FINAL

TECHNICAL MEMORANDUM
FOR
POHAKULOA TRAINING AREA (PTA) AERIAL SURVEYS
THE BIG ISLAND (HAWAII), HAWAII

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ACRONYMS, ABBREVIATIONS, AND SYMBOLS

%	Percent
^{234}Th	Thorium-234
^{234}U, ^{235}U, ^{238} U	Isotopes of uranium: uranium-234, uranium-235, uranium-238
ASR	Archives Search Report
AGL	Above Ground Level
BHHRA	Baseline Human Health Risk Assessment
A-CLASS	Cabrera Large Area Scanning System
C	Celsius
CABRERA	Cabrera Services Inc
COC	Contaminant of Concern
DQO	Data Quality Objective
DU	Depleted Uranium
EPA	U.S. Environmental Protection Agency
ft	Foot
GPS	Global Positioning System
GFS	Gamma Flyover survey
in.	Inch
kg	Kilogram
Lb	Pound
m	Meter
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MCL	Maximum Contaminant Level
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
MEC	Munitions and explosives of concern
NaI (Tl)	Sodium iodide thallium activated
NRC	U.S. Nuclear Regulatory Commission
pCi/g	Pico Curies per gram
ppm	parts per million
PRG	Preliminary Remedial Goal
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAGS	Risk Assessment Guidance for Superfund
RDL	Reporting detection limit
RESRAD	Residual radioactivity
SAP	Sampling and Analysis Plan
SDAD	Surface Danger Area Diagram
Sec	Second
SOP	Standard Operating Procedure
U	Uranium
U_3O_8	Triuranium octaoxide
UO2	uranium dioxide
USACE	United States Army Corps of Engineers
USAG-HI	United States Army Garrison, Hawaii
USEPA	United States Environmental Protection Agency
UXO	Unexploded Ordnance
µg/l	Micrograms per liter

1.0 INTRODUCTION

Cabrera Services Inc (CABRERA) was contracted by the U.S. Army Joint Munitions Command to perform confirmatory aerial radiation and visual surveys of potential Davy Crocket impact areas at the Pohakuloa Training Area (PTA), Hawaii (hereafter referred to as "PTA" or "the site"). And to the extent practical, conduct confirmatory ground based gamma walkover surveys (GWS) and soil sampling to correlate measurements taken during aerial surveys for the presence of DU. Due to the potential presence of UXO/MEC, improved conventional munitions (ICM), and terrain conditions at the PTA range, only limited access for GWS and soil sampling was anticipated to be available.

The methodology for aerial surveys to be performed at PTA was established during June 30, 2008 through July 7, 2008 at Schofield Barracks. The aerial surveys at Schofield Barracks demonstrated the ability of the Aerial Cabrera Large Area Scanning System (A-CLASS) to identify spatial distribution patterns and trends which correlated to ground based GWS surveys taken during characterization of the Schofield Barracks DU impact area in 2007 (CABRERA 2008). This technical memorandum has been prepared to present the findings of the aerial surveys conducted at PTA from October 28, 2008 through December 12, 2008.

2.0 SITE HISTORY

PTA is located on the island of Hawaii between Mauna Loa, Mauna Kea, and the Hualalai Volcanic Mountains (Figure 2-2). It extends up the lower slopes of Mauna Kea to approximately 6,800 feet in elevation and to about 9,000 feet on Mauna Loa. The training area is about midway between Hilo on the east coast and the Army landing site at Kawaihae Harbor on the west coast. The area is the largest Department of Defense (DOD) installation in Hawaii. The area is accessible by air with permission of military Air Traffic Control helicopter or land via Saddle Road from Hilo or Kona.

According to the *Archives Search Report* (ASR) *On the Use of Cartridge, 20MM Spotting M101 For Davy Crockett Light Weapon M28, Schofield Barracks and Associated Training Areas, Islands of Oahu and Hawaii* (USACE 2007), training on the Davy Crockett weapons system was likely conducted at PTA between 1962 and 1968. Preliminary aerial reconnaissance conducted in 2007 and early 2008 identified the presence of pistons, spotter round bodies (SRB), DU fragments and other components indicative of the Davy Crockett system use at PTA (CABRERA 2008A).

The primary contaminant associated with the spotter rounds body (SRB) is D-38 uranium alloy (92% DU and 8% Molybdenum), also called depleted uranium (DU). This DU alloy was used in the SRB of training rounds for the Davy Crockett weapon system because of its high density and weight. The DU component of the spotter round is approximately four inches in length and one inch in diameter.

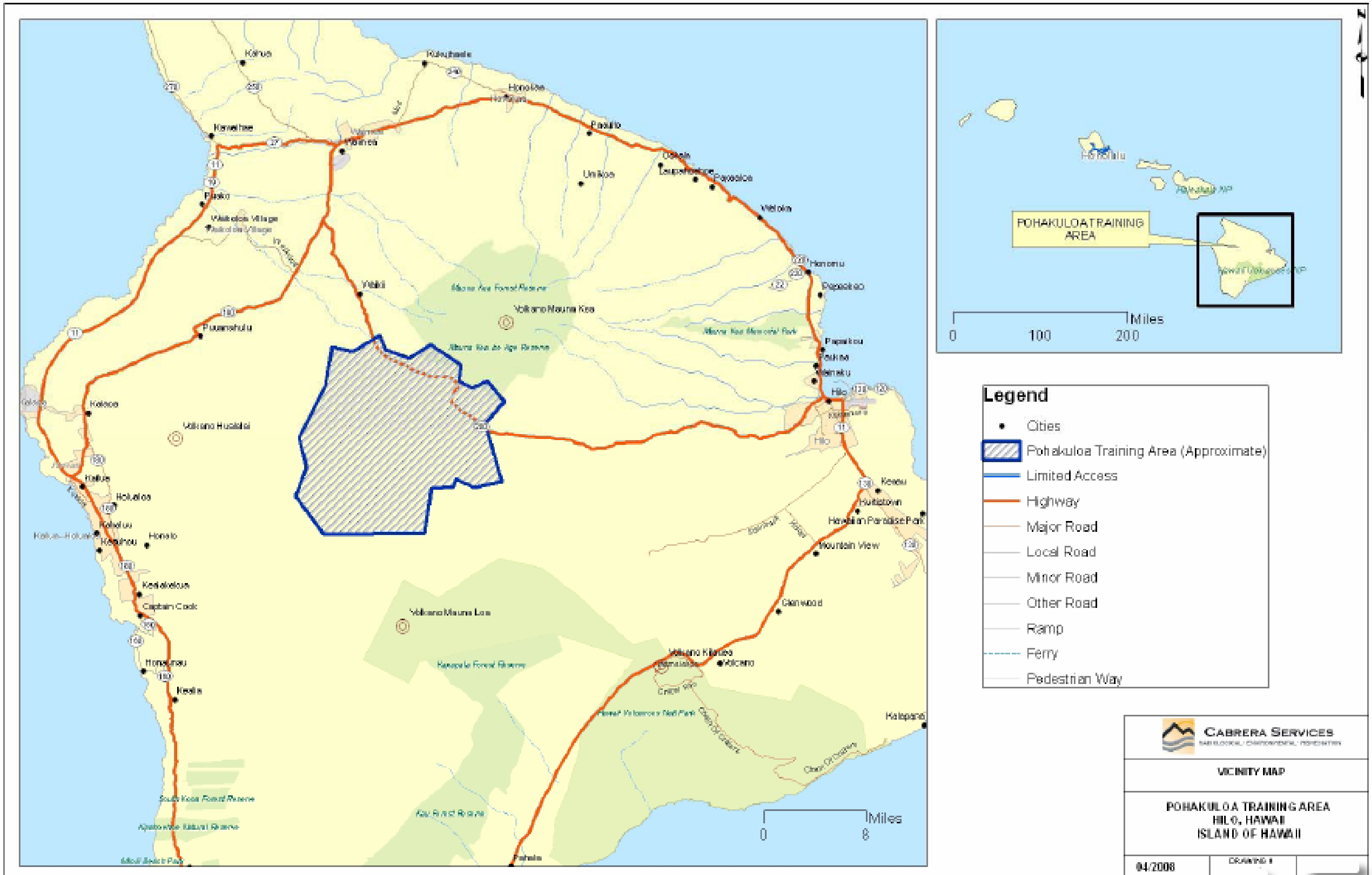


FIGURE 2-1: PTA VICINITY MAP

2.1 Summary of Existing Data

The presence of DU at PTA been the subject of recent scoping investigations, and Characterization Surveys completed in 2007 by CABRERA and described in *Technical Memorandum, Depleted Uranium Scoping Investigations Makua Military Reservation, Pohakuloa Training* Area*, Schofield Barracks Impact Area, Islands of Oahu and Hawaii* (CABRERA 2008A).

Historic records searches and map analyses identified at least twelve present and past range locations at the PTA. Based on criteria known to have been regulated for Davy Crockett ranges (e.g., size of area, security provisions) the USACE identified four potential Davy Crockett Ranges (Range 10, 11T, 14 and Range 17). Field observations at these four ranges were recommended.

The 2007 scoping survey and characterization efforts consisted of site visits, surface soil and debris sampling and analysis, and radiological scanning. Laboratory analyses of the samples included gamma spectroscopy, alpha spectroscopy for uranium (U) isotopes, total metals, and herbicides. Results of the scoping and characterization survey relevant to an aerial survey are summarized as follows:

- The visual and scanning surveys identified no distinct surface areas with yellow, oxidized DU metal fragments.
- The visual and scanning surveys did identify non-oxidized metal fragments, partial spotter round bodies, and Davy Crockett system components on Range 11T consistent with DU and the Davy Crockett weapons.
- Pistons associated with the Davy Crockett system were identified on Ranges 11T, 10, 14 and 17.
- During the scoping survey, nine soil samples were collected around the perimeter of PTA at locations areas where sediment had or may have collected from past runoff/erosion. These analysis of these soil samples showed no indication of DU.

The soil sample locations are shown in Figure 2-3. All of the samples were analyzed for isotopic uranium by alpha spectrometry. The results of the analyses are provided in Table 2-1. All of the results are consistent with naturally occurring concentrations of uranium. None of the results indicate uranium depletion, where the ^{234}U activity concentration is significantly lower than the ^{238}U activity concentration.

Aerial site reconnaissance was conducted at PTA using a Bell Long Ranger and Hughes 500 helicopters to look for pistons and other visually identifiable indicators of the Davy Crockett weapons system. The aerial team included two personnel, one situated on each side of the aircraft. Numerous Davy Crockett system pistons were identified in four general areas during the aerial reconnaissance survey of PTA on the four ranges.

FIGURE 2-2: 2007 SCOPING SURVEY SOIL SAMPLING LOCATIONS AND DAVY CROCKETT AREAS

TABLE 2-1: 2007 PTA SOIL SAMPLE RESULTS

Sample	Analyte	Activity (pCi/g)	2σ Counting Error (pCi/g)	Total Error (pCi/g)	MDA (pCi/g)
4010	U-233/234	0.117	0.04	0.046	0.009
	U-235	0.004	0.008	0.008	0.011
	U-238	0.132	0.042	0.05	0.009
4011	U-233/234	0.157	0.047	0.057	0.009
	U-235	0.008	0.011	0.012	0.011
	U-238	0.215	0.056	0.07	0.009
4012	U-233/234	0.344	0.078	0.104	0.01
	U-235	0.009	0.013	0.013	0.012
	U-238	0.324	0.075	0.099	0.01
4013	U-233/234	0.098	0.037	0.042	0.009
	U-235	0	0	0	0.011
	U-238	0.114	0.04	0.046	0.009
4014	U-233/234	0.12	0.043	0.049	0.01
	U-235	0	0	0	0.012
	U-238	0.127	0.044	0.051	0.01
4015	U-233/234	0.1	0.037	0.042	0.009
	U-235	0.004	0.008	0.008	0.011
	U-238	0.086	0.035	0.039	0.009
4016	U-233/234	0.302	0.068	0.091	0.009
	U-235	0.025	0.02	0.021	0.011
	U-238	0.238	0.059	0.076	0.009
4017	U-233/234	0.254	0.061	0.079	0.009
	U-235	0.008	0.012	0.012	0.011
	U-238	0.22	0.056	0.071	0.009
4018	U-233/234	0.285	0.067	0.088	0.009
	U-235	0.021	0.019	0.02	0.012
	U-238	0.239	0.061	0.077	0.009

3.0 PTA 2008 AERIAL SURVEY PROJECT DESCRIPTION

3.1 Scope and Objectives

The scope of this project encompasses: a) Aerial collection and analysis of gamma spectroscopic data over defined areas of interest (Figure 3-1) of potential Davy Crockett impact areas using the CABRERA A-CLASS system consisting of a large volume energy stabilized thallium activated sodium iodide NaI(Tl) detector system over areas of interest outlined in red on Figure 3-1; b) Visual inspection/observation from both the ground and air of the defined areas of interest for the presence of the following Davy Crockett system components:

- Aluminum shrapnel/pieces from the rear body assembly and plastic fiberglass from the fins and windscreen of the Projectile, Atomic Supercaliber 279 millimeter (mm) Practice M390,
- Aluminum fin assemblies and projectile body pieces from the Cartridge, 20 mm spotting M101,
- Pistons from either the light or heavy Davy Crockett weapon, or,
- Bright yellow (oxidized) and non-oxidized fragments from uranium alloy components.

c) Ground based GWS for the confirmation/correlation of indications of DU presence and/or absence as well as entry into potential areas not accessible by aerial survey, and, d) Collection of soil samples (where available) from areas identified as potential locations of SRBs, fragments, DU contaminated soil, Davy Crockett debris, and runoff/sedimentation areas.

