures, and detection sensitivities.

### 6.1 Surface Scans

Table 6.1 provides a summary of the scanning survey data collected at HBPP during the August 2019 survey activities.

**Table 6.1. Summary of Scan Results**

| Area | Scan Ranges (cpm) | | |
|---|---|---|---|
| | Gamma Lower Walls and Floors | Alpha-plus-Beta Lower Walls | Alpha-plus-Beta Floors |
| Land Areas | 3,200 to 8,800 | --[a] | -- |
| WMF | 2,900 to 6,500 | 6 to 590 | 320 to 1,200 |
| WMF Pad | 3,300 to 6,000 | -- | 700 to 1,800 |
| Security Building | 5,700 to 7,700 | 76 to 620 | 480 to 1,200 |
| Security Building Roof | 2,400 to 6,700 | -- | -- |
| Soil Lab | 3,100 to 13,000 | 44 to 530 | 340 to 1,100 |

[a] data not collected

A gamma walkover map of all of the land areas surveyed, the security building roof, and the WMF pad are provided in Appendix A. No elevated areas were identified in the land areas, security building roof, or WMF pad surveys. Q-Q plots for the scan data from inside the three buildings are shown in Figures 6.1 through 6.3. For most of the scan data, the Q-Q plots show a straight line indicating a normal distribution which is expected for background conditions. Gamma scans in the soil lab, however, do not indicate background conditions as there is a sharp increase in the right tail. This was due to the presence of sealed sources stored within the soil lab during the time of the survey.