Based on the range of the Davy Crockett system spotter rounds the areas of interest aerial radiation survey areas were further refined to include areas from 1 km to approximately 2 km to encompass the most likely to contain remains of the spotter rounds. Visual reconnaissance for pistons was conducted at distances from suspected launch points of between 600 and approximately 800 meters.

Virtual grid lines (Figure 4-2) were projected over aerial survey areas to maintain aerial survey spacing and to aid with navigation in areas due to the lack of fixed and easily identifiable visual reference points. Grid lines were projected in prevailing wind directions where possible to take advantage of lift and reduce power and torque requirements due to the demands on the helicopter which occurred due to the increased altitude of the training area.

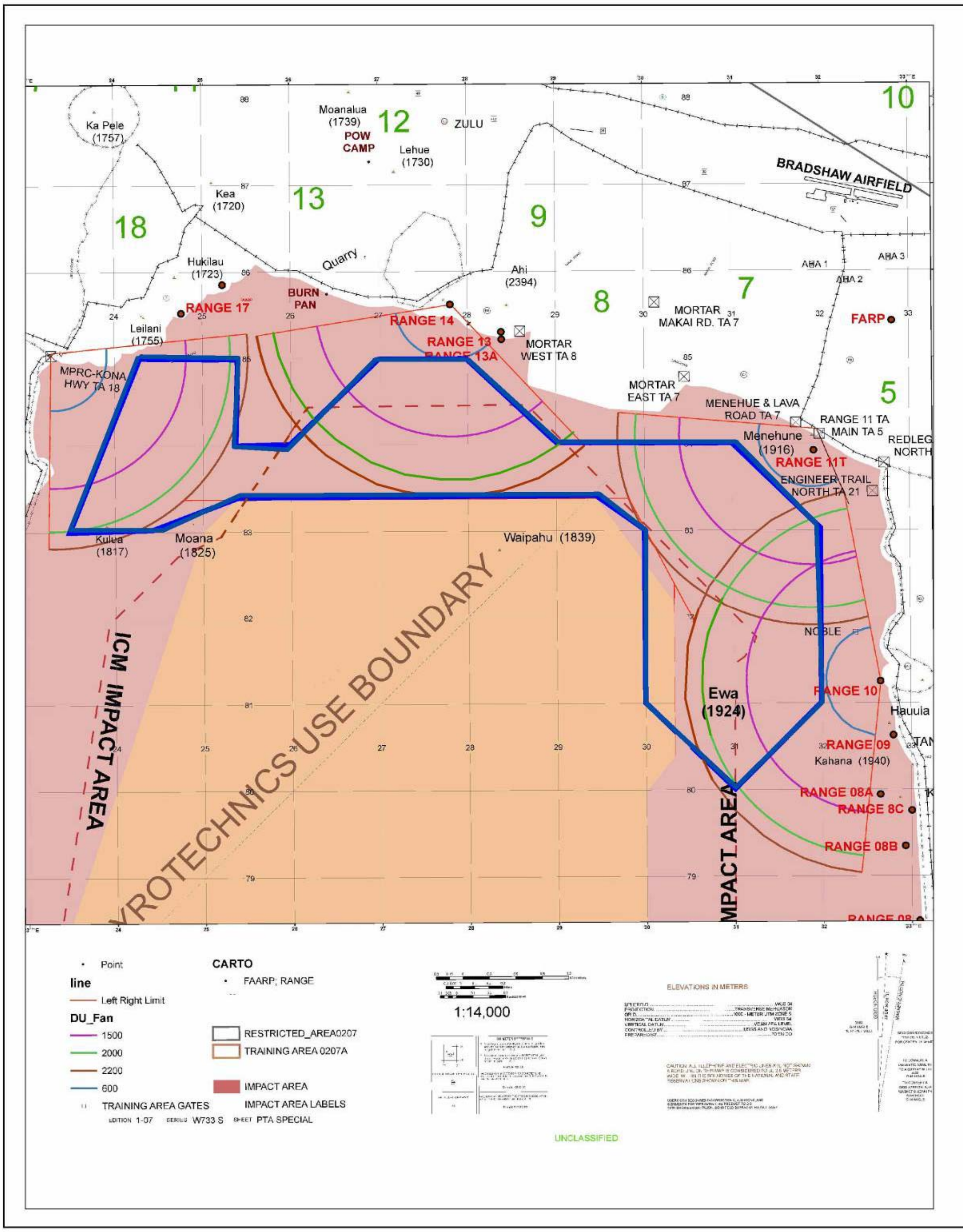


FIGURE 3-1: PTA AREA OF INTEREST

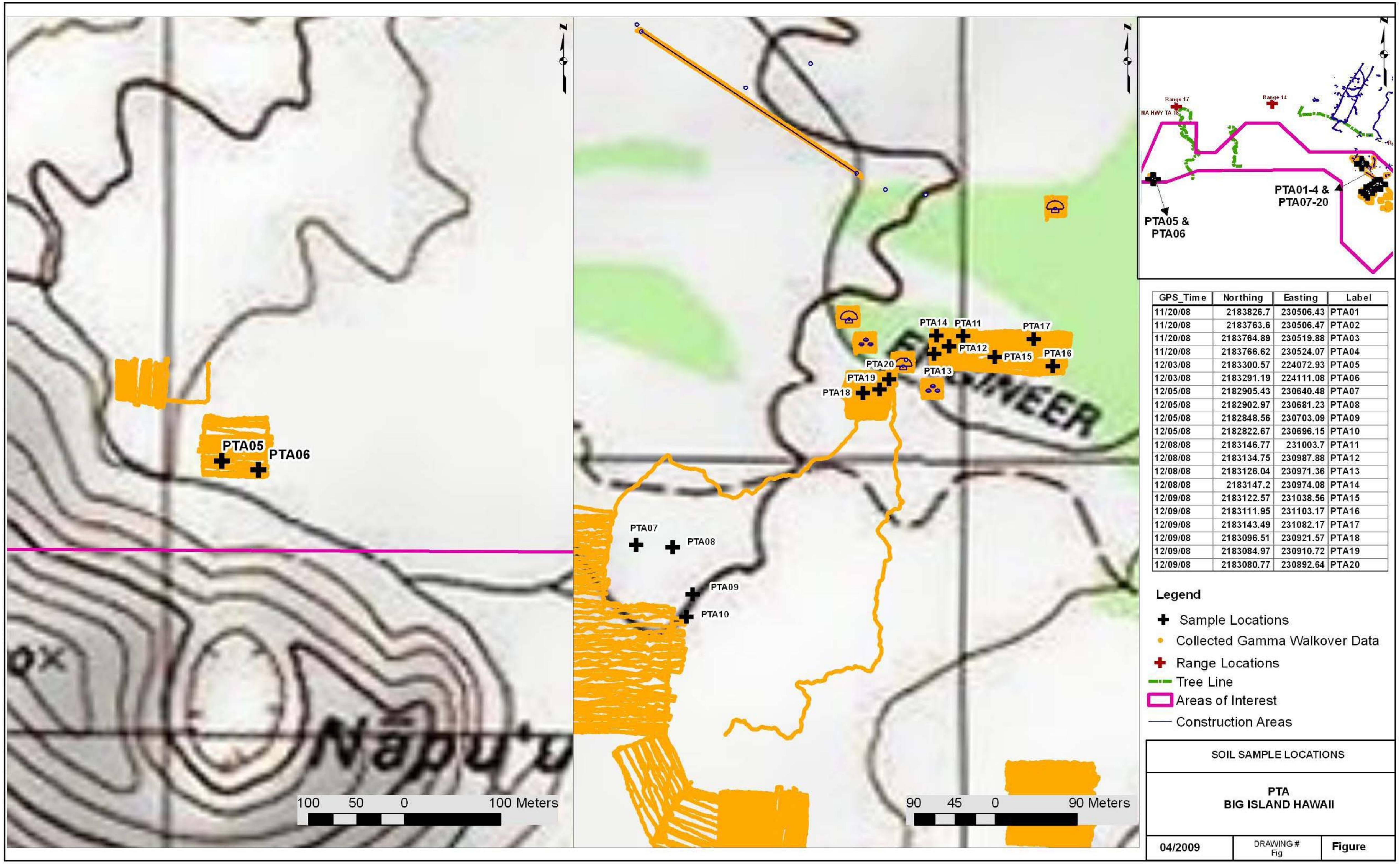
4.0 SAMPLE COLLECTION AND ANALYSIS METHODS

4.1 Soil Collection/Sampling

A total of twenty surface soil samples were collected in areas of interest within ranges 10, 11T and 17 (Figure 4-1). These samples included locations in the vicinity of DU fragments and finds on ranges 10 and 11T, down range areas of 17, and BAX construction areas within the 1 to 2 km areas of range 11T. Sample locations are listed in figure 4-1 and in table 4-2

Small hand tools (trowels) and either nitrile or vinyl gloves were used for sample collection. Samples were collected and stored in double re-sealable plastic bags. Soil and fragmented volcanic material was collected from approximately the top 1-2" inches of the ground, in area that was generally 6 by 6 inches, but up to 12 by 12 inches in size due the very shallow layer of soil/volcanic material that was available. Approximately 200-250 grams of soil/volcanic material was collected at each sample location. Tools were rinsed with potable water and surveyed for contamination between samples. Field personnel removed visible vegetation and large rocks from the soil samples. All samples were scanned before and after being collected and, as were all sample containers prior to packaging for shipment to the laboratory.

Soil samples were analyzed for uranium via alpha spectroscopy by a NELAP accredited laboratory using method ATSM-D3972. The sample results are consistent with the presence of natural uranium in which the activities of both ^{238}U and ^{234}U are essentially equivalent. Samples containing DU would have ^{234}U activity significantly below that of ^{238}U. The results of the sample analyses are listed in Table 4-1.



GPS_Time	Northing	Easting	Label
11/20/08	2183826.7	230506.43	PTA01
11/20/08	2183763.6	230506.47	PTA02
11/20/08	2183764.89	230519.88	PTA03
11/20/08	2183766.62	230524.07	PTA04
12/03/08	2183300.57	224072.93	PTA05
12/03/08	2183291.19	224111.08	PTA06
12/05/08	2182905.43	230640.48	PTA07
12/05/08	2182902.97	230681.23	PTA08
12/05/08	2182848.56	230703.09	PTA09
12/05/08	2182822.67	230696.15	PTA10
12/08/08	2183146.77	231003.7	PTA11
12/08/08	2183134.75	230987.88	PTA12
12/08/08	2183126.04	230971.36	PTA13
12/08/08	2183147.2	230974.08	PTA14
12/09/08	2183122.57	231038.56	PTA15
12/09/08	2183111.95	231103.17	PTA16
12/09/08	2183143.49	231082.17	PTA17
12/09/08	2183096.51	230921.57	PTA18
12/09/08	2183084.97	230910.72	PTA19
12/09/08	2183080.77	230892.64	PTA20

FIGURE 4-1: PTA SOIL SAMPLE LOCATIONS

TABLE 4-1: PTA ALPHA SPECTROSCOPY SOIL ANALYSIS RESULTS

Sample	Analyte	Activity (pCi/g)	Total Error (pCi/g)	MDC (pCi/g)
PTA01-112008	U-234	0.48	0.13	0.05
	U-235	0.051	0.041	0.044
	U-238	0.37	0.11	0.04
PTA02-112008	U-234	0.202	0.079	0.053
	U-235	0.001	0.028	0.062
	U-238	0.209	0.079	0.037
PTA03-112008	U-234	0.44	0.13	0.07
	U-235	0.032	0.041	0.069
	U-238	0.43	0.13	0.08
PTA04-112008	U-234	0.228	0.094	0.099
	U-235	0.015	0.031	0.061
	U-238	0.243	0.089	0.062
PTA05-120308	U-234	0.41	0.13	0.04
	U-235	0.011	0.033	0.051
	U-238	0.3	0.11	0.05
PTA06-120308	U-234	0.42	0.12	0.02
	U-235	0	0.031	0.021
	U-238	0.36	0.11	0.05
PTA07-120508	U-234	0.112	0.068	0.092
	U-235	0.025	0.038	0.068
	U-238	0.099	0.057	0.063
PTA08-120508	U-234	0.078	0.056	0.062
	U-235	0.009	0.038	0.025
	U-238	0.01	0.032	0.071
PTA09-120508	U-234	0.135	0.063	0.046
	U-235	0.027	0.034	0.054
	U-238	0.039	0.039	0.059
PTA10-120508	U-234	0.158	0.074	0.075
	U-235	0.037	0.041	0.064
	U-238	0.174	0.072	0.039
PTA11-120808	U-234	0.205	0.081	0.04
	U-235	0.01	0.03	0.047
	U-238	0.214	0.084	0.049
PTA12-120808	U-234	0.33	0.12	0.1
	U-235	0.01	0.033	0.073
	U-238	0.27	0.1	0.08
PTA13-120808	U-234	0.231	0.089	0.063
	U-235	0.025	0.031	0.047
	U-238	0.31	0.1	0.04
PTA14-120808	U-234	0.39	0.12	0.02
	U-235	0.022	0.029	0.02
	U-238	0.187	0.078	0.061
PTA15-120908	U-234	0.24	0.11	0.03
	U-235	0.012	0.047	0.032