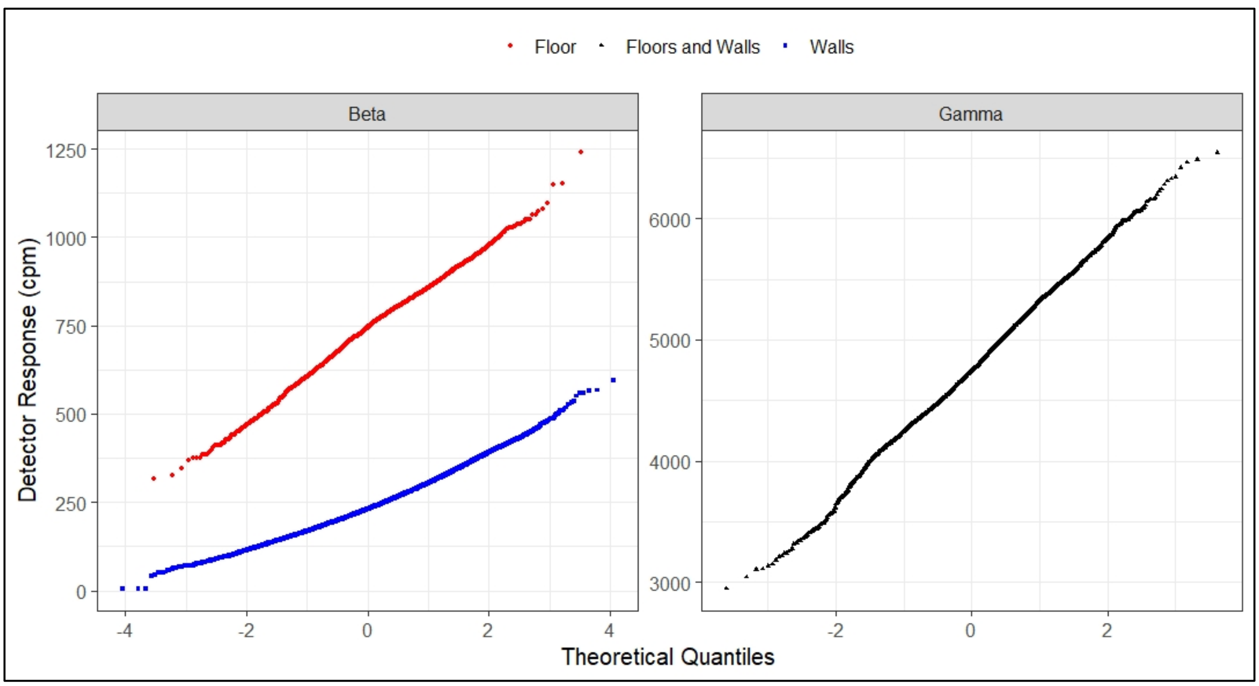


**Figure 6.1. Q-Q Plots of WMF Scan Data**

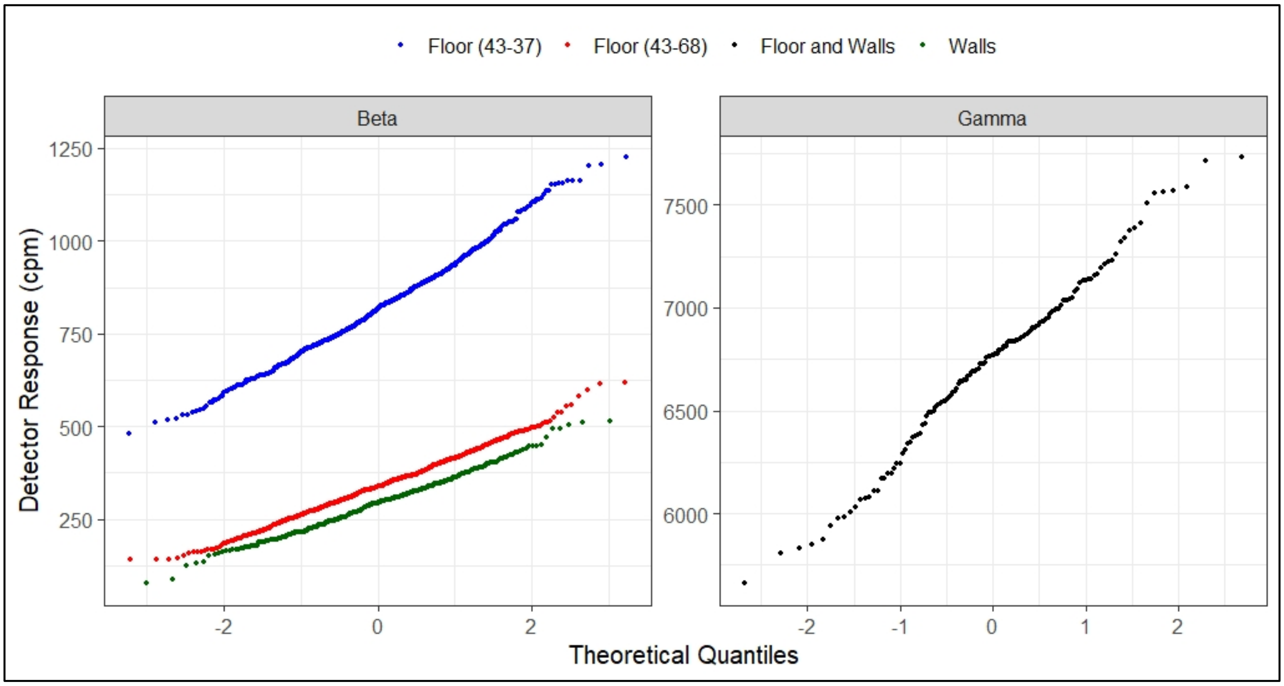


**Figure 6.2. Q-Q Plots of Security Building Scan Data**

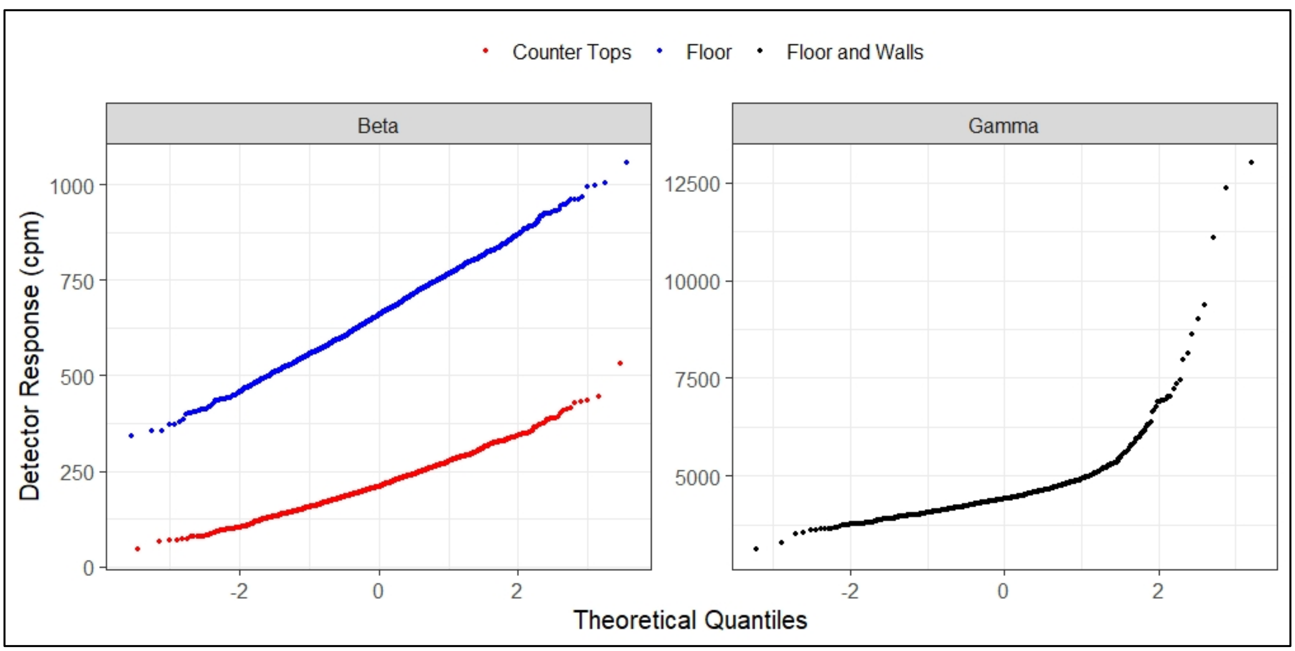


**Figure 6.3. Q-Q Plots of Soil Lab Scan Data**

## 6.2 SURFACE ACTIVITY MEASUREMENTS

Table 6.2 provides a summary of the surface activity measurements collected within the WMF. Full data tables can be found in Appendix B. In total nine locations were selected for direct measurements and smear sampling. The confirmatory data were compared against the investigation levels presented in Table 3.4. All total activity measurements were below the $DCGL_{WS}$, thus confirming the Class 2 FSS SU classification. All removable activity was less than 10% of the total activity.

| Table 6.2. Summary of Surface Activity Results[a] | | | | | | |
|---|---|---|---|---|---|---|
| Area | Total Activity | | Removable Activity | | | |
| | Alpha | Beta | Alpha | Beta | H-3 | C-14 |
| | dpm/100 $cm^2$ | | dpm/100 $cm^2$ | | | |
| WMF | 10 to 50 | 1,200 to 1,800 | 0[b] | 0 to 3 | -7 to -2 | -4 to 1 |

[a] Zeros due to rounding.
[b] All nine values were 0 dpm/100 $cm^2$

## 6.3 GAMMA RADIATION MEASUREMENTS AND SOIL SAMPLING

Soil sampling locations are displayed in Appendix A. Table 6.3 provides a summary of the NaI(Tl) direct measurements collected pre- and post-sample. Table 6.4 provides a summary of the radionuclide concentrations. Appendix B provides individual sample results.

| Table 6.3. Summary of Soil Sampling Direct Measurements | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sample Type | No. of Samples | Gamma Measurement (cpm) | | | | | |
| | | Pre-Sample | | | Post-Sample | | |
| ORISE Random | 8 | 3,500 | to | 5,000 | 3,500 | to | 5,700 |
| ORISE Judgmental | 2 | 3,700 | to | 5,400 | 5,100 | to | 5,600 |
| Archived FSS Random | 10 | -- [a] | to | -- | -- | to | -- |

[a] Pre- and post-sample gamma measurements not provided.

| Table 6.4. Summary of Soil Sample Concentrations[a] | | | | | | |
|---|---|---|---|---|---|---|
| ROC[b] | ORISE Random | | ORISE Judgmental | | FSS Samples | |
| | Min | Max | Min | Max | Min | Max |
| | pCi/g | | | | | |
| Am-241 | -0.10 | -0.004 | -0.023 | 0.050 | -0.083 | 0.021 |
| Cm-245 | -0.06 | 0.7 | 0.00 | 0.06 | -0.082 | 0.11 |
| Co-60 | -0.09 | 0.040 | -0.027 | 0.016 | -0.022 | 0.012 |
| Cs-137 | 0.010 | 0.429 | 0.077 | 0.132 | -0.013 | 0.058 |
| Eu-152 | -0.12 | 0.14 | -0.010 | 0.035 | -0.050 | 0.029 |
| Eu-154 | -0.38 | 0.2 | -0.146 | 0.001 | -0.36 | -0.048 |
| Nb-94 | -0.06 | 0.005 | 0.009 | 0.013 | -0.005 | 0.015 |
| Np-237 by Pa-233 | -0.23 | 0.012 | 0.036 | 0.042 | -0.008 | 0.013 |
| SOF | 0.003 | 0.104 | 0.056 | 0.058 | 0.002 | 0.015 |

[a] Zeros due to rounding.
[b] Only these gamma emitting ROCs were used in the ORISE SOF calculations.

None of the individual ROC concentrations exceeded the $DCGL_W$s and all SOF results were less than 1. The confirmatory data were compared against the investigation levels presented in Table 3.4. None of the ROC concentrations exceeded 50% of the respective gamma-emitting $DCGL_W$s, thus confirming the licensee's FSS SU classifications.

## 7. SUMMARY

At the NRC's request, ORISE conducted confirmatory survey activities at the HBPP during the period of August 26-29, 2019. Confirmatory survey activities included gamma walkover scans, gamma direct measurements, and soil sampling in the accessible land areas and alpha-plus-beta scans, alpha only and beta only direct measurements, and smear sampling in select buildings.

No elevated direct gamma radiation levels above localized background were identified in any of the land areas surveyed. In total, 20 soil samples were collected for laboratory analysis: eight random and two judgmental samples from areas thought to be native soil and ten archived samples from areas before backfill. The radionuclide concentrations in the soil samples were compared to the NRC approved $DCGL_W$s established for the site. All concentrations were below the $DCGL_W$s and all

sum-of-fractions results were less than 1. For all samples, the ROC concentrations were less than 50% of the respective gamma-emitting $DCGL_{W}$s, thus confirming the licensee's FSS classification.

Three buildings were also limitedly investigated during this survey: the security building (Building 7), the WMF, and the soil lab (Building 13). A portion of the interior of all the buildings and additionally, the roof of the security building and the asphalt/concrete pad north and east of the WMF were scanned. Only the area where the site's sources were stored within the soil lab was identified with elevated gamma radiation levels. Judgmental direct measurements and smear samples were collected behind the push walls in the WMF. Total activities measured in the WMF did not exceed the $DCGL_{W}$s and the removable activity was less than ten percent of the total activity, thus confirming the licensee's Class 2 FSS SU classification.

The confirmatory results indicate that the residual radioactivity concentrations in the remaining land areas and structural surfaces were below the applicable release criteria, and the confirmatory results support the licensee's classification of the FSS SUs. The confirmatory results indicate that the areas surveyed meet the NRC-approved criteria for release for unrestricted use. Such conclusions cannot be drawn about the soil lab at this time as radioactive materials (i.e., sources) were still present during the confirmatory survey.

# 8. REFERENCES

Bartlett 2011. *Historical Site Assessment 2011 Update*, prepared for Humboldt Bay Power Plant Pacific Gas & Electric Company, Eureka, California. Bartlett Nuclear Incorporated. Plymouth, Massachusetts. July.

EPA 2006. *Guidance on Systematic Planning Using the Data Quality Objectives Process*. EPA QA/G-4. U.S. Environmental Protection Agency. Washington, D.C. February.

ESI 2008. *Historical Site Assessment,* prepared for the Humboldt Bay Power Plant Pacific Gas & Electric Company, Eureka, California, Draft. September.

NRC 1998. *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*. NUREG-1507. U.S. Nuclear Regulatory Commission. Washington, D.C. June.

NRC 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*. NUREG-1575; Revision 1. U.S. Nuclear Regulatory Commission. Washington, D.C., August.

ORAU 2016a. *ORAU Radiological and Environmental Survey Procedures Manual*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. November 10.

ORAU 2016b. *ORAU Health and Safety Manual*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. January.

ORAU 2019a. *ORAU Environmental Services and Radiation Training Quality Program Manual*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. July 20.

ORAU 2019b. *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. June 27.

ORAU 2019c. Email exchange between Erika Bailey/Oak Ridge Associated Universities and Marshall Blake/Pacific Gas & Electric. August 21.

ORISE 2016. *Project-Specific Plan for the Confirmatory Survey Activities at the Humboldt Bay Power Plant; Eureka, California*. Oak Ridge Institute for Science and Education. Oak Ridge, Tennessee. August 3.

PG&E 2014. *Humboldt Bay Power Plant, Unit 3 License Termination Plan,* Rev. 1. Pacific Gas & Electric Company. Avila Beach, California. August 13.

PG&E 2019. *Final Status Survey Planning (FSSP) Worksheet*. Attachment 9.1. Rev. 2D. Pacific Gas & Electric Company. Avila Beach, California. July 12.

# APPENDIX A: FIGURES

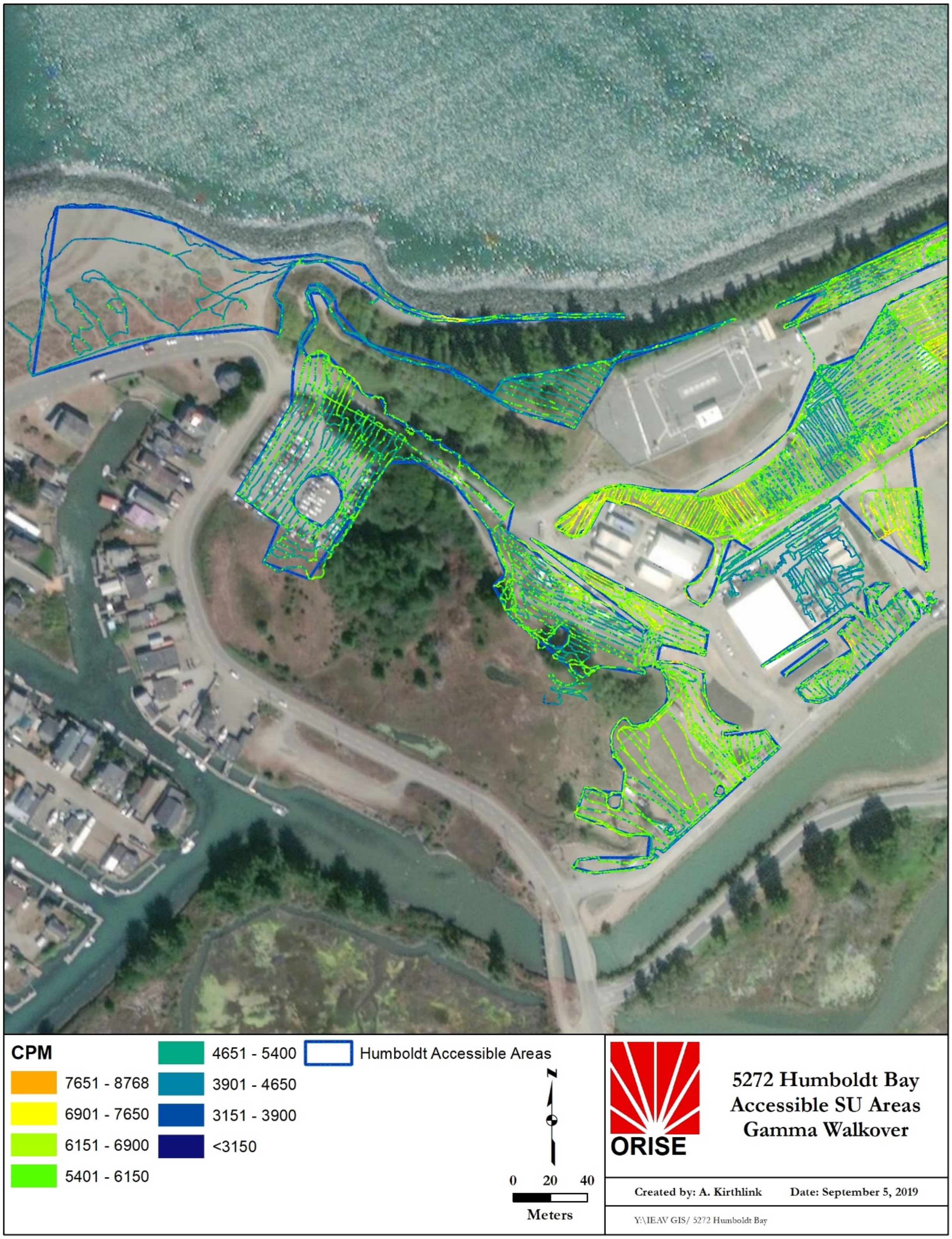


**Figure A.1. Western Side of Site Gamma Walkover Data**

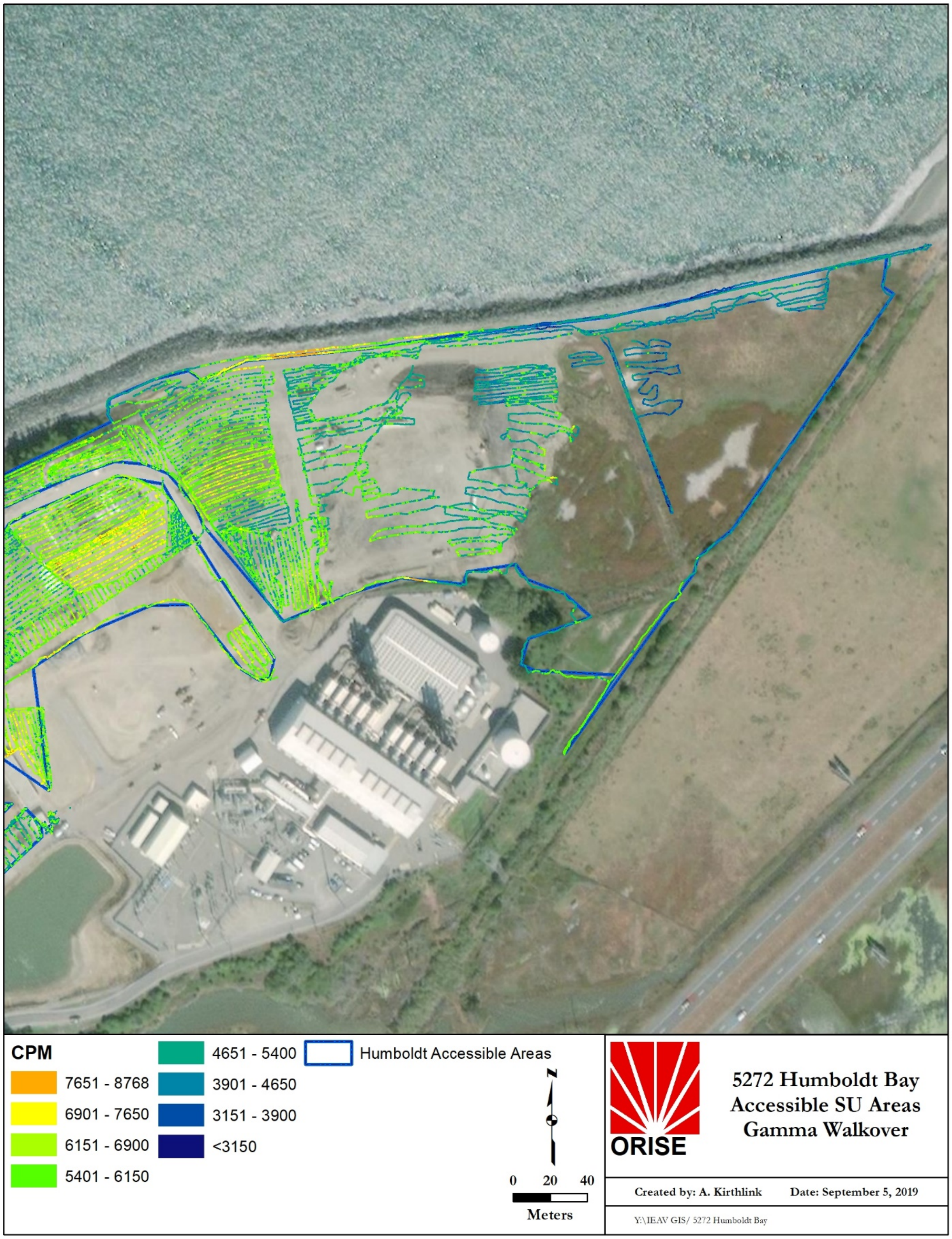


**Figure A.2. Eastern Side of Site Gamma Walkover Data**

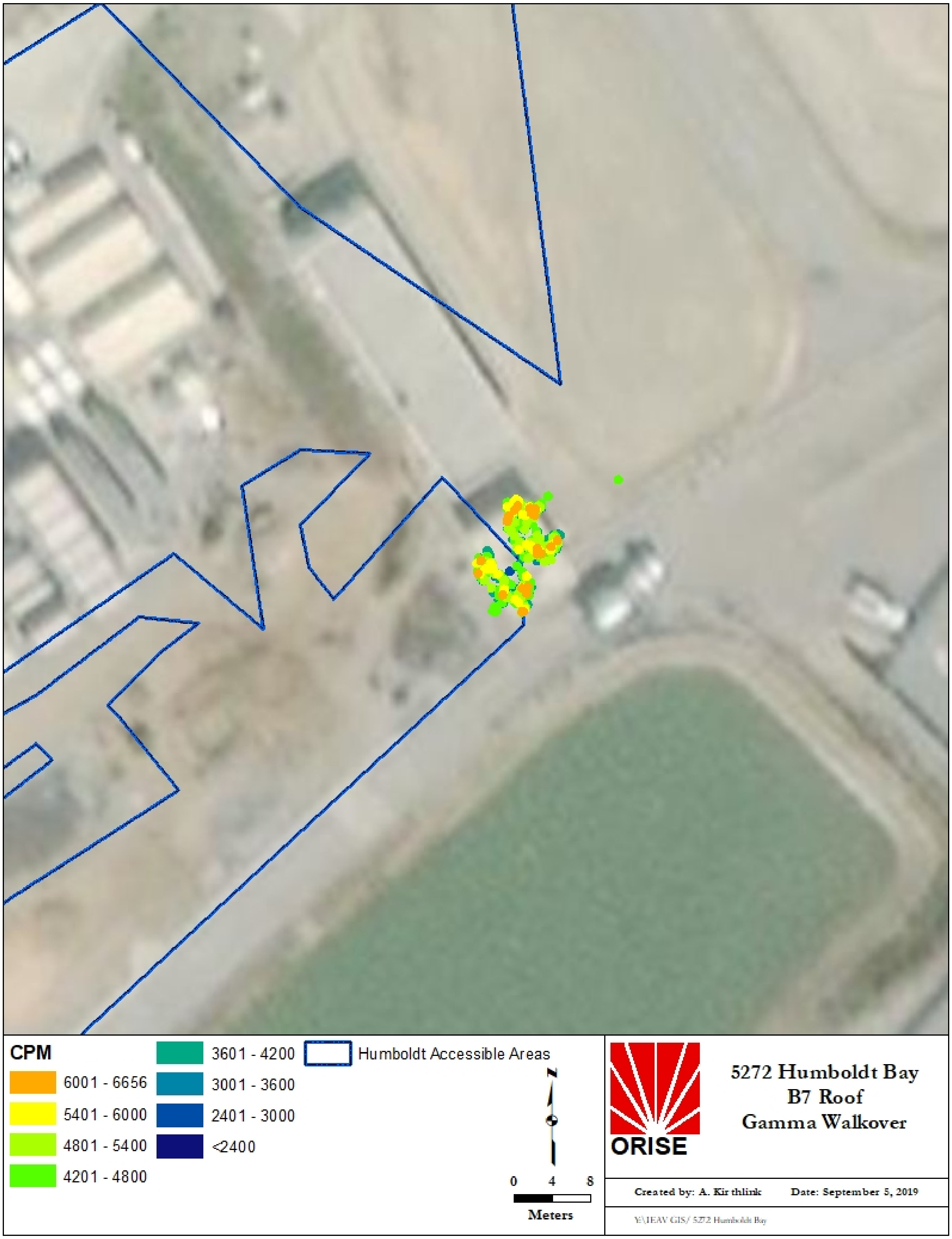


**Figure A.3. Security Building Roof Gamma Walkover Data**

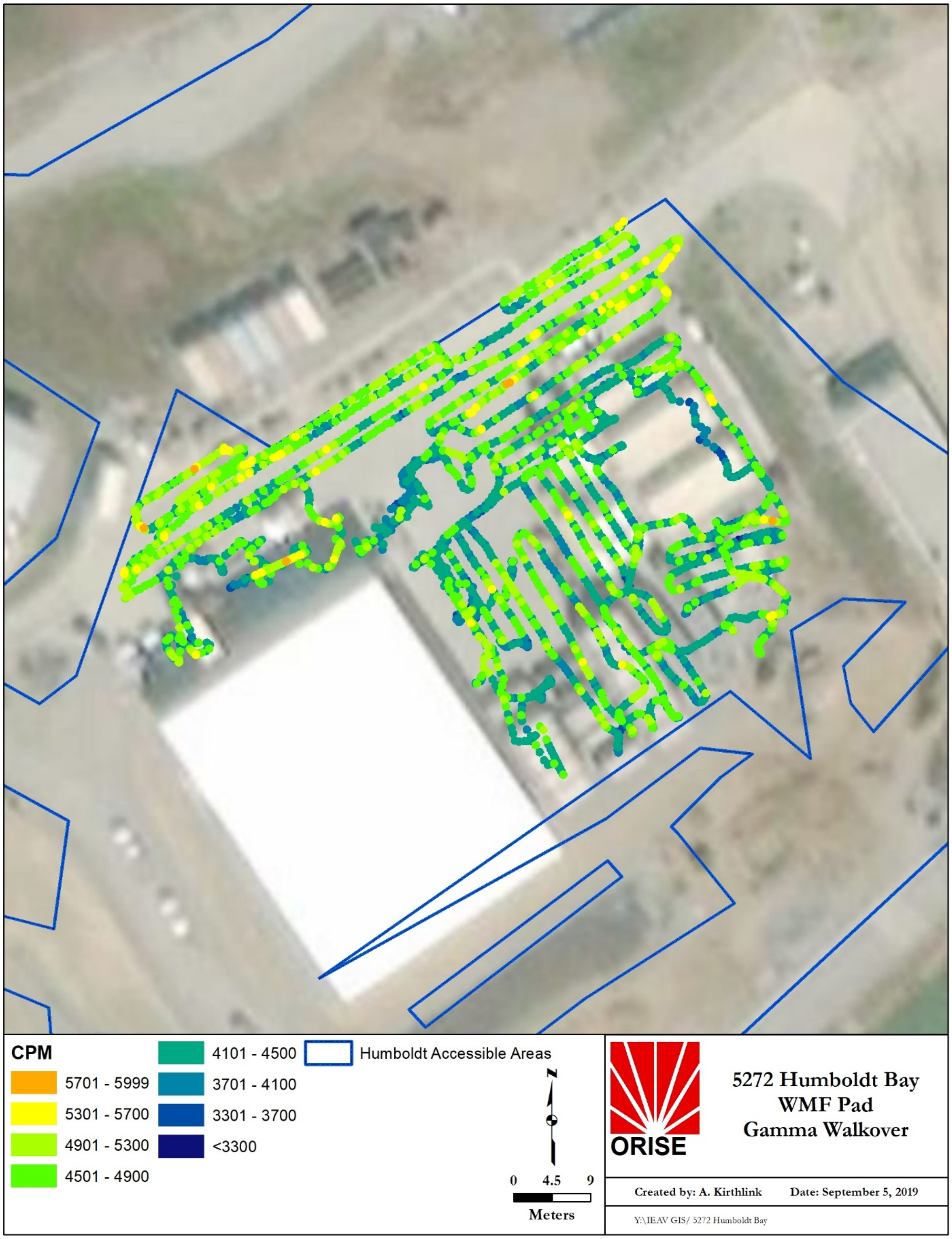


**Figure A.4. WMF Pad Gamma Walkover Data**

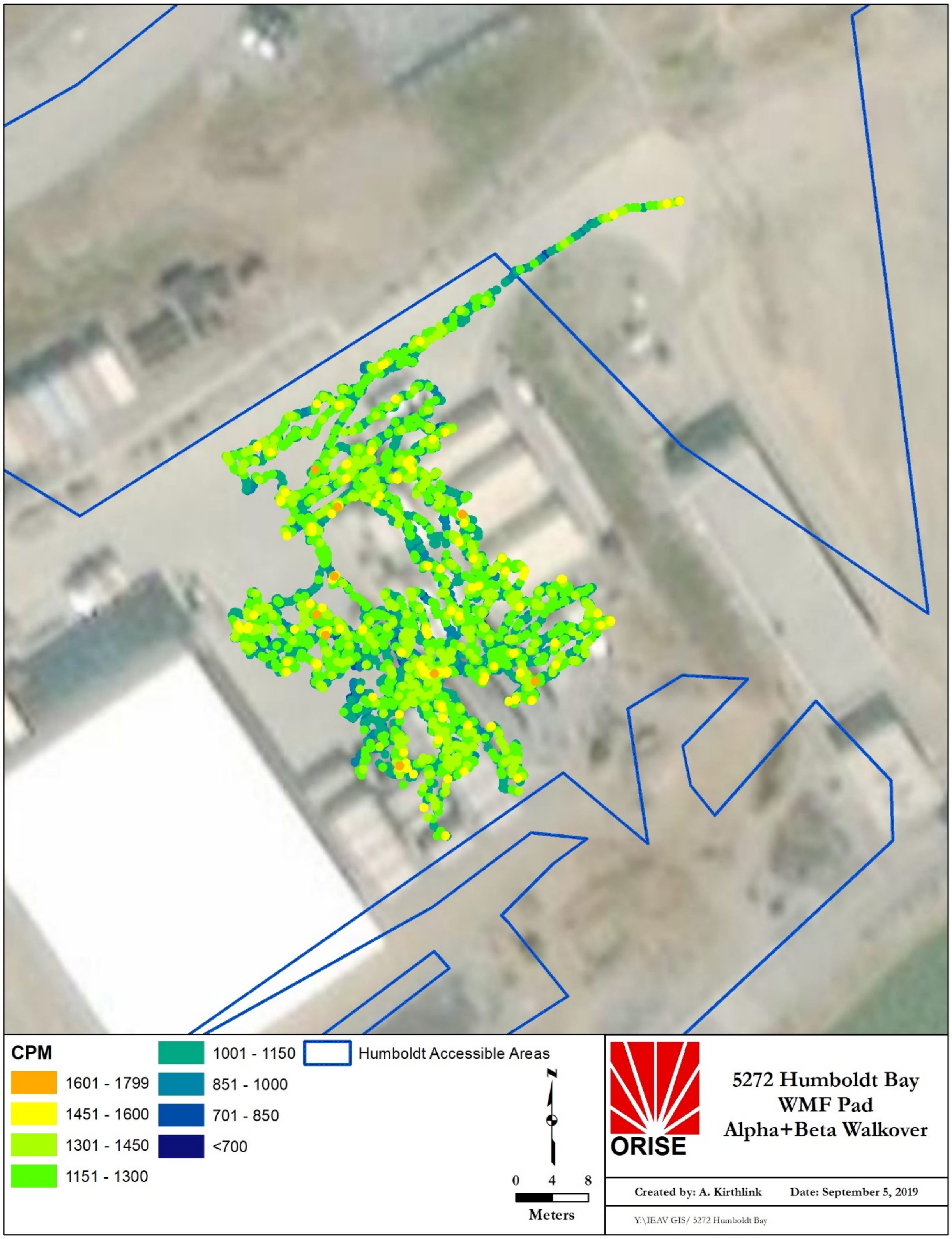


**Figure A.5. WMF Pad Alpha-plus-Beta Walkover Data**


**Figure A.6. Soil Sample Locations**

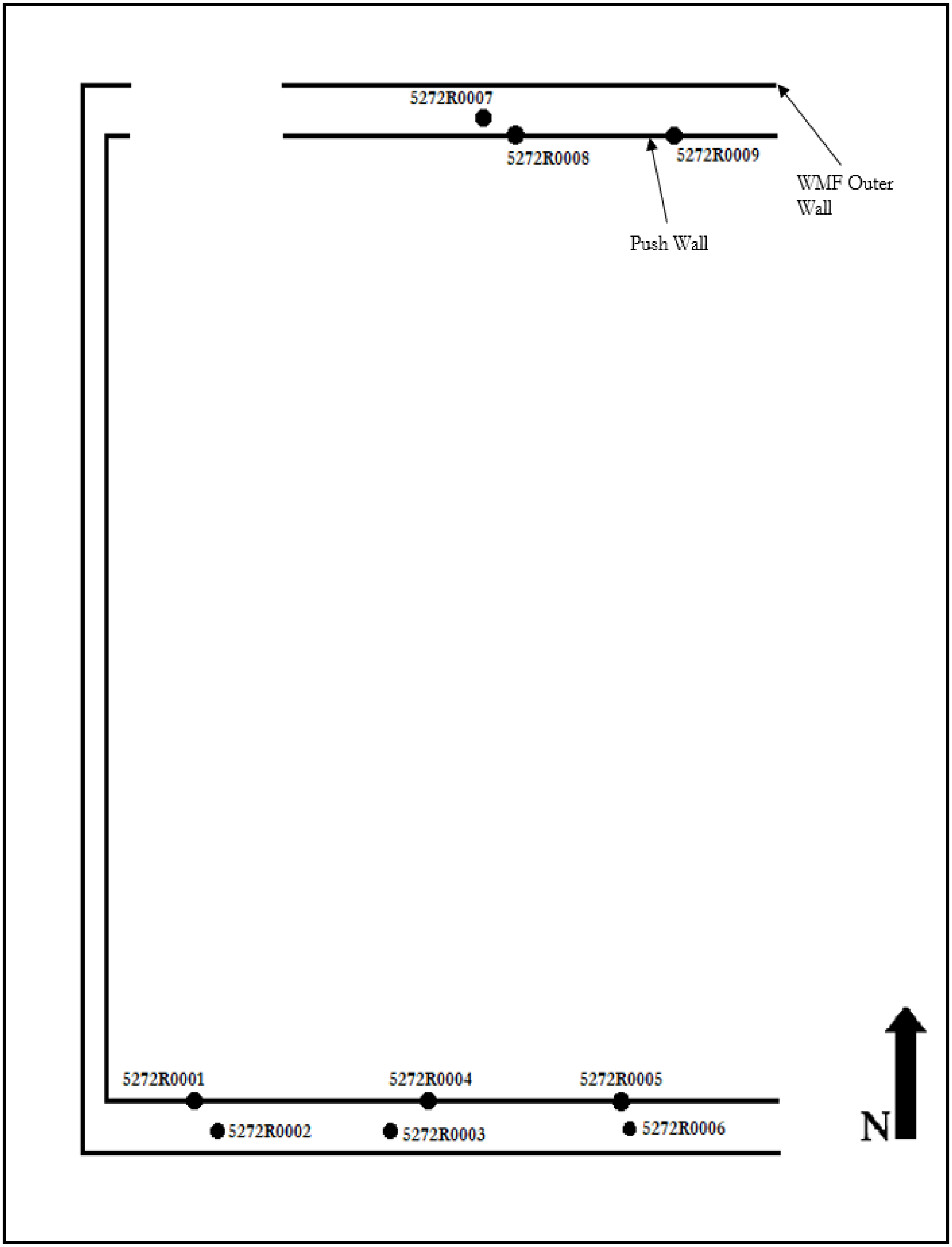