Sample	Analyte	Activity (pCi/g)	Total Error (pCi/g)	MDC (pCi/g)
	U-238	0.136	0.087	0.099
PTA16-120908	U-234	0.36	0.12	0.05
	U-235	0.015	0.033	0.064
	U-238	0.4	0.13	0.04
PTA17-120908	U-234	0.31	0.1	0.06
	U-235	0.037	0.035	0.043
	U-238	0.285	0.096	0.052
PTA18-120908	U-234	0.236	0.086	0.039
	U-235	0.039	0.037	0.046
	U-238	0.183	0.076	0.048
PTA19-120908	U-234	0.41	0.12	0.08
	U-235	0.028	0.036	0.06
	U-238	0.259	0.092	0.069
PTA20-120908	U-234	0.31	0.1	0.06
	U-235	0.017	0.028	0.044
	U-238	0.258	0.09	0.038

TABLE 4-2: PTA SOIL SAMPLE LOCATIONS

Figure Label	Easting	Northing
PTA01	230506.4	2183827
PTA02	230506.5	2183764
PTA03	230519.9	2183765
PTA04	230524.1	2183767
PTA05	224072.9	2183301
PTA06	224111.1	2183291
PTA07	230640.5	2182905
PTA08	230681.2	2182903
PTA09	230703.1	2182849
PTA10	230696.2	2182823
PTA11	231003.7	2183147
PTA12	230987.9	2183135
PTA13	230971.4	2183126
PTA14	230974.1	2183147
PTA15	231038.6	2183123
PTA16	231103.2	2183112
PTA17	231082.2	2183143
PTA18	230921.6	2183097
PTA19	230910.7	2183085
PTA20	230892.6	2183081

4.2 Gamma Walkover Surveys

GWS surveys were conducted on ranges 10, 11T, 17 and a proposed BAX construction area located in the Eastern area of range 11T due to the large number of pistons identified on these ranges and to enable clearance for BAX construction activities. A total of 50 acres was surveyed by GWS. UXO avoidance was practiced in other GWS areas and coverage was dependent on the ability to enter an area. The very rugged terrain and long distances to reach areas for GWS reduced the productivity of the ground teams anywhere from 1 to 3 acres per day.

The purpose of the GWS was to locate radiation anomalies that indicate potential areas with relatively elevated radioactivity where biased soil sampling, and/or further investigations may be warranted. The GWS was performed using a thin crystal sodium iodide (NaI) Field Instruments for the Detection of Low Energy Radiation (FIDLER) detector with a Ludlum Model 2221 scaler/ratemeter. The detector was suspended a few inches above the ground while the surveyor walked over the area at a speed of approximately 0.5 meters per second, spacing each pass one meter from the previous pass. Each pass was spaced using GPS coordinates, and/or flags/marking tape, or other appropriate method to ensure straight survey paths. Measurement data were position correlated using a Trimble Pathfinder® global positioning system (GPS) receiver mated with a Trimble TSC™ graphical interface system (GIS) field device.

The GPS was used to link survey data to spatial locations (northing and easting) using state plane coordinates for Hawaii Zone 1 (island of Hawaii) and Zone 3 (island of Oahu), North American Datum 1983. By design, the GPS unit is self-checking, using data received from the satellite constellation to determine the precision and accuracy of its readings. Measurement and position data were automatically logged at one-second intervals.

The survey team also had a Ludlum Model 3 rate meter with a Ludlum Model 44-9 GM Pancake Probe and Ludlum Model 19 µR meter, which accompanied the field team for measurement of possible DU fragments and/or contaminated soil.
GWS data was post processed and analyzed and sorted by both Z-Score and/or count rate ranges due to the very wide range of data due to the detection of almost an entire spotting round. The data is plotted in figures for each range area as discussed in the sections below. An overall GWS coverage map of PTA is presented in Figure 4-2.

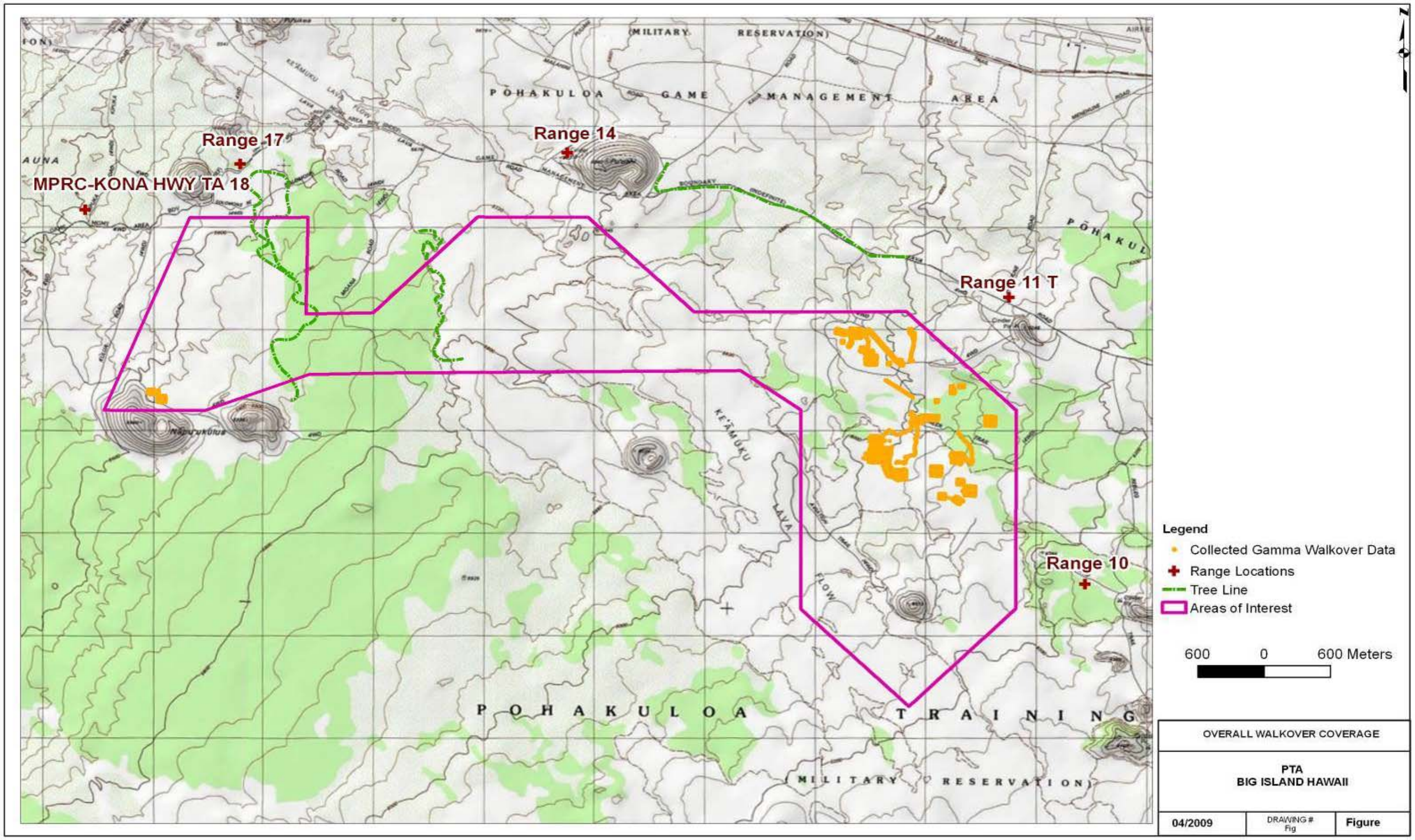


FIGURE 4-2: PTA GWS WALKOVER COVERAGE MAP

Ranges 10 and 11T

The ground survey team conducted GWS over an area of approximately 37.5 acres on range 11T and 2 acres within range 10. The survey team was directed to areas of suspected DU content based on helicopter observations of visible Davy Crockett components visible during aerial surveys, as well as areas of future BAX construction which fell into the area of interest as outlined in Figure 3-1. A concentrated effort was made in 11T due to the number of pistons identified on that range and the previous identification of DU on Range 11T. Gamma walkover surveys identified a largely intact spotter round with energetic material still remaining (PETN high explosive pellet and red phosphorus charge still intact) PHOTO 4-1, a partial spotter round body with attached aluminum tail assembly, photo 4-2, and small fragments of DU (not shown).

PHOTO 4-1: MOSTLY INTACT SPOTTER ROUND BODY

This spotter round was removed from the surface of the range, marked with pink flagging tape and placed in a nearby hole shielded from weather and potential disturbance by other surface detonations. The GPS coordinates and landmarks were provided to USAG-HI for future retrieval and disposal actions.

PHOTO 4-2: PARITAL SPOTTER ROUND WITH FIN ASSEMBLY

The aluminum fin with the partial DU spotter round body attached (figure 4-2) as well as the DU fragments that were recovered, were given to USAG-HI for storage and disposal. The conditions of the DU round and fragments showed only very minor oxidation as seen in figure 4-1 and were generally shiny and non-oxidized. These conditions demonstrated the significant differences in environment between Schofield Barracks (highly oxidized DU) and PTA (very low oxidizing conditions).

Within the remaining areas of 11T and 10 no additional DU was detected or located by GWS. GWS did identify five locations in the BAX construction area of range 11T with count rates of between 34,000 and 44,000 cpm, as compared to the area norm of approximately 2500 cpm, which should be revisited. These locations are identified by the red markings in the Northern most area of range 11T on figure 4-4A. The GPS positions/data for these positions are noted in the table 4-3.

TABLE 4-3: BAX CONSTRUCTION AREAS FOR REINVESTIGATION

CPM	Northing	Easting
35352	2183115	231110.2
39712	2183938	230347.7
34339	2183918	230367.2
44421	2184004	230457.1
35337	2184004	230457.1

Other than the partial SRB, tail section and small DU fragments, as described above, and these 5 locations, there were no other discrete and/or localized elevations in count rates that are typically associated with fragments of DU or contaminated soil. Soil sample results in these areas also did not indicate the presence of uranium, natural or depleted, in excess of natural background levels. Surveys of the future BAX construction areas, with the exclusion of the three possible locations for re-investigation, indicated the neither the presence of DU nor Davy Crockett system components. The GWS coverage results for range 11T and 10 and the BAX construction areas within the defined areas of interest and impact range of the Davy Crockett spotter rounds are presented in figure 4-3. Surveys of BAX areas outside the firing range areas of interest to the North of 11T were not conducted as the weapons system would not have been fired in this direction and no indications are present that these BAX areas were impact areas for the Davy Crockett system.

Range 17

GWS surveys in range 17 were conducted at a lower portion of the range where older targets (tanks and jeeps) of the Davy Crockett era were located. These particular areas were chosen for GWS survey because the very dusty conditions in this portion of the range precluded helicopter entry for aerial surveys. The survey area covered 2.1 acres. Results of the GWS in range 17 detected no DU fragments, Davy Crockett system, and no visual indications of use. Figure 4-4A includes the GWS data for range 17 in the lower right hand portion of the figure.