**Figure A.7. WMF Direct Measurement and Smear Sampling Locations**

# APPENDIX B: DATA TABLES

| Table B.1. Soil Sample Locations and Gamma Measurements | | | | | |
|---|---|---|---|---|---|
| Sample ID | | Coordinates (ft) | | Gamma (cpm) | |
| | | Easting | Northing | Pre- | Post- |
| **Random Locations** | | | | | |
| ORISE | 5272S0024 | 5948288 | 2161054 | 5,000 | 5,500 |
| ORISE | 5272S0025 | 5947703 | 2161509 | 3,600 | 4,100 |
| ORISE | 5272S0026 | 5947897 | 2161303 | 4,400 | 4,800 |
| ORISE | 5272S0028 | 5950292 | 2161514 | 3,500 | 3,500 |
| ORISE | 5272S0029 | 5950679 | 2161710 | 3,700 | 4,200 |
| ORISE | 5272S0030 | 5950407 | 2161732 | 4,400 | 4,900 |
| ORISE | 5272S0031 | 5950482 | 2161758 | 4,900 | 5,700 |
| ORISE | 5272S0032 | 5950140 | 2161278 | 4,800 | 5,300 |
| Archived FSS | FSS-2377: OOL10-20-005-F | 5948629 | 2160869 | -- | -- |
| Archived FSS | 2012-003: HBPP-CHAR-OOL10-05-C[a] | 5949079 | 2160855 | -- | -- |
| Archived FSS | FSS-2154: OOL10-25-003-F-RC | 5949019 | 5121046 | -- | -- |
| Archived FSS | FSS-1857: OOL10-25-007-F | 5949120 | 2161264 | -- | -- |
| Archived FSS | FSS-0694: NOL01-03-01-106-F-RC | 5949366 | 2161272 | -- | -- |
| Archived FSS | FSS-0519: OOL01-03-011-F-RC | 5949628 | 2161279 | -- | -- |
| Archived FSS | FSS-1707: OOL09-02-004-F | 5949885 | 2161269 | -- | -- |
| Archived FSS | FSS-2190: OOL07-03-120-F | 5949504 | 2161518 | -- | -- |
| Archived FSS | FSS-2057: OOL09-07-020-F | 5949752 | 2161494 | -- | -- |
| Archived FSS | FSS-1589: OOL09-06-003-F-RC | 5950018 | 2161501 | -- | -- |
| **Judgmental Locations** | | | | | |
| ORISE | 5272S0027 | 5948353 | 2161310 | 3,700 | 5,100 |
| ORISE | 5272S0033 | 5949710 | 2160611 | 5,400 | 5,600 |