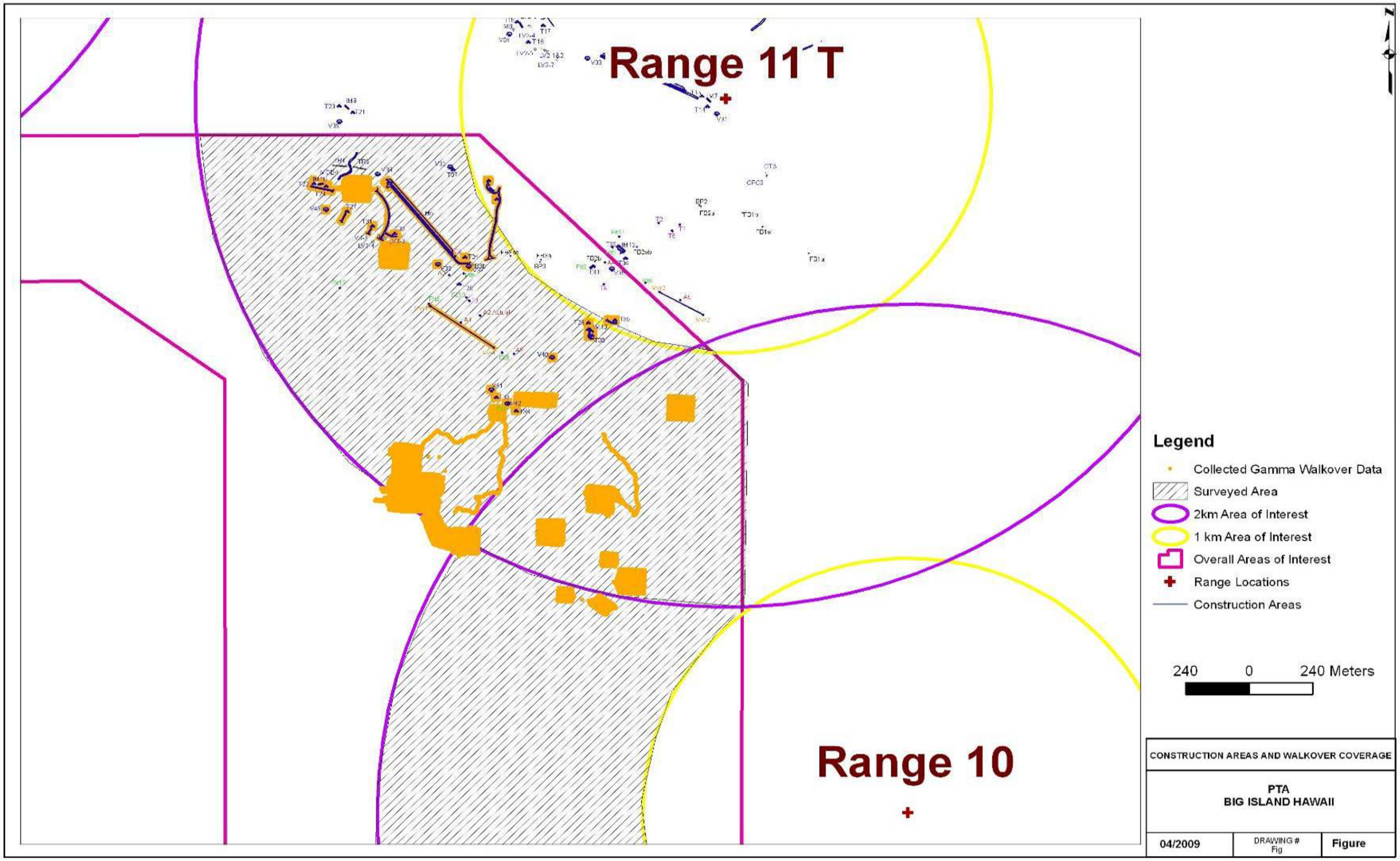


FIGURE 4-3: GWS COVERAGE ON RANGES 10, 11T AND BAX CONSTRUCTION AREAS

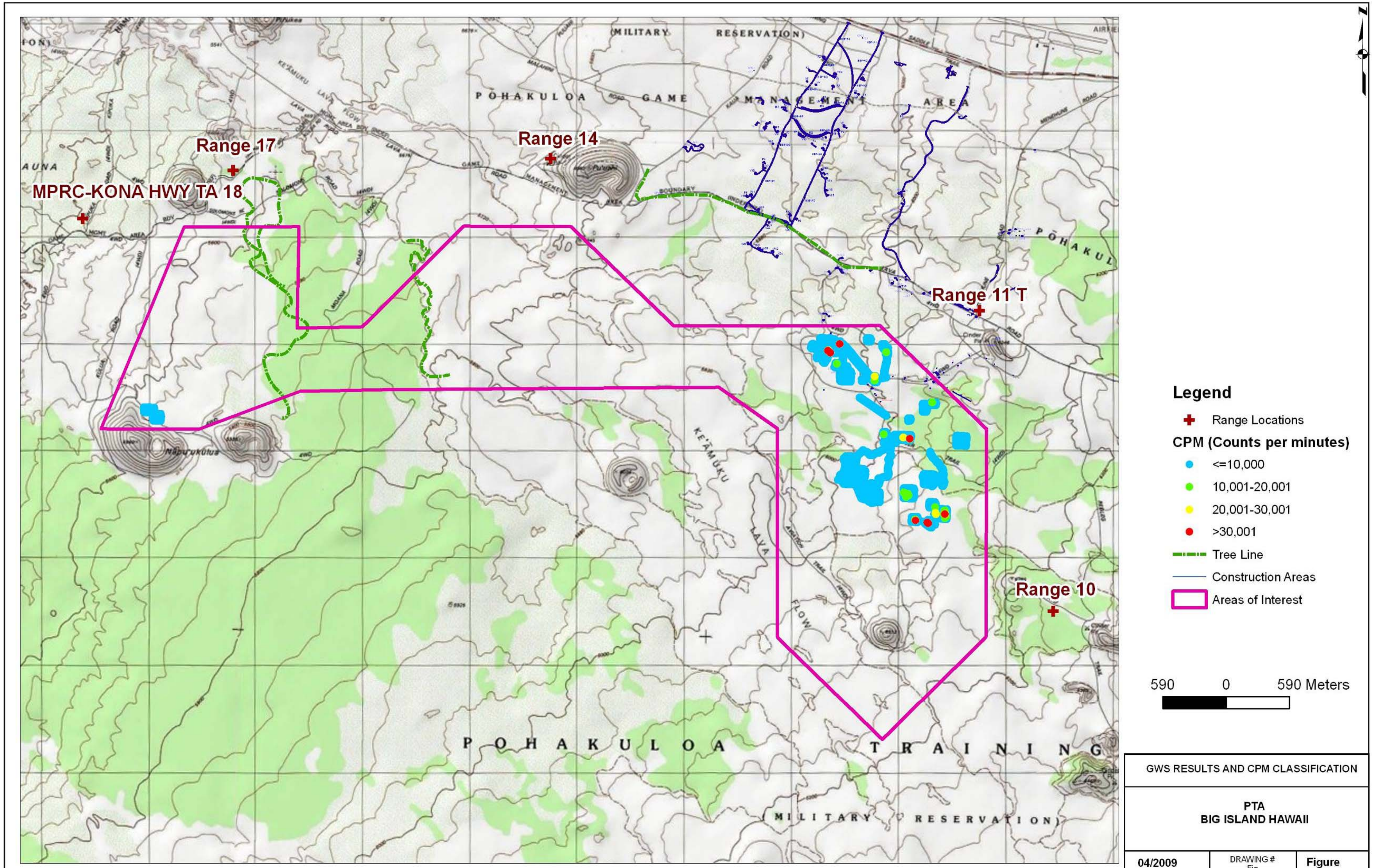


FIGURE 4-4: GWS PLOTS RANGES 10, 11T, BAX AND 17

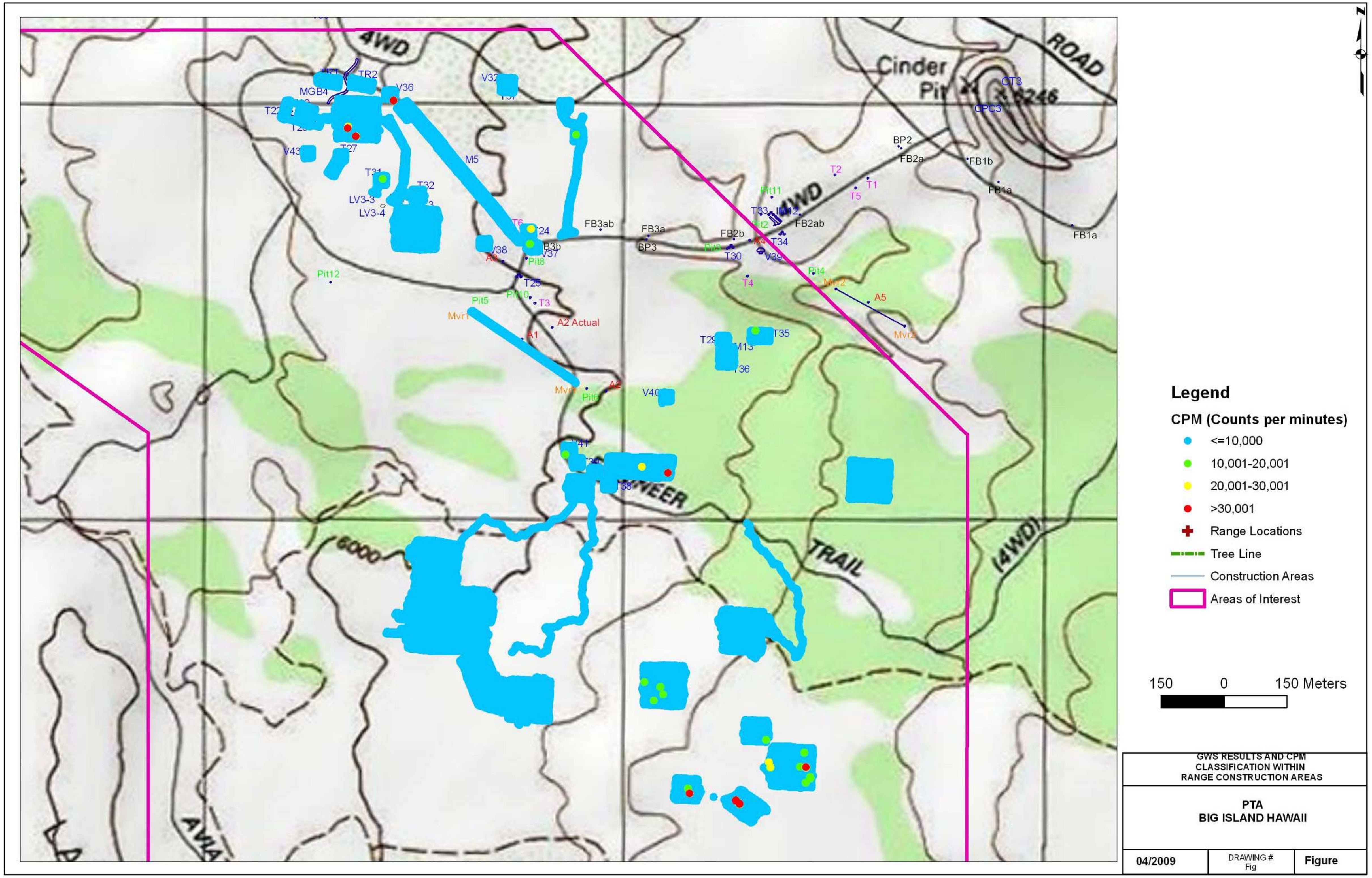


FIGURE 4-5: GWS RESULTS FOR BAX, 10, 11T

4.3 Aerial Gamma Flyover Surveys

The project included the advanced configuration platform for function and increased stability in flight conditions of the A-CLASS system on a helicopter platform. The platform was modified specifically for a Hughes 500 helicopter to include padded standoffs and a central adjustable lifting shackle/turnbuckle system which stabilized the platform from movement as compared to the nylon lifting straps used on the original system. In addition a large helicopter inverter system provided AC current. The system included a RSI-701 Controller Console digital gamma ray spectrometer/multi-channel analyzer (MCA)/data controller, four (4) RSX-256 4-liter (256 cubic inch) sodium-iodide (thallium activated) (NaI(Tl)) gamma scintillation detectors, internal Trimble Lassen SQ embedded GPS module, and a software integrated externally mounted Contour XLR laser range finder. The CLASS is designed as a turn-key system to rapidly measure, spatially correlate, and GIS map radioactivity concentrations in support of environmental characterization, remediation, and site closure activities.

The A-CLASS is an aerial design of the CLASS system mountable on a variety of helicopter models via cargo hook. It is ruggedized to operate in a variety of environmental conditions (Photos 4-3 and 4-4) and is equipped with a cloned video display to enable pilot navigation and altitude feedback data over the desired flight paths. A handheld Garmin GPS60cx system was also used on the helicopter to mark the locations over range targets, pistons, and debris from the Davy Crockett system during aerial surveys. Radiation and location information is collected by

PHOTO 4-3 CLASS SYSTEM MOUNTED ON A HUGHES 500

the system at a very high data transfer rate (nominally one data point every second), and stored in a non-corruptible data file for real-time feedback and data validation/post-processing. The system operator receives real-time feedback using "waterfall" plots of total and radionuclide specific energy response and geo-referenced mapping of relative radiation intensity. The data can also be transferred through a wireless network back to our data management center for real-time processing, and for conversion into GIS maps and data presentation formats.

The A-CLASS digital interface enables the user to pre-set multiple regions of interest (ROIs) within the energy spectrum to identify and track specific gamma radiation emissions from radioactive contaminants of concern (RCOCs). Using an ROI for field scanning is advantageous as it greatly reduces the detector background, which in turn reduces the scan minimum detectable concentration (MDC). The CLASS also utilizes internal energy gain stabilization to ensure the ROIs remain centered on the corresponding energy peaks. The A-CLASS operates with four (4) large volume (4L) NaI detectors and can be set up to collect data independently from each detector or in a serial collection mode. The independent data collection allows for better spatial sensitivity while the serial or summed collection mode allows for overall maximum detection sensitivity. The serial collection mode can operate effectively due to the digital gain stabilization which maintains consistent response over the survey interval.