[a] This sample is likely a characterization sample based on the naming convention.

| ROC | 5272S0024 | | | | 5272S0025 | | | | 5272S0026 | | | | 5272S0028 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Conc. | | TPU[a] | MDC[b] | Conc. | | TPU | MDC | Conc. | | TPU | MDC | Conc. | | TPU | MDC |
| Am-241 | -0.020 | ± | 0.029 | 0.088 | -0.004 | ± | 0.054 | 0.132 | -0.031 | ± | 0.022 | 0.069 | -0.10 | ± | 0.44 | 1.08 |
| Cm-245 | -0.039 | ± | 0.095 | 0.221 | -0.011 | ± | 0.086 | 0.200 | -0.047 | ± | 0.079 | 0.179 | 0.7 | ± | 1.6 | 3.8 |
| Co-60 | 0.009 | ± | 0.020 | 0.048 | -0.014 | ± | 0.015 | 0.027 | 0.013 | ± | 0.020 | 0.048 | -0.09 | ± | 0.21 | 0.54 |
| Cs-137 | **0.033**[c] | ± | 0.015 | 0.029 | **0.019** | ± | 0.009 | 0.017 | 0.010 | ± | 0.012 | 0.028 | 0.33 | ± | 0.17 | 0.36 |
| Eu-152 | 0.011 | ± | 0.047 | 0.109 | 0.005 | ± | 0.029 | 0.069 | -0.005 | ± | 0.040 | 0.089 | -0.12 | ± | 0.61 | 1.43 |
| Eu-154 | -0.142 | ± | 0.092 | 0.196 | -0.130 | ± | 0.064 | 0.106 | -0.012 | ± | 0.059 | 0.174 | 0.2 | ± | 1.0 | 2.3 |
| Nb-94 | 0.005 | ± | 0.018 | 0.041 | 0.001 | ± | 0.008 | 0.026 | 0.003 | ± | 0.015 | 0.033 | -0.06 | ± | 0.23 | 0.49 |
| Np-237 by Pa-233 | 0.012 | ± | 0.029 | 0.067 | -0.003 | ± | 0.020 | 0.047 | 0.001 | ± | 0.026 | 0.058 | -0.23 | ± | 0.42 | 0.95 |
| **SOF** | 0.019 | | | | 0.003 | | | | 0.006 | | | | 0.104 | | | |

Table B.2. ORISE Random Soil Sample Results (pCi/g)

[a] Uncertainties are based on total propagated uncertainties at the 95% confidence level.
[b] MDC = minimum detectable concentration.
[c] Results greater than the analytical MDC are bolded.

| ROC | 5272S0029 | | | | 5272S0030 | | | | 5272S0031 | | | | 5272S0032 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Conc. | | TPU[a] | MDC[b] | Conc. | | TPU | MDC | Conc. | | TPU | MDC | Conc. | | TPU | MDC |
| Am-241 | -0.024 | ± | 0.027 | 0.063 | -0.046 | ± | 0.061 | 0.144 | -0.026 | ± | 0.029 | 0.069 | -0.084 | ± | 0.068 | 0.156 |
| Cm-245 | 0.017 | ± | 0.079 | 0.189 | -0.035 | ± | 0.092 | 0.213 | 0.024 | ± | 0.079 | 0.189 | -0.06 | ± | 0.27 | 0.63 |
| Co-60 | 0.003 | ± | 0.016 | 0.037 | 0.001 | ± | 0.016 | 0.033 | 0.022 | ± | 0.016 | 0.043 | 0.040 | ± | 0.069 | 0.165 |
| Cs-137 | 0.011 | ± | 0.015 | 0.034 | 0.016 | ± | 0.010 | 0.022 | 0.016 | ± | 0.009 | 0.027 | **0.429**[c] | ± | 0.077 | 0.096 |
| Eu-152 | 0.009 | ± | 0.038 | 0.089 | -0.013 | ± | 0.032 | 0.074 | -0.013 | ± | 0.036 | 0.079 | 0.14 | ± | 0.15 | 0.36 |
| Eu-154 | -0.029 | ± | 0.070 | 0.179 | -0.049 | ± | 0.058 | 0.134 | -0.079 | ± | 0.077 | 0.155 | -0.38 | ± | 0.34 | 0.65 |
| Nb-94 | -0.002 | ± | 0.015 | 0.032 | -0.002 | ± | 0.013 | 0.028 | -0.005 | ± | 0.013 | 0.028 | 0.001 | ± | 0.066 | 0.146 |
| Np-237 by Pa-233 | -0.014 | ± | 0.016 | 0.059 | 0.002 | ± | 0.023 | 0.054 | -0.004 | ± | 0.024 | 0.054 | -0.02 | ± | 0.10 | 0.23 |
| **SOF** | 0.004 | | | | 0.004 | | | | 0.009 | | | | 0.079 | | | |

Table B.3. ORISE Random Soil Sample Results (pCi/g)

[a] Uncertainties are based on total propagated uncertainties at the 95% confidence level.
[b] MDC = minimum detectable concentration.
[c] Results greater than the analytical MDC are bolded.

| Table B.4. Archived FSS Soil Sample Results (pCi/g) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ROC | FSS-2377: OOL10-20-005-F | | | | 2012-003: HBPP-CHAR-OOL10-05-C | | | | FSS-2154: OOL10-25-003-F-RC | | | | FSS-1857: OOL10-25-007-F | | | |
| | Conc. | | TPU[a] | MDC[b] | Conc. | | TPU | MDC | Conc. | | TPU | MDC | Conc. | | TPU | MDC |
| Am-241 | -0.045 | ± | 0.063 | 0.153 | -0.016 | ± | 0.032 | 0.077 | -0.083 | ± | 0.037 | 0.083 | 0.021 | ± | 0.019 | 0.075 |
| Cm-245 | 0.008 | ± | 0.095 | 0.222 | 0.032 | ± | 0.087 | 0.209 | -0.020 | ± | 0.098 | 0.227 | -0.082 | ± | 0.095 | 0.215 |
| Co-60 | -0.004 | ± | 0.016 | 0.032 | -0.006 | ± | 0.049 | 0.102 | -0.022 | ± | 0.028 | 0.050 | 0.006 | ± | 0.019 | 0.045 |
| Cs-137 | -0.013 | ± | 0.013 | 0.027 | **0.058**[c] | ± | 0.020 | 0.035 | 0.015 | ± | 0.020 | 0.046 | 0.004 | ± | 0.018 | 0.047 |
| Eu-152 | -0.034 | ± | 0.036 | 0.079 | 0.029 | ± | 0.059 | 0.140 | -0.037 | ± | 0.048 | 0.102 | -0.001 | ± | 0.048 | 0.109 |
| Eu-154 | -0.104 | ± | 0.065 | 0.141 | -0.29 | ± | 0.18 | 0.31 | -0.085 | ± | 0.090 | 0.202 | -0.113 | ± | 0.069 | 0.181 |
| Nb-94 | 0.015 | ± | 0.013 | 0.031 | 0.006 | ± | 0.017 | 0.040 | -0.001 | ± | 0.017 | 0.040 | -0.005 | ± | 0.016 | 0.035 |
| Np-237 by Pa-233 | 0.013 | ± | 0.022 | 0.054 | -0.006 | ± | 0.028 | 0.062 | -0.003 | ± | 0.032 | 0.072 | 0.004 | ± | 0.030 | 0.068 |
| **SOF** | 0.014 | | | | 0.013 | | | | 0.002 | | | | 0.007 | | | |

[a] Uncertainties are based on total propagated uncertainties at the 95% confidence level.
[b] MDC = minimum detectable concentration.
[c] Results greater than the analytical MDC are bolded.

| Table B.5. Archived FSS Soil Sample Results (pCi/g) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ROC | FSS-0694: NOL01-03-01-106-F-RC | | | | FSS-0519: OOL01-03-011-F-RC | | | | FSS-1707: OOL09-02-004-F | | | | FSS-2190: OOL07-03-120-F | | | |
| | Conc. | | TPU[a] | MDC[b] | Conc. | | TPU | MDC | Conc. | | TPU | MDC | Conc. | | TPU | MDC |
| Am-241 | -0.035 | ± | 0.034 | 0.081 | -0.024 | ± | 0.063 | 0.155 | -0.029 | ± | 0.026 | 0.082 | -0.063 | ± | 0.029 | 0.085 |
| Cm-245 | 0.015 | ± | 0.090 | 0.215 | 0.042 | ± | 0.098 | 0.233 | -0.007 | ± | 0.070 | 0.219 | 0.054 | ± | 0.095 | 0.228 |
| Co-60 | 0.004 | ± | 0.028 | 0.061 | 0.010 | ± | 0.026 | 0.057 | 0.012 | ± | 0.014 | 0.059 | -0.003 | ± | 0.015 | 0.044 |
| Cs-137 | 0.018 | ± | 0.015 | 0.033 | **0.026**[c] | ± | 0.012 | 0.024 | 0.025 | ± | 0.014 | 0.027 | -0.009 | ± | 0.023 | 0.046 |
| Eu-152 | -0.021 | ± | 0.053 | 0.116 | -0.010 | ± | 0.040 | 0.094 | -0.050 | ± | 0.046 | 0.096 | -0.022 | ± | 0.050 | 0.109 |
| Eu-154 | -0.048 | ± | 0.095 | 0.226 | -0.195 | ± | 0.097 | 0.160 | -0.14 | ± | 0.11 | 0.22 | -0.19 | ± | 0.11 | 0.20 |
| Nb-94 | 0.002 | ± | 0.018 | 0.040 | -0.003 | ± | 0.014 | 0.030 | -0.003 | ± | 0.015 | 0.033 | 0.008 | ± | 0.017 | 0.040 |
| Np-237 by Pa-233 | -0.007 | ± | 0.030 | 0.066 | 0.007 | ± | 0.023 | 0.055 | 0.005 | ± | 0.029 | 0.066 | -0.000[d] | ± | 0.030 | 0.068 |
| **SOF** | 0.004 | | | | 0.015 | | | | 0.011 | | | | 0.004 | | | |

[a] Uncertainties are based on total propagated uncertainties at the 95% confidence level.
[b] MDC = minimum detectable concentration.
[c] Results greater than the analytical MDC are bolded.
[d] Zero due to rounding

| Table B.6. Archived FSS Soil Sample Results (pCi/g) | | | | | | |
|---|---|---|---|---|---|---|
| ROC | FSS-2057: OOL09-07-020-F | | | FSS-1589: OOL09-06-003-F-RC | | |
| | Conc. | TPU[a] | MDC[b] | Conc. | TPU | MDC |
| Am-241 | 0.013 | 0.052 | 0.126 | -0.08 | 0.12 | 0.28 |
| Cm-245 | 0.06 | 0.11 | 0.26 | 0.11 | 0.15 | 0.36 |
| Co-60 | -0.013 | 0.018 | 0.034 | 0.004 | 0.027 | 0.058 |
| Cs-137 | 0.001 | 0.009 | 0.040 | -0.002 | 0.021 | 0.048 |
| Eu-152 | -0.030 | 0.037 | 0.084 | 0.014 | 0.055 | 0.132 |
| Eu-154 | -0.078 | 0.079 | 0.174 | -0.36 | 0.14 | 0.23 |
| Nb-94 | 0.007 | 0.015 | 0.034 | 0.007 | 0.022 | 0.049 |
| Np-237 by Pa-233 | -0.008 | 0.025 | 0.059 | -0.005 | 0.036 | 0.085 |
| **SOF** | 0.005 | | | 0.010 | | |

[a] Uncertainties are based on total propagated uncertainties at the 95% confidence level.
[b] MDC = minimum detectable concentration.
[c] Results greater than the analytical MDC are bolded.

| Table B.7. ORISE Judgmental Soil Sample Results (pCi/g) | | | | | | |
|---|---|---|---|---|---|---|
| ROC | 5272S0027 | | | 5272S0033 | | |
| | Conc. | TPU[a] | MDC[b] | Conc. | TPU | MDC |
| Am-241 | -0.023 | 0.097 | 0.239 | 0.050 | 0.094 | 0.236 |
| Cm-245 | -0.00[d] | 0.14 | 0.32 | 0.06 | 0.13 | 0.30 |
| Co-60 | 0.016 | 0.021 | 0.052 | -0.027 | 0.023 | 0.037 |
| Cs-137 | **0.077**[c] | 0.019 | 0.028 | **0.132** | 0.023 | 0.028 |
| Eu-152 | 0.035 | 0.047 | 0.119 | -0.010 | 0.045 | 0.107 |
| Eu-154 | 0.001 | 0.081 | 0.202 | -0.146 | 0.094 | 0.172 |
| Nb-94 | 0.013 | 0.018 | 0.044 | 0.009 | 0.018 | 0.041 |
| Np-237 by Pa-233 | 0.042 | 0.025 | 0.053 | 0.036 | 0.031 | 0.078 |
| **SOF** | 0.058 | | | 0.056 | | |

[a] Uncertainties are based on total propagated uncertainties at the 95% confidence level.
[b] MDC = minimum detectable concentration.
[c] Results greater than the analytical MDC are bolded.
[d] Zero due to rounding.

| Table B.8. WMF Sample Locations and Direct Measurements | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Sample ID** | **Location** | **Total Activity** | | **Removable Activity** | | | |
| | | **Alpha** | **Beta** | **Alpha** | **Beta** | **H-3** | **C-14** |
| | | **dpm/100 cm²** | **dpm/100 cm²** | **dpm/100 cm²** | | | |
| 5272R0001 | Behind South Push Wall, Western Wall | 30 | 1,300 | 0 | 2 | -- | -- |
| 5272R0002 | Behind South Push Wall, Western Floor | 50 | 1,600 | 0 | 0 | -2 | -4 |
| 5272R0003 | Behind South Push Wall, Middle Floor | 10 | 1,800 | 0 | 2 | -- | -- |
| 5272R0004 | Behind South Push Wall, Middle Wall | 10 | 1,200 | 0 | 2 | -- | -- |
| 5272R0005 | Behind South Push Wall, Eastern Wall | 20 | 1,300 | 0 | 2 | -- | -- |
| 5272R0006 | Behind South Push Wall, Eastern Floor | 20 | 1,600 | 0 | 3 | -- | -- |
| 5272R0007 | Behind North Push Wall, Middle Floor | 40 | 1,600 | 0 | 0 | -7 | 1 |
| 5272R0008 | Behind North Push Wall, Middle Wall | 20 | 1,200 | 0 | 0 | -- | -- |
| 5272R0009 | Behind North Push Wall, Eastern Wall | 20 | 1,400 | 0 | 0 | -- | -- |
| **Minimum** | | 10 | 1,200 | 0 | 0 | -7 | -4 |
| **Maximum** | | 50 | 1,800 | 0 | 3 | -2 | 1 |

# APPENDIX C: MAJOR INSTRUMENTATION

## C.1. SCANNING AND MEASUREMENT INSTRUMENT/ DETECTOR COMBINATIONS

The display of a specific product is not to be construed as an endorsement of the product or its manufacturer by the author or his employer.

### C.1.1 GAMMA

Ludlum NaI Scintillation Detector Model 44-10, Crystal: 5.1 cm × 5.1 cm
(Ludlum Measurements, Inc., Sweetwater, Texas)
coupled to: Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, Texas)
coupled to: Trimble Geo 7X
(Trimble Navigation Limited, Sunnyvale, CA)

### C.1.2 ALPHA-PLUS-BETA

Ludlum Gas-flow Proportional Detector Model 43-68, 126 $cm^2$ physical area, 0.8 $mg/cm^2$ Mylar window
(Ludlum Measurements, Inc., Sweetwater, Texas)
coupled to: Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, Texas)

Ludlum Gas-flow Proportional Detector Model 43-37, 584 $cm^2$ physical area, 0.8 $mg/cm^2$ Mylar window
(Ludlum Measurements, Inc., Sweetwater, Texas)
coupled to: Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, Texas)

### C.1.3 ALPHA

Ludlum Gas-flow Proportional Detector Model 43-68, 126 $cm^2$ physical area, 0.8 $mg/cm^2$ Mylar window
(Ludlum Measurements, Inc., Sweetwater, Texas)
coupled to: Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, Texas)

### C.1.4 BETA

Ludlum Gas-flow Proportional Detector Model 43-68, 126 $cm^2$ physical area, 3.8 $mg/cm^2$ Mylar window
(Ludlum Measurements, Inc., Sweetwater, Texas)
coupled to: Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, Texas)

## C.2. LABORATORY ANALYTICAL INSTRUMENTATION

Low-Background Gas Proportional Counter
Series 5 XLB
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Eclipse Software
Dell Workstation
(Canberra, Meriden, Connecticut)

High-Purity, Extended Range Intrinsic Detector
CANBERRA/Tennelec Model No: ERVDS30-25195
Canberra Lynx ® Multichannel Analyzer
Canberra Gamma-Apex Software
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, Tennessee) and
Dell Workstation
(Canberra, Meriden, Connecticut)

High-Purity, Intrinsic Detector
EG&G ORTEC Model No. GMX-45200-5
Canberra Lynx ® Multichannel Analyzer
Canberra Gamma-Apex Software
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, Tennessee) and
Dell Workstation
(Canberra, Meriden, Connecticut)