Two regions of interest corresponding to the approximately 766 and 1001 keV photons emitted by ^{234m}Pa (a decay product in the ^{238}U decay chain), as well as others, can be used as a surrogate for the presence of ^{238}U. In addition the CLASS system tracks contributions to the spectrum from naturally occurring ^{40}K and Thorium for stabilization purposes. These two naturally occurring radionuclides may contribute background interference which can be subtracted from the spectrum. The RSI system is essentially continuously stabilized. Automatic Stabilization occurs approximately every 1 to 5 minutes. The RSI-701 controller uses three naturally occurring elements to achieve stabilization ^{40}K, ^{238}Uranium and ^{232}Th are combined with a least squares fit and compared to the accumulated spectral data. The system holds three "reference" spectrums in memory. An accumulated spectrum for each crystal is maintained in memory and when the count total exceeds a preset total the system then compares the individual crystal's spectrum to the reference spectrum and adjusts the gain accordingly to maintain the proper gain and energy calibration in each detector.

Data density during aerial surveys at PTA was controlled by using custom generated virtual flight lines (Figure 4-5) and by maintaining spacing manually by using spacing provided by the controller system display on both the laptop and the cloned pilot's display (Photo 4-4). At PTA it was only possible to use manual spacing provided within RSI system on a limited basis due to the decreased maneuverability and increased power requirements with the helicopter at altitude. Data was collected at intervals of one second and spacing between passes of the helicopter at an interval of approximately 10 meters and at a speed of approximately 2 to 3 meters per second, or less. Altitude above ground level (AGL) is determined by a laser range finder and the data display in the helicopter is color coded to give the system operator and the pilot immediate feedback on system AGL. The pilot can appropriately adjust altitude, in accordance with safety protocols, obstacles, flight conditions and the presence of foreign object debris (FOD).

At PTA an increased awareness and flight restrictions were required due to the presence of lightweight debris (plywood, aluminum scrap, aluminum target, and munitions debris) which could become airborne due to helicopter rotor wash. Volcanic dust limited the minimum altitude in places throughout the range. The target range for AGL is 10 to 12 feet or lower. Processing of the spectral data is accomplished within ESRI/ARCGIS which enables a variable radial wide area averaging of radiation data within individual ROIs and gamma ray spectrums.

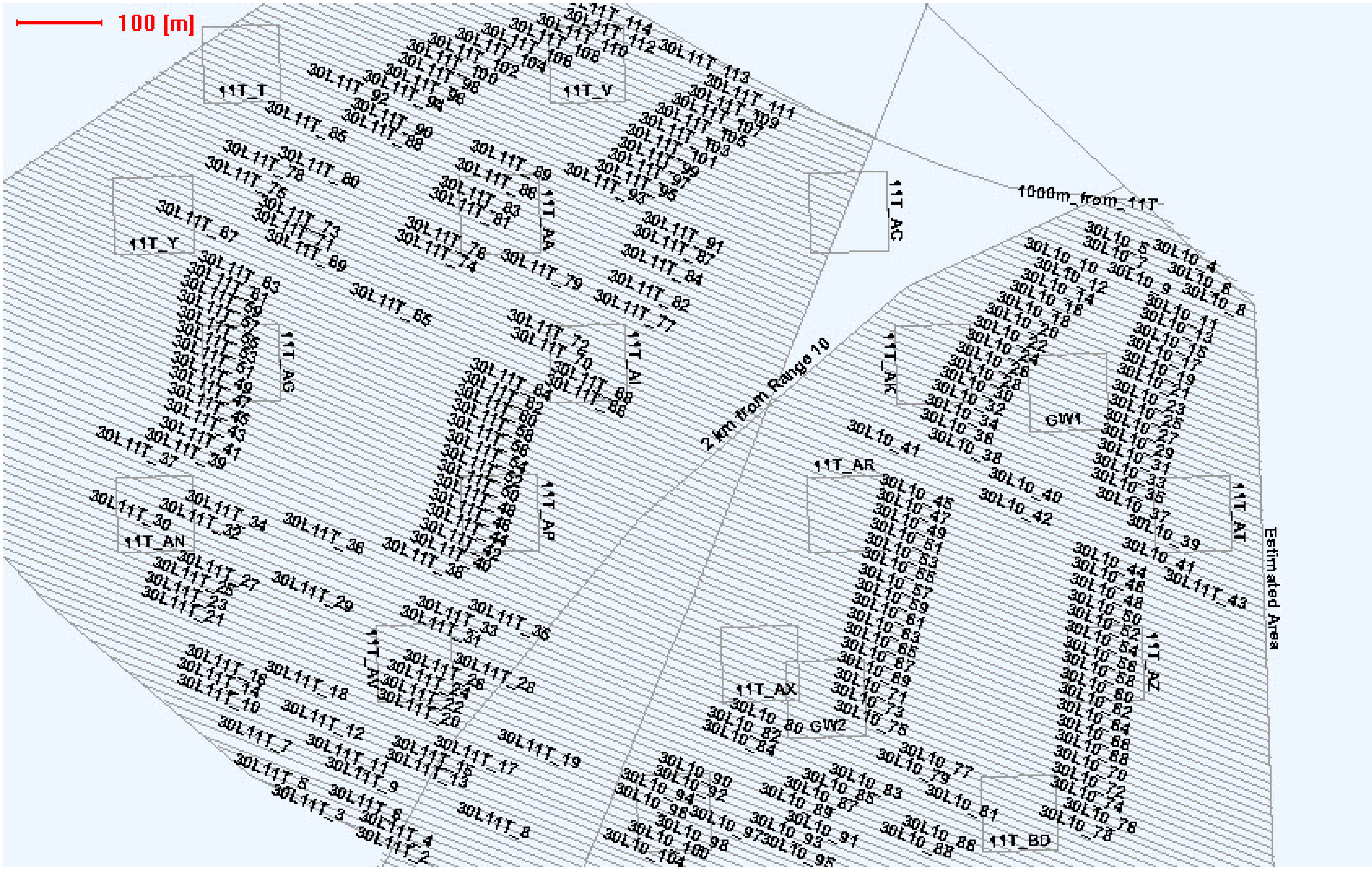


FIGURE 4-6: VIRTUAL GRID AREA OF INTEREST OVERLAY AT PTA

PHOTO 4-4: MANUAL SPACING USING CLONED DISPLAY AT PTA

4.4 Aerial Gamma Flyover Survey Results

Approximately 936 acres were surveyed using the A-CLASS system and the results are shown in Figures 4-6 through 4-10. In the outlined areas of interest, surveys concentrated in the 1 to 2 km range and were focused on covering areas indicated by the location of pistons as well as the location of older Davy Crockett era, and other target structures as shown in figure 4-8. These older target structures were identified as steel pipes and era vehicles. The terrain was rugged and presented many locations (cracks, crevices and holes) primarily in the ‘a‘a (pronounced it "ah-ah") lava into which portions of the Davy Crocket system components could fall. However, large flat areas existed in portions of the range, largely on Pahoehoe (pronounced *“pa-hoi-hoi”)* lava flows upon which Davy Crockett components could be easily identified visually from the helicopter and ground crews directed to these areas for additional on ground verification for the presence of DU. While large cracks and holes also existed in the Pahoehoe, this type of lava flow presents the largest amount of flat surface area at PTA. Typical types of terrain at PTA are show in photos 4-5, 4-6 and 4-7.

PHOTO 4-5: PAHOEHOE LAVA ON RANGE 11T-PTA

PHOTO 4-6: HELICOPTER OVERFLYING A'A' LAVA AT PTA

PHOTO 4-7: GRASSY TERRAIN WITH ROCK OUTCROPPINGS-RANGE 17

Distinct patterns of elevated Z-scores in excess of 3, noted by the red areas on the flyover data results, were present throughout a number of areas at PTA. These areas, when investigated by ground field teams and GWS, did not contain DU or evidence of the Davy Crockett weapons system. The areas did have an overall higher level of background, but no discrete sources could be identified.

During flyover surveys, these areas of increased activity were evaluated in real time using the RSI console system's regions of interest and peak search capabilities. During this evaluation it appeared that these fluctuations in activity were associated with natural distributions and geological formations such as a rock out cropping.

Within survey areas which Z-scores indicated a pattern of increase, the gamma ray spectrums from these areas (the red highlighted areas on figures 4-8 through 4-10), was reviewed for consistency of ratios between naturally occurring radioactive materials ^{40}K, ^{232}Th, ^{238}U and ^{226}Ra and indications of increase in ^{238}U by itself. The ratios that were observed were consistent between areas considered within the normal distribution range to those outside of a Z-Score of 3. Review of the integrated gamma-ray spectrum from the areas did not indicate an increase in ^{238}U activity indicative of the presence of DU.

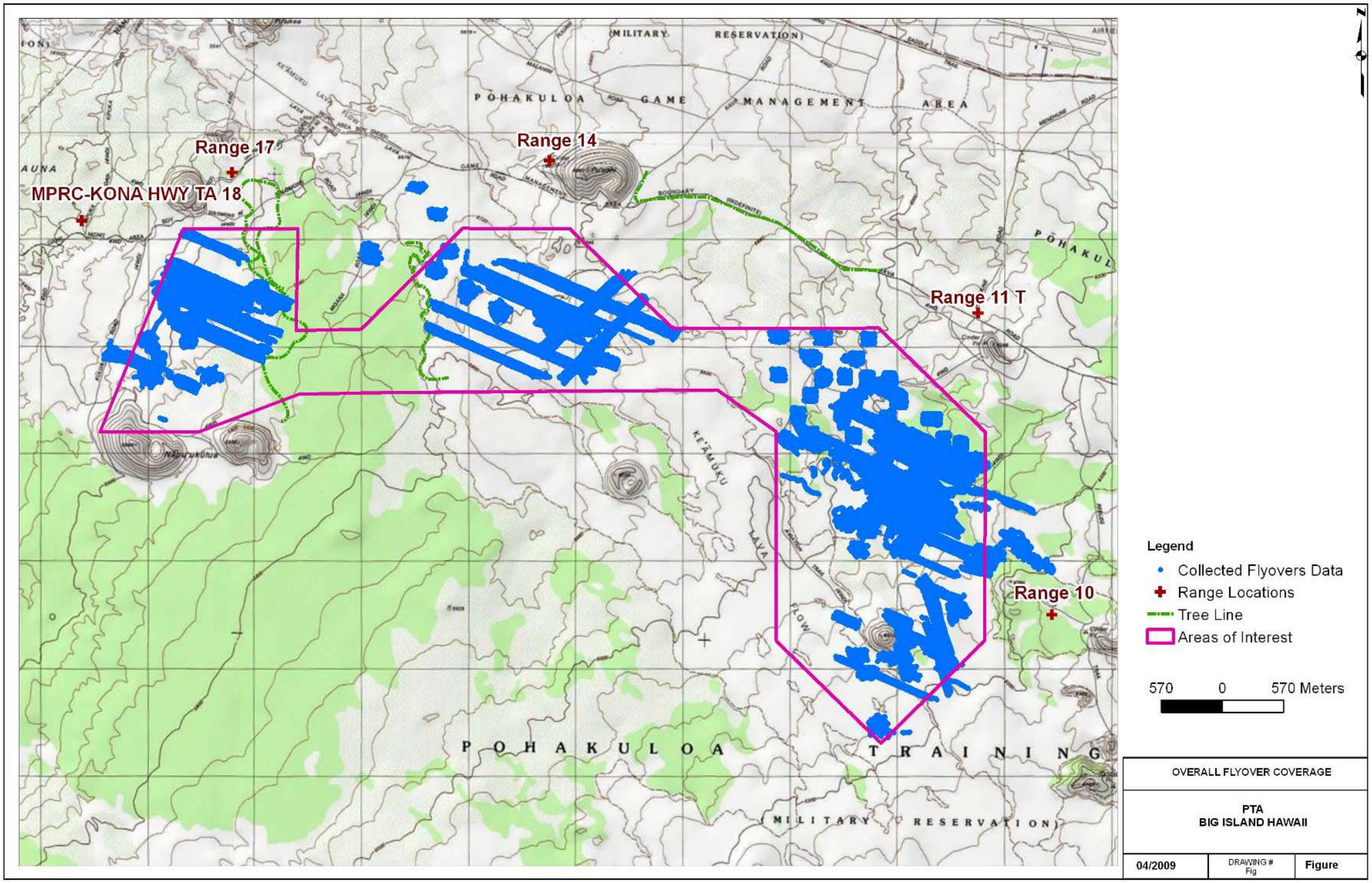


FIGURE 4-7: AERIAL SURVEY COVERAGE MAP

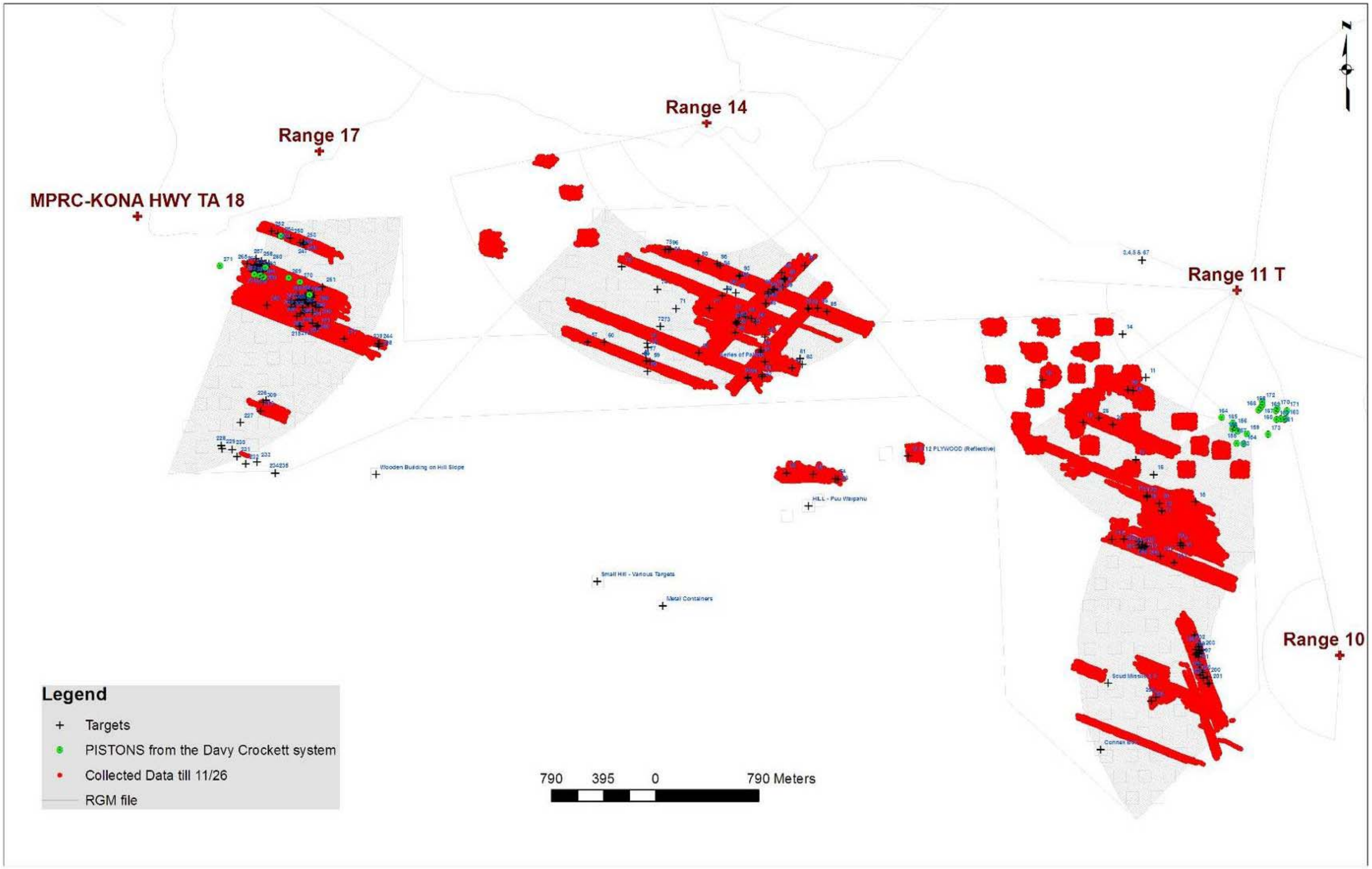


FIGURE 4-8: COVERAGE MAP AND TARGET LOCATIONS

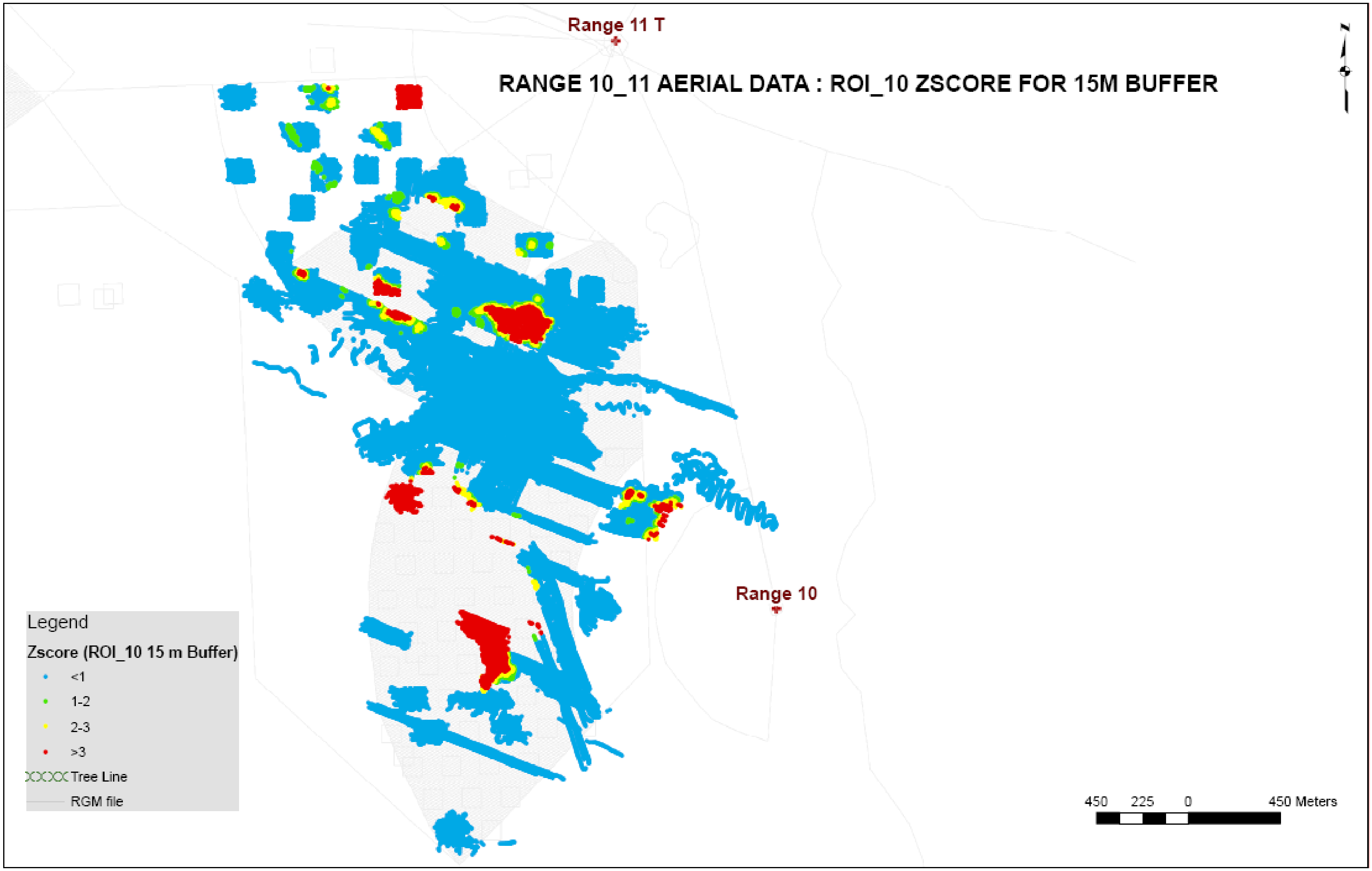


FIGURE 4-9: AERIAL SURVEY Z-SCORE DATA RANGES 10 AND 11T

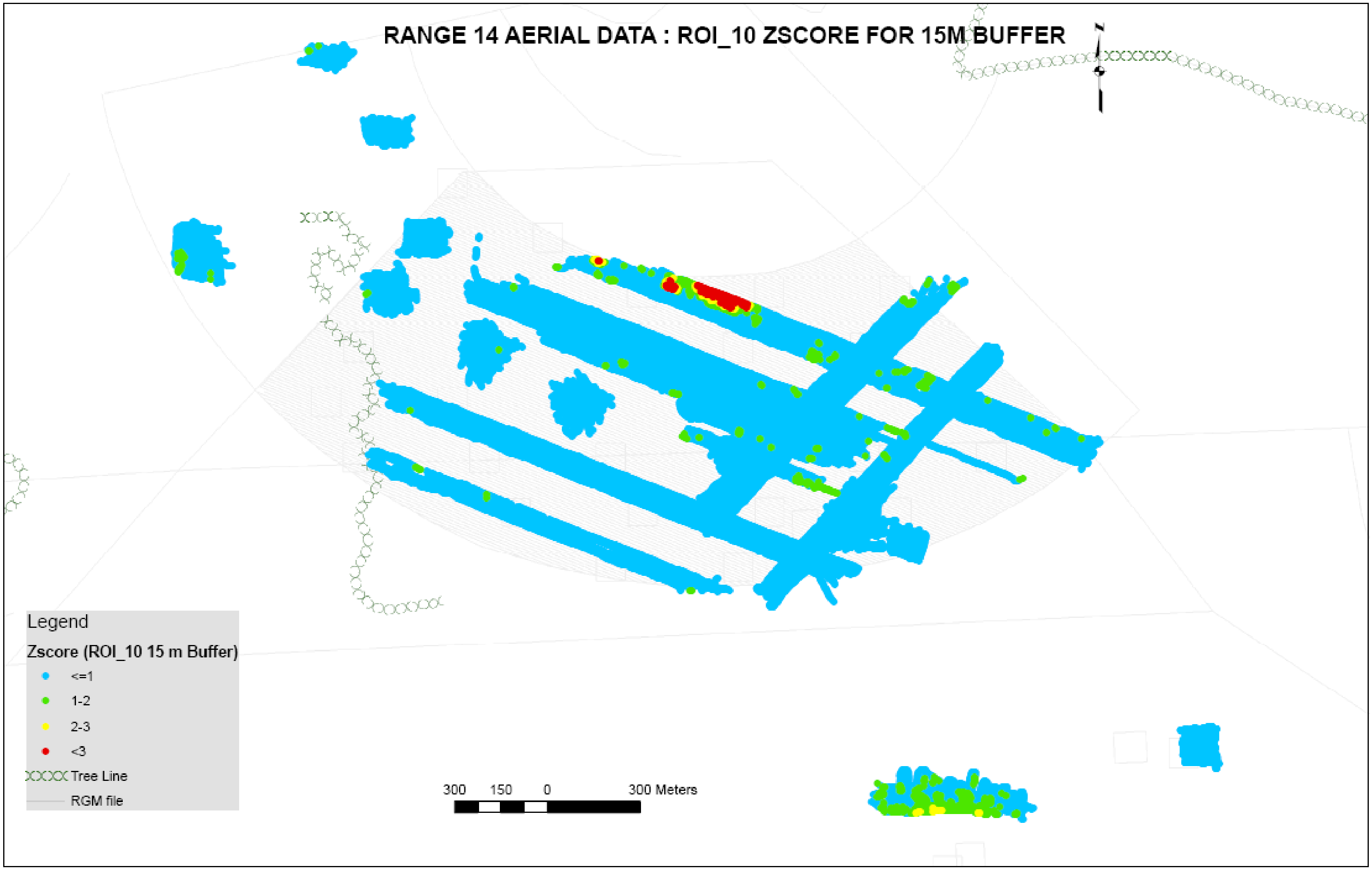


FIGURE 4-10: AERIAL SURVAY Z-SCORE DATA FOR RANGE 14

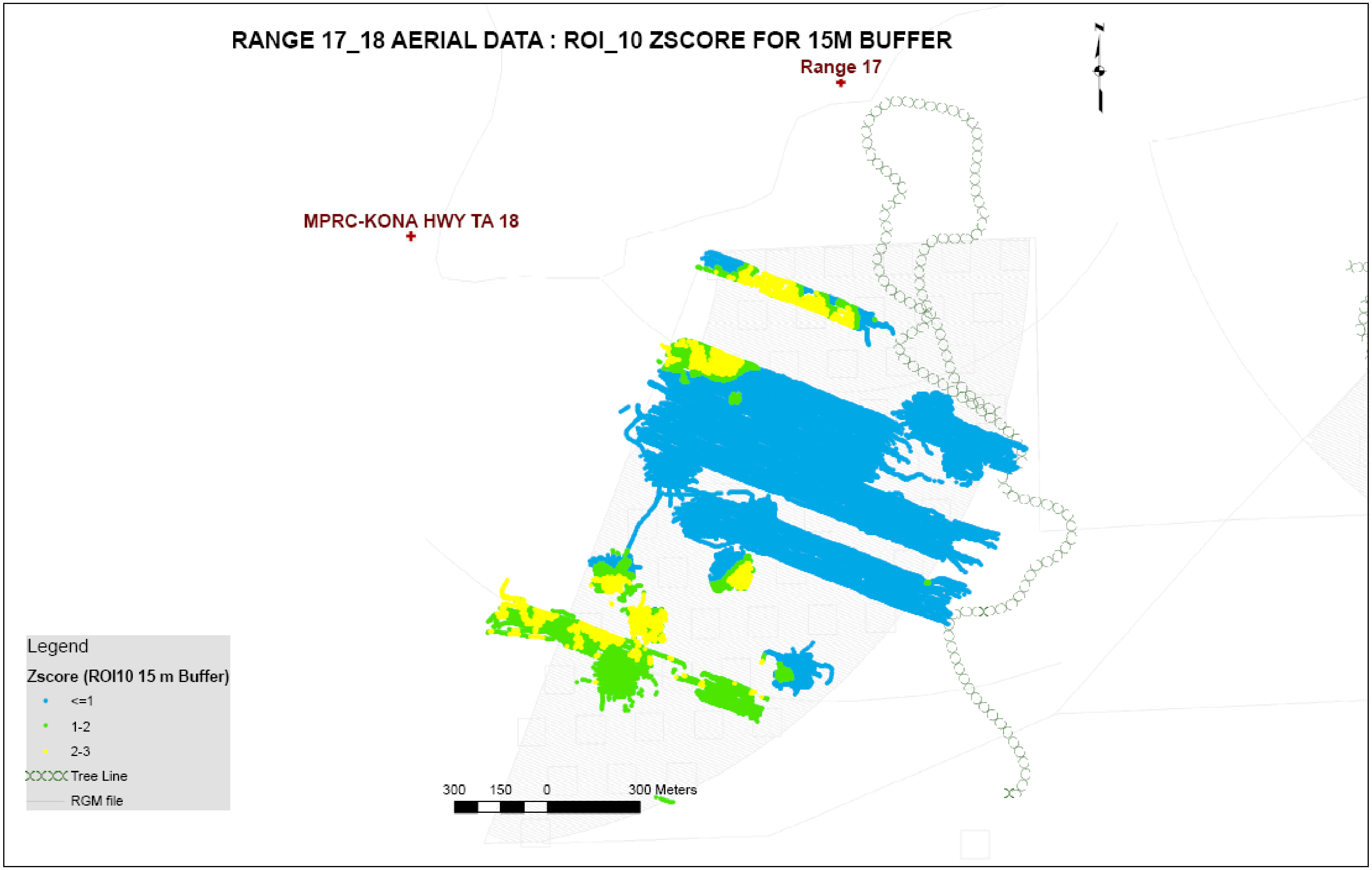


FIGURE 4-11: AERIAL SURVEY Z-SCORE DATA RANGE 17

4.5 Aerial Visual Reconnaissance Survey Results and Flight Obstacles

A visual aerial survey from the Hughes 500 was also conducted to look for pistons and other visually identifiable indicators of the Davy Crockett system while radiological data was being collected in the range areas and during some higher altitude over-flights around the perimeter of the range at distances of between 600 to 800 meters from the launch point. Additional pistons were located during the perimeter visual survey, the identification of these pistons identified served to confirm that the existing ranges suspected of containing Davy Crockett DU and systems appear to be the correct locations of interest.

Due to the very low altitude of flight and obstacles (Trees, branches, bushes) the A-CLASS system operator assisted the pilot in the identification of FOD and object avoidance. During flyovers it was not uncommon for pieces of plywood, wood and scraps of aluminum and branches/brush to be lifted up and become airborne. These objects presented a significant hazard for the helicopter and these areas were avoided in the future. At PTA volcanic dust presented a significant problem for helicopter rotor (both tail and main rotor) and engine wear and it was not possible to fly in these locations. Even by practicing avoidance of these areas the helicopter rotors experienced significant wear throughout the survey (Photo 4-8).

PHOTO 4-8: HELICOPTER ROTOR WEAR AT PTA

More pistons, back plates, spotter round bodies, and aluminum tail fins were identified during the surveys at PTA. The components of the Davy Crockett system particularly back plate assemblies and windscreens have a very distinct coloring as seen in photos 4-4 and 4-5 and are readily observable from the air. All photographs taken during the PTA surveys are included in appendix E.

PHOTO 4-9: PART OF DAVY CROCKETT REAR PLATE ASSEMBLY

PHOTO 4-10: PART OF DAVY CROCKETT REAR PLATE ASSEMBLY

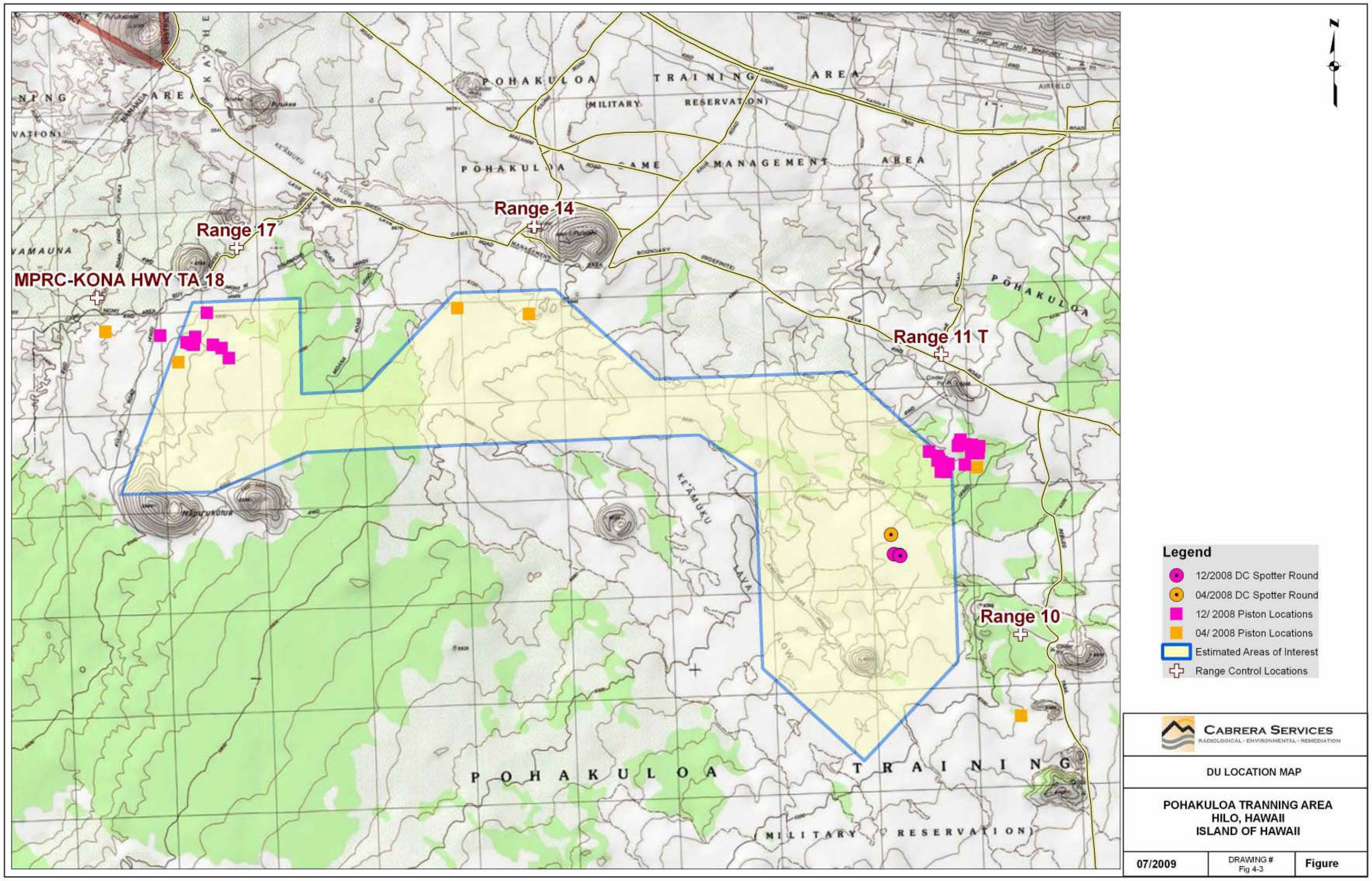


FIGURE 4-12: LOCATIONS OF PISTONS AND DU AT PTA

4.6 Quality Control Measures

Data collection activities were performed in a controlled and deliberate manner. Data were collected by trained individuals with calibrated instruments following written procedures and/or protocols. Data were recorded and reviewed, and documentation is auditable. Instrumentation capable of detecting the radiation types and energies of interest were selected, calibrated, and maintained for survey data collection and sample analysis. All equipment used in the field was checked using either a thorium-230 (^{230}Th) alpha check source, a technetium-99 (^{99}Tc) beta check source, or a cesium-137 (^{137}Cs) beta/gamma check source and/or in accordance with manufacturer recommendations. Operational checks were performed for each instrument before and after each use. All instruments used in the field met data quality requirements. Samples were collected in the field using clean tools and gloves. All samples were scanned before and after being collected, as were all sample containers prior to packaging for shipment to the laboratory. Sample tools were cleaned between each sample collection.

4.7 Data Quality Objectives

The Data Quality Objectives (DQOs) specify the type, quality, quantity, and uses of data needed to support decisions and are the basis for designing data collection activities. To determine the project DQOs, a series of planning steps were used as specified in QA/G4, *Environmental Protection Agency (EPA) Guidance for Data Quality Process* (USEPA 2006). The DQO development process was used to optimize the data collection necessary to meet the applicable decision criteria. The seven (7) steps of the DQO process are presented in the following subsections along with summary answers addressing each DOQ step.

4.7.1 Step 1 – State the Problem

The problem is that due to both the nature of the UXO, and the extremely rugged terrain of some of the firing ranges, it is impractical to perform ground based surveys either efficiently or safely to gather data about the nature and extent of DU contamination in the impact areas of PTA or Makua.

4.7.2 Step 2 – Identify the Decision

The principal study question and decision statement is whether the DU present on the ranges that cannot be accessed effectively or safely can be adequately detected and quantified using an aerial platform (in this case a helicopter) equipped with a large area sodium iodide (NaI) gamma spectroscopy system. From a comparison of GWS data of an area known to contain DU from the Davy Crockett System at Schofield Barracks, to flyover data gathered by the A-CLASS system, it can be seen that the aerial system can identify the presence of DU which correlates well to distributions of DU found during GWS surveys at on ground level.

4.7.3 Step 3 – Identify Inputs to the Decision

4.7.3.1 <u>Contaminants of Concern</u>

The only known source of radionuclides is DU contained in the spotter round bodies of training rounds found during previous investigations at Schofield Barracks. Depleted uranium is the waste product of U enrichment processes and is defined as U containing less than 0.711 percent (%) ^{235}U. Depleted uranium consists primarily of ^{238}U with smaller amounts of uranium-234 (^{234}U) and ^{235}U from both a mass and activity perspective. Natural U that is present in the environment consists of approximately equal activities of ^{234}U and ^{238}U.

The DU was U metal-molybdenum alloy when it was released to the environment. The DU fragments identified at PTA are largely intact; however some of the metal has oxidized and is present as uranium oxide in the surface soils. The DU is expected to be intact or present as large and small fragments of U metal, and very little in the form of oxides in surface soils due to the environmental conditions at PTA.

Uranium and its decay products emit characteristic energy photons which can be detected by gamma spectroscopic methods and distinguished from other gamma emitting radionuclides. It is by the detection of specific energy photons discrimination from other radionuclides and natural background that the presence of elevated levels of DU will be determined.

Two regions of interest (ROI) were established for collection of data which correspond to the 766 keV and 1001 keV energy photons of protactinium (^{234}Pa) which provide distinct indications of the presence of ^{238}U. ^{234}Pa is a decay product in the decay chain of ^{238}U. Elevated levels of ^{234}Pa indicate elevated uranium levels and thus the potential presence of DU on the ranges.

4.7.3.2 <u>Potentially Affected Media</u>

The media of concern for the aerial surveys are surface soil and shallow subsurface soil (i.e., to a depth of approximately 6 inches).

4.7.3.3 Natural Background Variations

Due to the presence and variation of naturally occurring radionuclides in the environment, including natural U, Th and potassium 40 (^{40}K), elevated areas of naturally occurring radioactive materials may be present. By establishing ROIs which are specific to the decay products of uranium, the background variations can be minimized and accounted for since contributions from other radionuclides are minimized. Spectral analysis capabilities can assist in identifying increases within areas of interest.

4.7.4 Step 4 – Define the Study Boundaries

The area to be investigated will be a portion of the range where the Davy Crockett Spotting rounds containing DU may have been used. The study boundaries for the aerial survey was chosen and marked on topographical maps by USAG-HI based on possible range layout and locations for target areas. Aerial surveys will be conducted over the plateaus and valley floors based on both visual and GPS reference points. During the actual surveys, emphasis was placed on confirming the boundaries and plotting data immediately as it was gathered to ensure that the appropriate areas were covered.

4.7.5 Step 5 – Develop a Decision Rule

Preliminary specific decision rules regarding presence of DU from the aerial platform was established during system evaluation at Schofield Barracks. Applicable decision rules and goals for the evaluation of gamma flyover data during the characterization survey are listed in Table 4-4 and may be modified and refined based on the results and changes made in system configurations during aerial surveys, if required.

TABLE 4-4 DECISION RULES

Parameter of Interest	IF	THEN	Comments
Aerial Gamma Flyover Data			
Elevation Above Ground Level	Elevation is outside of operating parameters/tolerances	Discard data associated with measurements outside of tolerance or scale measurements if appropriate.	Laser Detection and Ranging will be used. Elevation above ground level is a parameter stored with each accumulated data point.
GIS Area Integration Radius	Data shows concentrations at/below detectable levels	Adjust radius to attempt to achieve enhanced sensitivity/detection levels	Enables increases sensitivity over larger areas of interest.
Gamma Spectroscopy Nuclide ID (NID)/ Elevated ROI counts	Data shows potential presence of increased activity	Perform ground based GWS, if possible. Perform NID and spectral examination to identify the source of increase	NID if possible, confirm with soil sampling and/or ground based surveys and ratios between KUT

Elevation above ground level: The elevation above ground level was determined by using laser ranging during the survey to direct the pilot to adjust altitude, if possible. Due to the presence of trees, large rocks and ravines, safety considerations were often the primary determinate of elevation during the survey. The use of the laser range finder enabled the classification and separation of data based on elevation above ground.

A potential complicating factor with laser data is the fact that objects such as high grass, large rocks, and trees, as well as range debris cause the laser range finder to be recorded as elevations closer to the ground than they actually are. Helicopter rotor wash reduces this effect in tall grassy areas by compressing/flattening the grass. These factors were observed and tested during static platform testing by transiting over the flat and mowed areas as well as high grasses and vegetation. Rotor wash also separated brush/small trees and also allowed the laser to penetrate to the ground surface. Figure 4-12 displays the altitude above ground level distribution of the survey. Over 86 percent of the data was collected at an altitude of 13 feet or lower.

Another critical use of altitude data enables the analysis of data to ensure that altitude is not a factor in the development of potential DU distribution patterns. If increased count rate patterns were the result of altitude influence the plotting of altitude data would mirror the plot of potentially elevated Z scores. As can be seen from a comparison of figures 4-9 through 4-11 with data plotted in Figure 4-12 these distinct patterns are not readily observed. The slight increase in count rates in the survey data do not appear to be attributable to altitude.

4.7.6 Step 6 – Specify Tolerable Limits on Decision Errors

The collection and analysis of data is designed as a graded approach using a combination of gross aerial gamma data, processed data, peak search and radionuclide identification, energy defined regions of interest, as well as the application of GIS data analysis and screening.

Analytical uncertainty is controlled by use of appropriate instruments, methods, techniques, and Quality Control (QC) procedures to ensure the proper function and calibration of the instrumentation to be used. Minimum detectable levels for individual radionuclides using specific gamma spectroscopic and analytical methods have been established for ground based application of the CLASS system which is primarily based on constant surface to detector distance. Detector ground distances for aerial based surveys are dependent on elevation above ground level which is influenced by variations in terrain and helicopter altitude. To qualify data for inclusion LADAR (*Laser Detection and Ranging*) will be used to classify data based on elevation for acceptance. Specifying values for the operating parameters controls the uncertainty associated with individual analytical results, which limits decision errors and improves data quality.

The A-CLASS system’s minimal detection limit was calculated using a NIST traceable Uranium Slab of 0.3 cm thickness with an area of approximately 250 cm^2 at various distances from the face of the system’s detectors to determine system efficiency. Assuming DU metal fragments lying on the surface/near surface at a depth of 1” to 2” of the soil and using an observation interval of 5 seconds (representing an integration averaging radius of approximately meters) an approximate MDA of 3 to 5 Davy Crockett Spotter Rounds (DCSR) in an area of approximately 150 ft^2 (14 m^2 at a distance of 10-12 feet at 1 to 2 meters per second (3 to 6 knots) helicopter speed.

Laser ranging data enabled both the classification and sorting of data by altitude (Figure 4-12) and the exclusion of data from the data set. Daily QA/QC of the detector system assured proper energy calibration and detector response prior to collection of survey data.

4.7.7 Step 7 – Optimize the Design for Collecting Data

Review and analysis of observations and collected gamma flyover data from the static testing and reference areas will be performed to optimize the flight parameters (helicopter speed, height above ground level, regions of interest, survey density) for use in the impact areas. Static testing will confirm the assumptions made with regard to regions of interest for peaks, background subtraction, and Minimum Detectable activities.

Data and flight parameters gathered during static testing and platform configuration targeted a height above ground of approximately 10 to 12 feet as a level which could be consistently and safely maintained. Helicopter speeds over the ground of approximately 2-3 knots or less also appeared to be easily obtained during system trials. Actual conditions on the range increased the altitude which could be maintained while maneuvering in the 10-14 foot range and increased the airspeed to 3-6 knots due to wind conditions and the need to be able to maneuver over and around objects and the slope of the range. Lowering the speed would increase residence time of the detectors over the ground but would increase survey time by a factor of approximately 1.6 based on speed alone. The decrease in maneuverability may impact the ability to hold straight transit lines and increase repeat flyovers to achieve coverage.

The regions of interest, approximately 30-36 channels of data appear appropriate and the ability to perform variable area averaging enable the detection of DU. Post processing of data will examine the adjustment of peak channel width for each of the two ROIs selected. Processing time for the variable area averaging performed at a 20 to 30 foot radius requires optimization to reduce processing times to reasonable levels.

The appropriate CABRERA standard operating procedures (SOPs) and other site-specific plans (e.g. Site Safety and Health Plan, UXO Avoidance plan, and Helicopter Safety Plan, etc.) were followed for all field activities under this project.

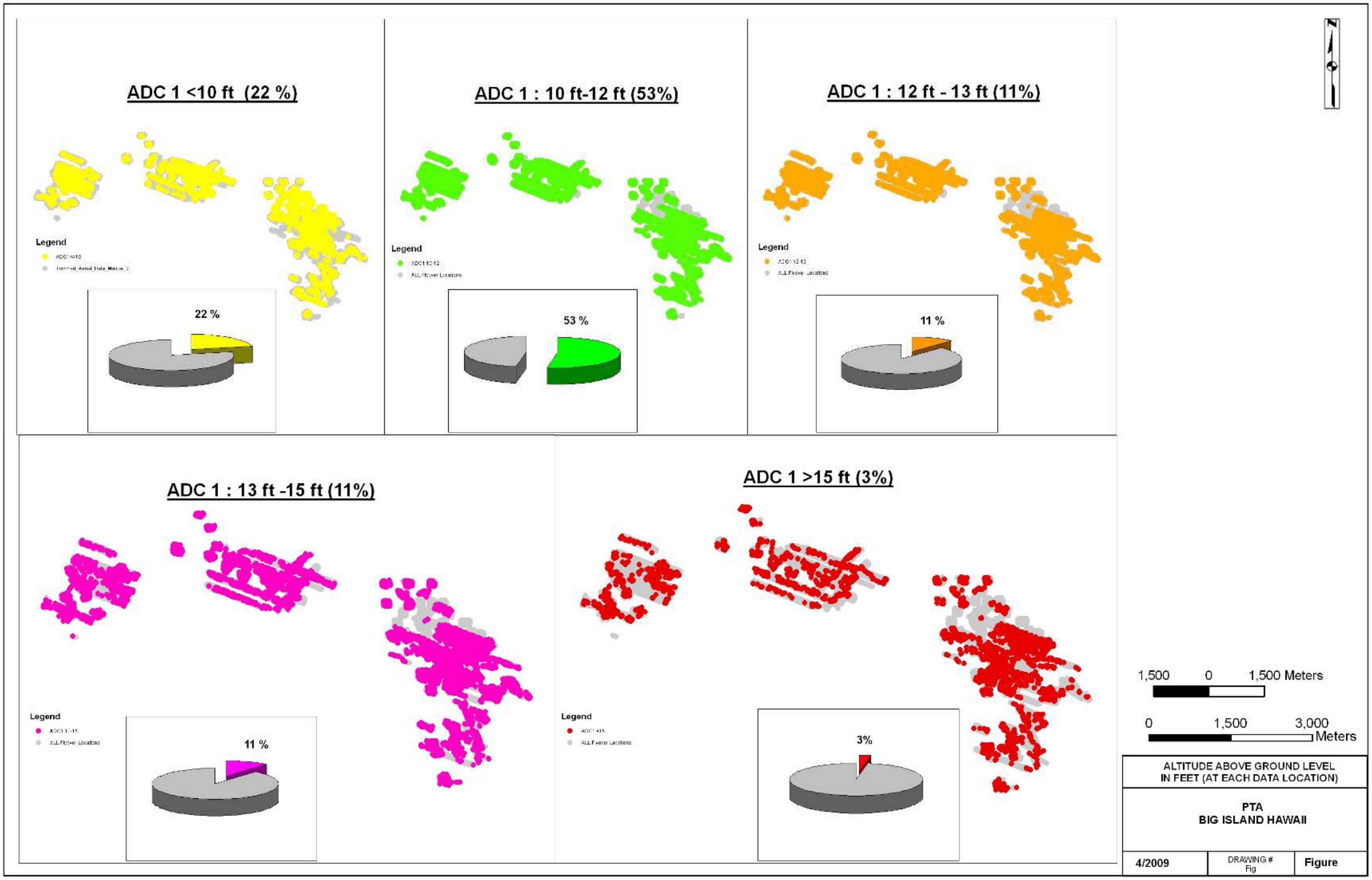


FIGURE 4-12: PTA ALTITUDE BREAK OUT

5.0 SUMMARY AND CONCLUSIONS

Aerial and GWS surveys were performed over at total of 936 and 50 acres, respectively, at the Pohakuloa Training Area on the Big Island of Hawaii. Surveys were concentrated in areas which were the most likely to contain Davy Crockett spotter rounds and debris from the weapons system by focusing on the range of the weapon (1 to 2 km), as well as identification of targets from the era of the weapons system. Only limited visual and radiological indications of any additional Davy Crockett spotter rounds and system debris were located and identified during these aerial and ground based surveys.

Visual reconnaissance was conducted surrounding the perimeter of the range to identify locations of additional pistons and on the range to identify other Davy Crockett system components such as back plate assemblies, spotter round bodies, aluminum tail sections, etc, associated with the weapons system. Visual surveys confirmed the presence of additional pistons, but only on those ranges which had been previously identified as locations for Davy Crockett systems use. On range visual examination identified Davy Crockett back plate assemblies only on Range 10/11T and the ground based survey team was directed to those locations. No on range visual identification of Davy Crockett system components was made at any other locations on the ranges. The back plate assemblies are highly visible from the air at the low altitude flown by the helicopter, as are the tail fin assemblies when they are located on the surface of the lava.

Ground based GWS located and identified 2 DU metal fragments, one essentially intact spotter round body with no tail fin assembly containing the PETN explosive pellet and phosphorus spotting charge, and one aluminum tail fine with some DU spotter round body still attached. The DU fragments were located in a crack in the lava. GWS surveys identified four locations on the upper area of interest on Range 11T near proposed BAX construction which require reinvestigation prior to BAX construction. The spotter round body containing the energetic material was later removed from the surface of the range and placed in an adjacent location protected from both the weather and surface disturbances from range activities. The location and landmarks for this location was provided to USAG-HI.

Soil sampling results in areas of GWS surveys and Aerial surveys on both the range and BAX construction areas indicated only naturally occurring uranium with no indications of depleted uranium.

Aerial Gamma surveys identified some areas of increased activity, but these locations were further investigated and analyzed and the increases were determined to be from variations in naturally occurring radioactive materials. Based on visual observations of the terrain and the numerous cracks and crevices present on the range, it is believed that the DU, if present, has fallen into these cracks or is covered over by large fragments of lava and likely may not be distributed on the surface at it is a Schofield Barracks. If the DU rounds and fragments were present on the surface, and within some cracks, the materials would have been positively identified by the extensive ground based observations and searches conducted at PTA. The number of DU spotter round bodies, aluminum fin assemblies and DU fragments are much fewer than would be expected given the total number of pistons which were identified. This fact, and in comparison to the number of DU fragments and portions of the Davy Crockett spotter rounds found at Schofield Barracks, suggests that some type of range clearance may have occurred at PTA.

6.0 REFERENCES

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APPENDIX A

GAMMA WALKOVER SURVEY DATA
(Provided electronically on CD)

APPENDIX B

SOIL ANALYSIS DATA AND COC
(Provided electronically on CD)

APPENDIX C

Flyover Data
(Provided electronically on CD)

APPENDIX D

INSTRUMENT QA/QC DATA
(Provided electronically on CD)

APPENDIX E

PHOTOS
(Provided electronically on CD)

APPENDIX F

Ratio Analysis
(Provided electronically on CD)