High-Purity, Intrinsic Detector
EG&G ORTEC Model No. GMX-30P4
Canberra Lynx ® Multichannel Analyzer
Canberra Gamma-Apex Software
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, Tennessee) and
Dell Workstation
(Canberra, Meriden, Connecticut)

High-Purity, Intrinsic Detector
EG&G ORTEC Model No. CDG-SV-76/GEM-MX5970-S
Canberra Lynx ® Multichannel Analyzer
Canberra Gamma-Apex Software
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, Tennessee) and
Dell Workstation
(Canberra, Meriden, Connecticut)

Liquid Scintillation Counter
Perkin Elmer Tricarb 5110TR
(Perkin Elmer, Waltham, Massachusetts)

# APPENDIX D: SURVEY AND ANALYTICAL PROCEDURES

## D.1. PROJECT HEALTH AND SAFETY

ORISE performed all survey activities in accordance with the *ORAU Radiation Protection Manual*, the *ORAU Radiological and Environmental Survey Procedures Manual,* and the *ORAU Health and Safety Manual*, (ORAU 2014, ORAU 2016a, and ORAU 2016b). Prior to on-site activities, a Work-Specific Hazard Checklist was completed for the project and discussed with field personnel. The planned activities were thoroughly discussed with site personnel prior to implementation to identify hazards present. Additionally, prior to performing work, a pre-job briefing and walk down of the survey areas were completed with field personnel to identify hazards present and discuss safety concerns. Should ORISE have identified a hazard not covered in the *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2016a) or the project's Work-Specific Hazard Checklist for the planned survey and sampling procedures, work would not have been initiated or continued until the hazard was addressed by an appropriate job hazard analysis and hazard controls.

## D.2. CALIBRATION AND QUALITY ASSURANCE

Calibration of all field instrumentation was based on standards/sources, traceable to National Institute of Standards and Technology (NIST).

Field survey activities were conducted in accordance with procedures from the following documents:

- ORAU *Radiological and Environmental Survey Procedures Manual* (ORAU 2016a)
- ORAU *Environmental Services and Radiation Training Quality Program Manual* (ORAU 2019a)
- ORAU *Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2019b)

The procedures contained in these manuals were developed to meet the requirements of U.S. Department of Energy (DOE) Order 414.1D and the U.S. Nuclear Regulatory Commission (NRC) *Quality Assurance Manual for the Office of Nuclear Material Safety and Safeguards*, and contain measures to assess processes during their performance.

Quality control procedures include:

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations
- Participation in Mixed-Analyte Performance Evaluation Program and Intercomparison Testing Program laboratory quality assurance programs
- Training and certification of all individuals performing procedures
- Periodic internal and external audits

## D.3. SURVEY PROCEDURES

### D.3.1 SURFACE SCANS

Gamma scans were performed using a hand-held thallium-doped sodium iodide (NaI[Tl]) scintillation detector with a 5 cm by 5 cm crystal. Alpha-plus-beta scans were performed using either the large-area (floor monitor) or hand-held gas proportional detector with a 0.8 (milligram per square centimeter (mg/cm$^2$) window with a physical detector area of 584 cm$^2$ or 126 cm$^2$, respectively. Scans for elevated radiation were performed by passing the detector slowly over the surface. The distance between the detector and surface was maintained at a minimum. The NaI[Tl] and floor monitor detectors were used solely as a qualitative means to identify elevated radiation levels in excess of background. Identifications of elevated radiation levels that could exceed the site criteria were determined based on an increase in the audible signal from the indicating instrument and quantitatively investigated using other hand-held instruments.

Surface scan minimum detectable concentrations (MDCs) for the hand-held gas proportional detectors were estimated using the approach described in NUREG-1507 (NRC 1998). The scan MDC is a function of many variables, including a two-second observation interval, a specific level of performance at the first scanning state of 95% true positive and 25% false positive rate, which yields a d' value of 2.32 (NUREG-1507, Table 6.1), and a surveyor efficiency of 0.5. The total efficiency for beta was 0.14 based on Cs-137. Per the PG&E Final Status Survey Planning Worksheet for the survey units in the Waste Management Facility building, Cs-137 was the only positive result for

plant-derived radionuclides identified during the characterization survey (PG&E 2019). The scan MDC was calculated using the following equation:

$$Scan\ MDC = \frac{d' \times \sqrt{C_b \times \left(\frac{i}{60}\right)} \times (60/i)}{\sqrt{p} \times \varepsilon_t \times \frac{Probe\ Area}{100\ cm^2}}$$

Where:

d' = index of sensitivity

$C_b$ = background (cpm)

i = observation interval (sec)

p = surveyor efficiency

$\varepsilon_t$ = total efficiency

The scan MDC for a nominal instrument background of 200 cpm was 1,500 dpm/100 $cm^2$ for the hand-held gas proportional detectors.

### D.3.2 SURFACE ACTIVITY MEASUREMENTS

Measurements of gross alpha and beta surface activity levels were performed using hand-held gas proportional detectors coupled to portable ratemeter-scalers. Count rates, which were a one-minute count with the detector held in a static position, were converted to activity levels by dividing the count rate by the total static efficiency and correcting for the physical area of the detector. For conservatism the licensee elected not to subtract out background. The MDC for static survey activity measurements was calculated using the following equation:

$$MDC = \frac{3 + (4.65\sqrt{B})}{T \times G \times \varepsilon_t}$$

Where:

B = background in time interval, T (1 min)

T = count time (min) used for field instruments

$\varepsilon_{tot}$ = total efficiency = $\varepsilon_i \times \varepsilon_s$ (instrument efficiency × source efficiency)

G = geometry correction factor (1.26)

The static MDC was 390 dpm/100 $cm^2$ for beta, based on a nominal instrument background of 200 cpm and 90 dpm/100 $cm^2$ alpha, with a nominal instrument background of 2 cpm (using an efficiency of 0.08 for Th-230).

### D.3.3. Removable Activity Sampling

Smear sampling for removable gross alpha and gross beta contamination as well as for hard-to-detect (HTD) radionuclides were obtained from independent confirmatory measurement locations. Removable activity samples were collected using numbered filter paper disks. Moderate pressure was applied to the smear and approximately 100 $cm^2$ of the surface was wiped. Smears for gross alpha and beta analysis were placed in labeled envelopes. Smears for HTD analysis were first wetted with deionized water before the surface was wiped. Wet smears were placed in glass vials with deionized water. Locations and other pertinent data were recorded and all samples were transferred under chain-of-custody.

### D. 3.4. Soil Sampling

Soil samples (approximately 0.5 kilogram each) were collected by ORISE personnel using a clean garden trowel to transfer soil into a new sample container. The container was then labeled and security sealed in accordance with ORISE procedures. ORISE shipped samples under chain-of-custody to the ORISE laboratory for analysis.

## D.4. RADIOLOGICAL ANALYSIS

### D.4.1 Gross Alpha/Beta

Dry smears were counted on a low-background proportional counter for gross alpha and beta activity. The minimum detectable activity of the procedures is approximately 11 dpm/100 $cm^2$ for alpha and 14 dpm/100 $cm^2$ for beta.

### D. 4.2. Gamma Spectroscopy

Samples were analyzed as received, and homogenized as necessary, and a portion sealed into an appropriate sized - Marinelli beaker. The quantity placed in the beaker was chosen to reproduce the calibrated counting geometry. Net material weights were determined and the samples counted using intrinsic, high purity, germanium detectors coupled to a pulse height analyzer system. Background

and Compton stripping, peak search, peak identification, and concentration calculations were performed using computer capabilities inherent in the analyzer system. All total absorption peaks (TAPs) associated with the ROCs were reviewed for consistency of activity. Spectra were also reviewed for other identifiable TAPs.

| Table D.1. Typical MDCs Total Absorption Peak | | |
|---|---|---|
| **Radionuclide** | **TAP (MeV)[a]** | **MDC (pCi/g)** |
| Co-60 | 1.332 | 0.06 |
| Cs-137 | 0.662 | 0.05 |
| Eu-152 | 0.344 | 0.10 |
| Eu-154 | 0.723 | 0.15 |

### D.4.3 H-3 AND C-14 ANALYSIS

Smear samples were placed into a scintillation cocktail without sample preparation and counted in a liquid scintillation analyzer. Tritium (H-3) and carbon-14 (C-14) values were calculated using the known efficiency in the appropriate energy region.

### D.4.4 DETECTION LIMITS

Detection limits, referred to as MDCs, were based on 95% confidence level. Because of variations in background levels, measurement efficiencies, and contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument.