FINAL
GAMMA RADIATION SCANNING REPORT
AREA IV RADIOLOGICAL STUDY
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

EPA Contract Number: EP-S7-05-05
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Prepared for:

U.S. Environmental Protection Agency, Region 9
75 Hawthorne Street
San Francisco, CA 94105

October 17, 2012

HGL
HydroGeoLogic, Inc

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LIST OF ACRONYMS AND ABBREVIATIONS

AOC	Administrative Order on Consent
ANSI	American National Standards Institute
CFR	Code of Federal Regulations
Co	cobalt
cm	centimeter
cps	counts per second
Cs	cesium
CSV	comma separated variable
DOE	Department of Energy
DQO	data quality objective
DTSC	Department of Toxic Substances Control
ERGS	Enhanced Radiation Ground Scanner
ESRI	Environmental Systems Research Institute, Inc.
ETEC	Energy Technology Engineering Center
FIDLER	field instrument for detection of low energy radiation
FOP	Field Operating Procedure
FOV	field of view
FWHM	full width at half maximum
GIS	geographic information system
GPS	global positioning system
GRAY	gamma radiation anomaly
HGL	HydroGeoLogic, Inc.
HHGS	hand-held gamma scanner
HPGe	high purity germanium
HSA	historical site assessment
IL	Investigation Level
ISGS	In-Situ Gamma Spectrometer
keV	kilo electron volt
lb	pound
LIDAR	light detection and ranging
μCi	microcurie
m	meter
MHz	megahertz

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

MMGS	mule-mounted gamma scanner
MWH	Montgomery Watson Harza
NAA	North American Aviation, Inc.
NaI	sodium iodide
NASA	National Aeronautics and Space Administration
NBZ	Northern Buffer Zone
NIST™	National Institute of Standards and Technology
NORM	naturally occurring radioactive material
NMEA	National Marine Electronics Association
OSHA	Occupational Safety and Health Administration
pCi/g	picocuries per gram
PGRAY	potential gamma radiation anomaly
Pu	plutonium
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
QCA	quality control areas
RBRA	Radiological Background Reference Area
RMHF	Radioactive Material Handling Facility
ROI	regions of interest
RSI	Radiation Solutions Inc.
RSIBN	Radiation Solutions Inc. binary output format
RSO	Radiation Safety Officer
RTL	radiological trigger level
SAP	Sampling and Analysis Plan
SMP	Site Management Plan
SOP	Standard Operating Procedure
SRE	Sodium Reactor Experiment
SSFL	Santa Susana Field Laboratory
SSHO	Site Safety and Health Officer
STGS	single detector track mounted gamma scanner
TMGS	dual detector track mounted gamma scanner
TSIP	Trimble® Standard Interface Protocol
USEPA	U.S. Environmental Protection Agency
WMGS	wheel mounted gamma scanner

GLOSSARY

Area IV Study Area: Area IV and the Northern Buffer Zone.

Biological Monitors: Biologists with the training necessary to identify protected and endangered plants and animals native to the region.

Button Source: Radioactive material of known radioactivity (i.e., 1 microcurie) encapsulated into an object the size of a coat button and used for instrument calibration.

Cultural Monitors: Qualified archaeologists and specialized in southern California Native American artifacts and culture.

Field of View: The effective diameter for radiation detection systems to achieve optimal sensitivity.

Million Dollar Hole: Site feature consisting of an approximately 120-foot diameter vertically walled circular excavation that extends approximately 65 feet into fractured bedrock.

Mule Rig: A pack saddle customized to carry gamma detectors and used on the mules for scanning.

Native American Advisors/Consultants: Local Southern California tribal representatives from the most likely descendents of the former Native American inhabitants of the SSFL.

Normalization Area: An area with relatively homogeneous gamma data distribution and flat topography, scanned by all detection systems to create Normalization Ratios for each detection system.

Normalization Ratio: A calculated ratio that allows measurements from all detection systems to be merged into a single dataset for ease of comparison and illustration in reports and on maps.

Priority Area: Subdivisions of the Northern Buffer Zone based on drainages from Area IV.

Protected Area: An area identified by a Cultural and/or Biological Monitor as containing a Protected Resource.

Protected Resource: Biological resources (local and federal protected plants and animals), and cultural resources (archeological sites or artifacts left behind by former Native American tribes).

Radiological Background Reference Areas: Areas located 3 to 6 miles outside the SSFL boundary that were initially surveyed for background reference data for the Santa Susana and Chatsworth geological formations.

Region of Interest: Individual gamma spectroscopic data for select radionuclides of concern.

Site-Related Contamination: Gamma emitting radioactive materials released to the environment from SSFL-related activities with concentrations greater than naturally occurring radioactive materials.

Stomp and Tromp Survey: An initial survey to determine the presence of radiological contamination prior to entering an area for gamma radiation scanning.

Subarea: Twelve subdivisions of the Area IV Study Area based on operational history, and features such as roads, drainage pathways, and buildings.

Survey Section: Seventy-four further subdivisions of the Area IV Subareas generally bounded by natural and manmade features developed to track daily progress of gamma scanning.

Telehandler: An off-road-capable forklift equipped with a telescoping boom.

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1.0 INTRODUCTION

HydroGeoLogic, Inc. (HGL) was tasked by the U.S. Environmental Protection Agency (USEPA) to conduct an extensive radiological characterization study of the Santa Susana Field Laboratory (SSFL) at Area IV and the Northern Buffer Zone (NBZ) located in Ventura County, California (Figure 1.1). The study was performed to meet the requirements of the State of California's Senate Bill 990 and subsequently the Administrative Order on Consent (AOC) for Remedial Action (DTSC, 2010). This work was executed under USEPA Region 7 Architect and Engineering Services Contract EP-S7-05-05, Task Order 0038, Amendment 004. The technical lead on the project was USEPA Region 9.

The Area IV Radiological Study consisted of completing historical site assessments (HSA); conducting a gamma radiation scan of accessible surfaces (defined in Section 6.3); conducting a geophysical survey; and collecting and analyzing soil, water and sediment samples. This report describes the approach and results for collecting real-time gamma radiation scanning and static measurements of surface and shallow subsurface soil within Area IV and the NBZ at SSFL, henceforth referred to as the Area IV Study Area. The investigation was conducted in accordance with the Final Gamma Radiation Scanning Sampling and Analysis Plan (SAP) (HGL and TPC, 2010a).

1.1 PURPOSE AND OBJECTIVES

The gamma radiation investigation was conducted in the Area IV Study Area to fully characterize surface soil for gamma emitting radiological contamination. Data gaps remaining from previous investigations of the Area IV Study Area indicated the need for further characterization. The USEPA committed to the public and the SSFL Radiological Study Technical Workgroup that 100 percent of accessible surfaces within the Area IV Study Area would be scanned for gamma radiation.

Real-time gamma radiation measurements were collected, and the measurements were used to determine the presence and location of gamma radiation anomalies (GRAY) in surface and shallow subsurface soil. The gamma radiation results are an essential component of the overall study, and with other lines of evidence (previous soil samples results, geophysical anomalies, historical information like environmental releases of contamination, etc.), were used to target soil sample locations.

In the design of a typical gamma radiation scanning investigation, selected radionuclides of concern would be prioritized and targeted for detection at pre-defined concentrations. For the

Area IV Radiological Study, pre-defined concentration limits had not been established; therefore, a key project objective was to achieve as low as achievable detection limits in the field with commercially available detection systems. For this reason, gamma spectroscopy data was collected at low scanning velocities and relatively close to the ground surface. Several types of portable detection systems and scanning equipment were deployed and the detection capability (sensitivities) of the detection systems were rigorously tested and operating parameters determined (Appendix E). The most sensitive detection system capable of scanning the ground surface in a specific area was generally deployed in that location.

1.2 SCOPE OF WORK

The scope of the gamma radiation investigation effort was to scan 100 percent of accessible surfaces within the SSFL Area IV Study Area using real-time gamma radiation measurement detection systems to achieve the data quality objectives (DQO) outlined in the SAP (HGL and TPC, 2010a). Activities conducted to meet project objectives included:

- Prepare surfaces by removal of vegetation to allow access for gamma scanning detection systems within prescribed limits (Section 6.2).
- Develop and construct gamma scanning detection systems capable of accessing as much of the Area IV Study Area as feasible (Section 3.1).
- Establish quality control (QC) background and radioactive source limits with evaluation criteria for each detection system (Section 5.0).
- Characterize detector sensitivities for each detection system (Section 7.2).
- Establish surface soil background gamma radiation levels for the Santa Susana and Chatsworth rock formations at the Radiological Background Reference Areas (Sections 7.1 and 9.1).
- Conduct gamma radiation scanning surveys with selected detection systems for 100 percent of accessible surfaces (Sections 6.0, 7.0 and 9.0).
- Compile and normalize data from different detection systems and individual surveys into a complete and coherent set of data for each subarea of the Area IV Study Area (Section 7.3).
- Determine the statistical mean and standard deviation of a spectrum in counts per second (cps) and individual gamma spectroscopic regions of interest (ROI), for select radionuclides of concern, for each subarea and detection system (Sections 7.6.1 and 9.0).
- Evaluate gamma radiation measurements to determine the presence of potential gamma radiation anomalies (PGRAY) (Section 7.8).
- Investigate PGRAYs to determine if they are “Not a GRAY,” a naturally occurring radioactive material (NORM), or a “Confirmed GRAY,” with site-related contamination (Section 7.8).
- Evaluate gamma spectroscopy data to identify radionuclides associated with a Confirmed GRAY (Sections 7.8 and 9.3).

- Prepare a final report summarizing all gamma scanning field activities and data findings (Sections 7.0 and 9.0).

1.3 REPORT LIMITATIONS

Findings discussed in this report were derived from data collection efforts conducted with the best commercially available detectors, software, techniques, and procedures available at the time the investigation was conducted. However, the gamma detectors used during the investigation were not capable of detecting radionuclides that emit only alpha or beta radiation. In addition, field-based detection systems are not as sensitive (meaning they have a higher detection limit) as laboratory based analytical methodologies. Consequently, less gamma emitting radionuclides were detectable than analytical laboratory based radiochemical methods. Findings of the gamma radiation scanning, and other lines of evidence, as presented in the soil Field Sampling Plans were used in identifying targeted soil sampling locations for collection and analyses. Subsequent surface and subsurface soil sampling and analysis results are presented in separate reports for each subarea.

1.4 ORGANIZATION OF THE REPORT

This report consists of Sections 1.0 through 10.0 and Appendices A through O. Referenced tables and figures are provided in separate, tabbed sections. The Appendices provide supporting technical information. The contents of each section are summarized below:

- Section 1.0, Introduction. Describes the purpose and objectives, scope of work and DQOs, limitations, and organization of the report.
- Section 2.0, Site Background. Describes the site location, site and regulatory history, and environmental setting including land use and zoning, soil types and topography, and geology. The radionuclides of concern are also discussed.
- Section 3.0, Detection Systems and Instrumentation. Presents detailed descriptions of the gamma radiation detection systems, including hardware and software developed and used to collect gamma radiation data. Additionally, the methods to determine detection system sensitivity and operating parameters for performing field surveys are described. A brief description of special training requirements also is provided.
- Section 4.0, Sampling and Analysis Plan Amendments and Deviations. Describes amendments and deviations to the SAP required over the course of the data collection activities to adapt to site conditions encountered to ensure objectives were achieved.
- Section 5.0, Quality Assurance (QA) and QC. Describes the calibration, daily QC checks, inspection, maintenance, and audits of equipment and procedures. In addition, procedures for deficiency resolution and corrective actions are described.
- Section 6.0, Area IV Study Area Accessibility. Describes terrain, culturally and biologically protected areas, reconnaissance activities, ground surface preparation, and accessibility.
- Section 7.0, Data Acquisition and Analysis. Discusses the methods and procedures of data collection, processing, evaluation, interpretation, and management required to meet project objectives.

- Section 8.0, Verification and Validation. Describes the tasks undertaken to verify and validate that the study objectives were completed.
- Section 9.0, Gamma Radiation Results. Discusses results and conclusions of all collected data including PGRAYs, Not a GRAY, and Confirmed GRAY.
- Section 10.0, References. Lists the documents cited in this report.

2.0 SITE BACKGROUND

2.1 SITE LOCATION AND DESCRIPTION

The SSFL is located in southeastern Ventura County, California, approximately 30 miles northwest of Los Angeles between the Simi and San Fernando valleys in the Simi Hills (Figure 1.1). Residential developments are near the southern, northern, and eastern boundaries of the site. The SSFL occupies 2,850 acres of rocky (sandstone) terrain with approximately 700 feet of topographic relief. The Area IV Study Area is comprised of approximately 471 acres (290 acres in Area IV and 181 acres in the NBZ) that vary from relatively flat to steep relief and rugged terrain. The elevation of the Area IV Study Area is between 1,880 feet and 2,150 feet above mean sea level.

The initial eight subarea boundaries were based on existing Resource Conservation and Recovery Act Facility Investigation areas for the Area IV Study Area. USEPA elected to further subdivide the eight subareas into 12 subareas based on features such as roads, drainage pathways, building use, and number of buildings for the radiological characterization study as follows (HGL, 2012a) (Figure 2.1):

- Subarea 3
- Subarea 5A
- Subarea 5B
- Subarea 5C
- Subarea 5D-North
- Subarea 5D-South
- Subarea 6
- Subarea 7
- Subarea 8-North
- Subarea 8-South
- NBZ Northeast
- NBZ Northwest

To facilitate field operations, each of the 12 subareas were subdivided into smaller Survey Sections generally bounded by natural and manmade features. A total of 74 Survey Sections were defined within the Area IV Study Area (Figure 2.2); note that Survey Sections 100 to 114 represented road surfaces and may be labeled more than once on Figure 2.2. The Survey Sections were developed to easily track daily progress of gamma scanning and support data management.

The NBZ Northeast and Northwest were also subdivided and categorized into three different types of Survey Sections called "priority areas" based on drainages from Area IV (Figure 2.3). The drainages were evaluated by proximity to potential radionuclide source areas within Area IV. Aerial photographic information and geophysical data collected within the NBZ also were evaluated to define the priority areas. The three types of priority areas were identified and categorized as follows.

Priority 1 Areas included drainages that received surface water runoff from nearby radiologically significant facilities or had geophysical evidence of buried material. These areas were considered to have the highest potential to transport radionuclides into the NBZ via surface water runoff. These drainages were designated the highest priority for gamma scanning and were scanned first.

Priority 2 Areas included drainages which received surface water runoff from Area IV but not nearby radiologically significant facilities or geophysical features. These areas were given a lower priority for gamma scanning, and were scanned after completion of Priority 1 areas.

Priority 3 Areas included drainages that had no surface hydrology connection to Area IV and had no evidence of past activities associated with SSFL as indicated by potential radionuclide source areas, geophysical survey, aerial photo analysis, and historical information. These areas were given the lowest priority for gamma scanning and were scanned after Priority 1 and Priority 2 areas had been completed. Some of the accessible Priority 3 Areas were not scanned because other lines of evidence indicated there was no potential for site-related contamination.

2.2 SITE HISTORY

The site history of the SSFL is extensive and numerous reports have been produced by several organizations to document the site history. USEPA conducted an extensive HSA to document the site history and facility past operations, as well as provide technical information for selection of soil samples. This section was derived from the USEPA's HSA and provides a very brief summary of the site history.

Before development of the SSFL site, the area was used for ranching. In approximately 1948, North American Aviation, Inc. (NAA) began development of the site for the design, development, and testing of liquid propellant rocket engines. The facilities at the SSFL site supported many major space programs, from the earliest satellite launches to the Space Shuttle. The Rocketdyne Division of NAA operated these portions of the SSFL site until approximately 1996 when Rocketdyne merged into The Boeing Company. Since approximately 1996, operations at the site have been conducted by The Boeing Company (ETEC, 2010 and HGL, 2012a).

The SSFL is separated into four administrative areas. The Boeing Company owns all of Area I, except for 42 acres that are owned by the National Aeronautics and Space Administration (NASA). Area II is owned by NASA and operated by The Boeing Company; and The Boeing Company owns and operates Areas III and IV. Areas I, II, and III were also used by The Boeing Company, NASA, and the Department of Defense for rocket engine and laser testing (HGL, 2012A).

Under contract to the Department of Energy (DOE), NAA also operated the Energy Technology Engineering Center (ETEC), located exclusively in Area IV, for researching, developing, and constructing nuclear reactors and associated equipment for harnessing nuclear energy through its Atomics International Division (NAA, 1960). Until its closure in 1996, DOE was responsible for operating ETEC. ETEC represented the group of facilities owned by DOE that were used for nuclear research and other experimental activities within Area IV. From the mid-1950s until the mid-1990s, DOE and its predecessor agencies were engaged in or sponsored nuclear operations including the development, fabrication, disassembly, and examination of nuclear reactors, reactor fuel, and other radioactive materials. Associated experiments included large-scale sodium metal testing for fast breeder reactor components. Nuclear operations at ETEC included 10 nuclear research reactors, seven critical facilities, the Hot Laboratory, the Nuclear Materials Development Facility, the Radioactive Materials Handling Facility (RMHF), and various test and radioactive material storage areas. Each of these facilities has been described in volumes II through VIII of the HSA (HGL, 2012a).

All nuclear research in Area IV was terminated in 1988 when DOE shifted its focus from research to decontamination and decommissioning activities. Decontamination and decommissioning of the sodium test facilities started in 1996 when DOE determined that the entire ETEC facility was surplus to its mission. DOE began formal cleanup and closure of its facilities in Area IV in preparation for returning the property to The Boeing Company (HGL, 2012a).

The HSA report includes a summary of past operations and activities involving radioactive materials for all subareas. The results of past radiological surveys performed in Area IV are also summarized. Radiological surveys have been performed for several purposes including health and safety, characterization, remedial action support, and release.

2.3 REGULATORY HISTORY

The Atomic Energy Commission became the DOE and Nuclear Regulatory Commission in 1975. During this period, radiological contamination in Area IV was extensively sampled and analyzed, including radiological surveys conducted in 1988 and again in 1995 including radiological release surveys within the footprints of former radiological facilities (DTSC, 2012).

In 1996, DOE issued procedures for radiological remediation requiring The Boeing Company and DOE to cleanup Area IV to a level that would have enabled Area IV to be used for suburban-residential purposes and limited exposure to future users to no more than 15 millirem of radiation per year (DTSC, 2012).

In August 2007, DTSC, as the lead regulatory agency, and The Boeing Company, DOE, and NASA, as potential responsible parties, entered into a Consent Order for Corrective Action (DTSC, 2007) governing the remediation of chemical contamination at SSFL. This Consent Order based the remediation of chemical contamination on an assumption that the site would be used for suburban residential purposes (DTSC, 2012).

In October 2007, California enacted SB990 entitled "Cleanup of Santa Susana Field Laboratory" and became effective on January 1, 2008. SB990 asserted state jurisdiction over the SSFL remediation and required calculating the cumulative risk from radiological and chemical contaminants to the lower of either suburban residential or rural residential (agricultural) land use scenarios, whichever produces the lower permissible residual concentration for each contaminant (DTSC, 2012).

Based on their assertion that remediation to rural residential (agricultural) land use is not a reasonable scenario for the site, The Boeing Company entered into a legal dispute with the State of California and asserted its commitment to dedicating the SSFL property for use as open-space parkland upon a soil remediation to suburban-residential standards (DTSC, 2012).

In December 2010, DTSC signed an AOC with DOE and NASA to address the federal radiological and chemical remediation of soil solely in the Area IV Study Area of the SSFL to background values for both groups of contaminants by the year 2017. The AOC does not apply to the remediation of groundwater and certain bedrock and leaves the cleanup of federal soil contamination outside the Area IV Study Area, (i.e., Areas I, II, and III) wholly unaddressed. The Boeing Company and USEPA are not a party to the AOC (DTSC, 2012).

2.4 RADIONUCLIDES OF CONCERN

The SSFL Radiological Background Study compiled a list of potential radionuclides of concern (HGL, 2009). Many of these do not emit gamma radiation that is detectable by real-time, field portable detection systems. Radionuclides undetectable with field gamma scanning detection systems generally fall into one or more of the following categories:

- Radionuclides that emit alpha radiation only; for example polonium-210;
- Radionuclides that emit beta radiation only; for example strontium-90;
- Radionuclides that emit very low energy gamma radiation that are not readily detectable with field based instruments; for example iodine-129; and
- Radionuclides that emit gamma radiation with low intensity (abundance); for example, plutonium (Pu)-239. Field based gamma radiation detection systems could possibly detect Pu-239 contamination if present in relatively large environmental concentrations.

Table A-1 in the SAP (HGL and TPC, 2010a) summarizes radionuclides of concern that potentially could have been detected during data collection activities. Consideration of field conditions reduced the number of radionuclides that were practically detectable with the detection systems deployed for this study. Detection of radionuclides is influenced by a combination of numerous factors.

The detection systems deployed in this study scanned slowly and near the ground surface to obtain the lowest practicable detection levels (greatest sensitivity) possible. Static (stationary) measurements supplemented scanning measurements to obtain increased sensitivity. Identification of radionuclides was significantly enhanced during data processing and interpretation. Additional information required for characterization was obtained by collecting and analyzing targeted soil samples in areas of elevated gamma radiation measurements identified during this investigation.

2.5 ENVIRONMENTAL SETTING

2.5.1 Land Use and Zoning

Historically, the SSFL was a complex of industrial research and development facilities for the testing and development of liquid propellant rocket engines, nuclear reactors, and the operation of a liquid metals research center (Sapere Consulting, Inc., 2005; Archeological Consultants, Inc., 2009). Various clean-up activities throughout the SSFL were concurrently conducted during the gamma radiation investigation (The Boeing Company, 2012).

The land directly northwest of and adjacent to the SSFL is occupied by the American Jewish University Brandeis-Bardin Campus which is zoned as rural agricultural and used for religious teaching and camping facilities. The land adjacent to the northeast is occupied by the Santa Monica Mountains Conservancy and is zoned as open space and operated as Sage Ranch Park.

The properties to the east of and adjacent to the SSFL are zoned as light agricultural land use with variances that permit higher density use such as for mobile home parks, golf courses, etc. A residential community is present in Woolsey Canyon approximately 0.25 miles east of the SSFL. Dense residential developments began in the San Fernando Valley approximately 2 to 3 miles east of the SSFL. Bell Canyon is situated directly to the south of the SSFL and used primarily for residential purposes.

The majority of properties situated to the west of the SSFL are designated by Ventura County as open space. Historically, this land was used for cattle grazing. In addition, the Runkle Canyon residential development is located west of and adjacent to the SSFL.

2.5.2 Soil Types and Topography

The SSFL is located on a ridge within the Transverse Ranges physiographic province. The facility is approximately 850 feet above the valleys to the north and south. While the laboratories and other facilities within Area IV are generally located on relatively flat ground, local relief can be up to approximately 270 feet. In the Area IV Study Area, the highest elevation (2,150 feet above mean sea level) is along the southern boundary (Figure 2.4). Along the northwest boundary, the land slopes steeply away to undeveloped land. The relatively flat area in the southern part of the Area IV Study Area is called "Burro Flats."

Surface water drainage in the northern portion of the Area IV Study Area flows north into Meier Canyon, which is a tributary to the Arroyo Simi, flowing westward and terminating in the Pacific Ocean. Drainage of the majority of the Area IV Study Area flows to the southeast into the Bell Creek drainage system as suggested by the location of the northeast-southwest trending drainage divide (Figure 2.4). Bell Creek is the headwater and tributary of the Los Angeles River, which flows south and eastward terminating in the Pacific Ocean.

Given the topographic divide and topographical rises to the east and west of Area IV, there is no drainage directly to the west or east from the Area IV Study Area (U.S. Geological Survey, 1952). Surface drainage within the Area IV Study Area is through manmade and natural ditches and swales that lead to natural streambeds. The drainage from some operational areas is directed through various settling and process ponds. The locations of surface drainage features are presented on Figure 2.4.

The parent material of the soil in the Area IV Study Area consists of weathered bedrock, colluviums and alluvium derived from the Chatsworth Formation. According to the Natural Resources Conservation Service, approximately 40 percent of the Area IV Study Area is classified as sedimentary rock outcrop. The two predominant soil types in the Area IV Study Area are a sandy loam of the Saugus series and a loam of the Zamora series. The Saugus series soils consists of deep, well drained soils that usually forms on dissected terraces and foothills and are moderately permeable. The sandy loam of the Saugus series usually has slopes of five to 30 percent. The Zamora series soils are typically well drained loam that forms on nearly level grade or on strongly sloping fans and terraces. The Zamora series in the Area IV Study Area has slopes that range from two to 15 percent (U.S. Department of Agriculture, 2003).

A shallow groundwater system exists in the surface soils at small isolated locations. A regional groundwater system exists in the deeper fractured Chatsworth Formation. In some areas, groundwater from the Chatsworth Formation flows through fractures in the rock and emerges at the ground surface as seeps or springs. Groundwater underlying the SSFL is not currently used, or anticipated to be used, as a source of drinking water for the nearby communities or at SSFL, but nearby residents may in the future consume groundwater emanating from this site.

2.5.3 Geology

The SSFL is situated within the Transverse Ranges physiographic province, approximately 30 miles north of downtown Los Angeles (Baily and Jahns, 1954). Two geologic formations underlie the Study Area, the Cretaceous Chatsworth Formation and the Tertiary Santa Susana Formation. The Chatsworth Formation underlies approximately 80 percent of the Study Area. The following descriptions are derived from the Preliminary Geologic Map of the Los Angeles 30 feet by 60 feet Quadrangle, Southern California (Yerkes and Campbell, 2005). A geologic map of the area is presented as Figure 2.5.

The SSFL is located on the south flank of an approximately east-west striking, westward plunging syncline. There are three categories of geologic structures present in the SSFL faults/fault zones, deformation bands, and structures (MWH, 2007). The fault zones and deformation features displace primary geologic features, the former showing displacement of at least five feet and the later with minimal located displacement (less than 6 inches). Mapped faults in the SSFL are presented on Figure 2.5. The Burro Flats Fault places the Chatsworth Formation in structural contact with the Santa Susana Formation in the southwest portion of the Area IV Study Area.

Fractures and joints are widespread in the Chatsworth Formation and these may be important conduits for groundwater and contaminant movement. Fractures are oriented parallel to bedding and dip 25 to 30 degrees to the northwest and strike north 70 degrees east. Steeply dipping joints are also present in the formation, and some cut across bedding planes. The openings are well interconnected vertically and horizontally (Cherry et al., 2007).

2.5.3.1 Chatsworth Formation

The Chatsworth Formation consists of three unnamed members. The members were deposited by turbidity currents in the deep ocean at depths ranging from 4,000 to 5,000 feet. Turbidity currents cause massive submarine landslides from the continental shelf into submarine canyons which are generally more than a half-mile wide and greater than ten miles in length. During periods without turbidity currents, silt and clay particles from runoff filtered to the ocean floor and formed the siltstone strata found in the formation (HGL, 2012b).

Deposited in the late Cretaceous, the Chatsworth Formation is in excess of 6,000 feet thick. The uppermost member is a thick strata of light gray to brown sandstone, which is hard, coherent, arkosic, micaceous, primarily medium grained separated by thin partings of siltstone. The middle member is a gray conglomerate of cobbles of rounded, polished clasts of quartzite, porphyry and granitic rocks in hard rock matrix. The lower member is gray clay shale, crumbly with ellipsoidal fracture where weathered, and may include sandstone strata (HGL, 2012b).

2.5.3.2 Santa Susana Formation

The Santa Susana Formation underlies the southwestern most portion of the Area IV Study Area and consists of four members. The unnamed uppermost layer of the Santa Susana Formation consists of gray micaceous claystone and siltstone with a limited number of thin rock beds. Below the uppermost layer lies a second unnamed layer that is made up of tan coherent fine grained rock, which locally contains thin shell-beds and calcareous concretions. Underlying this layer is the Las Virgenes Sandstone Member, which is composed of tan semi-friable bedded sandstone and is locally pebbly. The oldest member is the Simi Conglomerate Member. This member contains gray to brown cobble conglomerate with smooth cobbles of quartzite, metavolcanic and granitic rocks in sandstone matrix that locally includes thin lenses of red clay. The Santa Susana Formation also was formed by turbidity currents (HGL, 2012b).

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3.0 DETECTION SYSTEMS AND INSTRUMENTATION

Specialized gamma radiation detection systems were required to achieve the objectives of the gamma scanning investigation and support the overall objectives of the SSFL Area IV Radiological Study. Detection systems were custom-designed and constructed specifically for the SSFL project, because no commercial off-the-shelf equipment and software packaged into suitable detection systems were available to meet the challenges of the project. Field conditions of the Area IV Study Area were a key consideration and challenge of the gamma radiation survey, necessitating modifications to the survey approach which required equipment modifications and, in some cases, development of entirely new components. Detection systems were fabricated from available components, and from components specifically designed and constructed from conceptual plans to meet the needs of the project. Software required optimization to process the survey data. Detection systems were constructed to meet the requirements of conducting scanning surveys over varying terrain and achieving the highest sensitivity and surface coverage possible while meeting safety standards.

The principal goal was to develop a series of detection systems which, together, were capable of scanning as much of the Area IV Study Area as practical considering accessibility, detection sensitivity, and worker health and safety. Software development consisted of optimizing the sodium iodide (NaI) scintillator detection systems to provide useful spectral data, assembling the data into large datasets (many terabytes), and developing tools to analyze and evaluate these datasets to locate PGRAYs.

The Radiation Solutions Inc. (RSI) NaI detection systems used in most of the detection systems are real-time capable instruments. The following NaI detection systems, listed in order from most to least sensitive, were used to collect scanning and, occasionally, static measurements:

- Enhanced Radiation Ground Scanner (ERGS) II
- Dual Detector Track Mounted Gamma Scanner (TMGS)
- Wheel Mounted Gamma Scanner (WMGS)
- Single Detector Track Mounted Gamma Scanner (STGS)
- Mule-Mounted Gamma Scanner (MMGS)
- Hand Held Gamma Scanner (HHGS)

Additionally, an In Situ Gamma Spectrometer (ISGS) consisting of a high purity germanium (HPGe) detector designed for field deployment was used to perform static measurements for investigation of PGRAYs.

Each of these detection systems required specific operational software. Additional software programs were required to merge, process, and analyze the data. The creation of new software as well as redesign and optimization of existing commercially available software programs was essential to achieving the goals of the survey.

The unique combinations of detectors and transportation systems fabricated for the detectors required characterization tests to determine the operational parameters for performing field scanning surveys. Each detection system was tested to determine its detection sensitivity, field of view (FOV), transect width, operating height, and maximum acceptable scanning velocity.

The gamma scanning investigation employed several detection systems and instruments that required specialized training and/or certification for operators. Project personnel attended training to reliably and safely operate the various equipment and detection systems.

The following subsections detail the detection systems and software used throughout the investigation, the methodology to determine the operating parameters of detections systems, and required training to properly operate this equipment within the SSFL.

3.1 DESIGN AND CONSTRUCTION

3.1.1 Detection Systems and Instrumentation Hardware

Each gamma radiation scanning detection system consisted of five basic components:

- A single or an array of NaI thallium drifted scintillation detectors with lead shielding
- Global Positioning System (GPS)
- Data storage acquisition and storage module
- A transportation mechanism
- A field computer with wireless capability

Detector shields surrounding the sides and top of the detectors with an exposed "window" facing the ground were designed and constructed. A 0.25-inch polycarbonate sheet was incorporated into the design of the "window" to protect the bottom of the gamma NaI detectors. The shield increased the sensitivity of the detector toward the ground surface and reduced shine (extraneous gamma radiation from surrounding soil surfaces, objects, and the atmosphere). The majority of the detection systems incorporated real-time technology, allowing the operator to view in real time the instrument radiological readings coupled with the instrument GPS location as well as previously scanned areas. This section describes the mechanical framework, electronics, customized software programs, and operating parameters of each detection system. Schematics for detection system components are included in Appendix B.

After each detection system was constructed, preliminary sensitivity and velocity tests were performed to determine optimal operating parameters for each system. These parameters are a set of calculated measurements particular to each instrument focused on the system's ability to detect gamma radiation. The operating parameters included FOV, transect width, operating height, and maximum operating velocity. These parameters remained constant during field operations and throughout the course of the project to ensure data uniformity, and accurate, representative, and reproducible measurements. A summary of the operating parameters for each detection system is provided in Table 3.1. Details and findings of the sensitivity tests for each system are presented in the Sensitivity Report Gamma Radiation Detection Systems for Field Gamma Scanning (Appendix E).

3.1.1.1 Enhanced Radiation Ground Scanner II

The design of USEPA's preexisting ERGS was the model for the ERGS II detection system. The ERGS was developed in 1996 and consists of eight NaI detectors (each measuring 4 inches by 4 inches by 16 inches) with a steel and lead shield forming a window facing the ground. It was mounted on a four wheel drive tractor fitted with a forklift attachment. The purpose of the ERGS was for conducting ground surveys at radioactive waste sites and during emergency responses.

The ERGS II was very similar to the original ERGS and consisted of eight NaI scintillation detectors enclosed in a lead and stainless steel shield. A housing attached to the top of the shield contained the electronic components of the system (Figure 3.1). The shield was designed with forklift inserts (2.25 inches high by 7.5 inches wide) allowing it to mount onto an industrial off-road telehandler equipped with all terrain wheels. A telehandler is similar to a forklift, but with an extension boom with forks, wider chassis, off-road wheels, hydrostatic transmission, and other features to increase maneuverability on variable terrain (Photographs A.1 and A.2). Throughout the project, six telehandlers were used for various mechanical and accessibility reasons. The make and model of each telehandler, including the advantages and disadvantages of each, is summarized in Table 3.2.

Due to the offset center of gravity, weight, and larger turning radius of the telehandler, the ERGS II was operated only in open, flat or moderately sloping terrain. It was the preferred detection system because of its wide FOV, mobility, and high detection sensitivity.

The NaI detectors used in the ERGS II detection system were manufactured by RSI. The shield assembly was designed by USEPA and constructed by Radiation Shielding, Inc. (Figures B.1 through B.4). The system consisted of two RSX-4 detector units. Each RSX-4 contained a set of four NaI detectors contained in a carbon fiber casing (Figure 3.2). The two carbon fiber cases were enclosed in a lead and stainless steel shield. The design schematics for the RSX-4 are illustrated on Figure B.5.

Both RSX-4 units were connected to an RSI RS-501 multichannel analyzer and data storage console. During scanning operations, the RS-501 console located in the electronics housing (Figure B.6), integrated the measured gamma spectroscopy data from the RSX-4 units with a GPS signal. The GPS satellite signal was received by a Tornado™ antenna mounted and centered on the exterior shell of the ERGS II. The antenna was connected to a Trimble® Model AgGPS 332 receiver fixed on the front end of the exterior shell; this receiver was later replaced by a Trimble® Model SPS852 GPS receiver with a Zephyr™ II antenna for increased accuracy. The integrated data was transmitted via wireless router, located in the electronics housing, to a Panasonic Toughbook® laptop (Model CF-30 or CF-19) mounted in the operator's cab of the telehandler, providing display of real-time data. The electronics housing is illustrated on Figure 3.3. Table 3.3 summarizes the ERGS II detection system components and specifications. The RS-501 user manual and RSX-4 specifications are located in Appendix J.

To ensure optimal scanning coverage and to reduce data gaps, a transect width of 72 inches was used. This transect was approximately 85 percent of the calculated FOV (86 inches), providing overlap between transects and ensuring complete scanning coverage. A foam marker system, consisting of two foam emitters mounted on a wooden frame with a foam solution container was installed on the rear of the initial telehandler (JLG® Gradall® Model 534D9-45). A small amount of environmentally safe water-based foam was released approximately every ten seconds from the emitters. The distance between the foam emitters measured the length and width of the transect width to assure an overlap in coverage. The foam remained intact long enough for the operator to follow the marks on subsequent transect passes (Figure 3.4).

The RSI computer program RadAssist®, later replaced by Environmental Systems Research Institute, Inc. (ESRI) ArcPad® software program, was utilized with the ERGS II detection system to track scanning coverage in real time. These software programs were installed onto a Panasonic Toughbook® containing detailed georeferenced aerial maps with survey boundaries, areas of interest, and up-to-date gamma scanning coverage. This allowed the operator to view the scanned coverage with previously scanned coverage, thus allowing the operator to quickly verify complete coverage. Detailed descriptions of software and programs utilized are provided in Section 3.1.2.

To meet the requirement of a consistent detector height of 15 inches above the ground surface, plastic guide chains were affixed to the ERGS II shield to serve as scanning height guides (Figure 3.5). The operator viewed the ends of the chains touching the ground and received assistance by radio or hand gestures from a spotter to make proper adjustments to the detector height as necessary.

A rheostat speed control was installed in the initial telehandler (Gradall® 534D9-45) as a cruise type device to set the revolutions per minute output and maintain a proper speed of 2 feet per second. In subsequent telehandlers, this device was not installed; instead operators gauged speed by experience and with the aid of ArcPad®, which was modified to display velocity. The JCB® models had two speed settings: "rabbit" and "turtle." The "turtle" speed setting was used for scanning as it ensured a speed of 2 feet per second, while the faster "rabbit" speed setting was used for transporting the ERGS II to and from the scanning locations.

3.1.1.2 Dual Detector Track Mounted Gamma Scanner

The TMGS consisted of two NaI scintillation detectors enclosed in separate lead and copper shields. The detectors were mounted on a retrofitted CanyCom Model BP419, off-road, dual rubber-track carrier (Figure 3.6 and Photograph A.3). The CanyCom operators manual and specifications are provided in Appendix J.

The single-operator system was motorized with a gas engine and had hand controls for start, stop, pause, gears, and related drive functions. The electronics were stored in a customized metal electronics housing affixed to the vehicle, safe from sudden inclement weather, vehicle roll over, and dust (Photograph A.4). The detectors on the TMGS were mounted parallel at a distance of 18.5 inches apart, as measured from the centerline of the detectors. Top and side view schematics of the TMGS are located on Figure B.7 and B.8. A swivel wheel was installed on the front end of the carrier for maneuverability (Photograph A.5). The detector was mounted on a bracket that acted as a hinge to allow the detector to move vertically for increased maneuverability in uneven terrain (Photograph A.5). A schematic of the mounting plate bracket is provided on Figure B.9 (Appendix B).

The TMGS was selected to replace the WMGS by providing a wider FOV (56 inches) and greater sensitivity. The motorized carrier also relieved operator physical stress and fatigue, was capable of scanning a wider range of terrain, offered the ability to ascend and descend moderately steep slopes, and was able to maneuver around various obstacles in the terrain. Over the course of the project, two modifications were made to enhance the durability of the TMGS in rough terrain. The solid rubber tracks were upgraded to rubber tracks integrated with forged steel to prevent tracks from ripping, tearing, and stretching, and the stock yokes were upgraded to a 3130 Chromoly metal and, later, forged steel.

In conformance with the project health and safety standards, the TMGS was not operated on slopes with a grade greater than 20 percent.

The NaI detectors used in the TMGS detection system were developed by RSI and the mechanical mounted frames were designed by USEPA (Figure 3.7). The system consisted of two RSX-1 detectors which each contained a single NaI detector enclosed in a carbon fiber casing and copper-lined lead shield (Figure 3.8). Schematics of the RSX-1 and the shield are located on Figures B.10 and B.11.

The RSX-1 detectors were connected to an RSI Model RS-701 multichannel analyzer and data storage console. During scanning operations, the RS-701 console, stored in the customized electronics housing, integrated the measured gamma data with the GPS data (Figure 3.9). The GPS satellite signal was received by a Trimble® Model GeoXH™ GPS receiver mounted between the two detectors; this receiver was later replaced by a Trimble® Model SPS852 GPS receiver with a Zephyr™ II antenna for increased accuracy. This integrated data was transmitted via wireless router located inside the electronics housing to a Panasonic Toughbook® (Model CF-30 or CF-19) mounted on top of the electronics housing, providing display of real-time data. During scanning operations, an operator was capable of both simultaneously tracking scanning coverage and viewing gamma radiation data while scanning. Table 3.4 summarizes the TMGS detection system components and specifications. The RS-701 user manual and RSX-1 specifications are located in Appendix J.

To ensure optimal scanning coverage and reduce data gaps, a transect width of 48 inches was used. This transect was approximately 85 percent of the calculated FOV (56 inches), for overlap between transects ensuring complete scanning coverage. The computer programs ArcPad® and RadAssist® were used to track the scanning coverage in real time (Photograph A.4). These programs were installed onto a Panasonic Toughbook® containing georeferenced aerial maps with survey boundaries, areas of interest, and up-to-date, previous gamma scanning coverage. Based on the ground conditions, track marks were also used as an aid to determine previous surfaces covered.

The detectors had a fixed height of 15 inches. The only requirement to achieve uniform scanning coverage was to ensure the tracks and the front wheel remained in contact with the ground during operation. To maintain a speed of two feet per second, a preliminary test was completed to determine which gear and throttle level met the requirement. During scanning operations the system never exceeded fourth gear under full throttle while moving forward. Reverse low was used while backing up.

3.1.1.3 Wheel Mounted Gamma Scanner

The WMGS consisted of a single NaI scintillation detector enclosed in a lead and copper shield. The detector was mounted on a custom constructed, non-motorized, off-road, three-wheeled cart (Figure 3.10). The detection system was pushed by an operator (Photograph A.6). Figure B.12 consists of a schematic of the WMGS.

Operators were timed and performance-tested to ensure their pace did not exceed a velocity of 2 feet per second. The electronics were secured onto two tiers of shelves built into the handlebars for operator accessibility and visibility (Photograph A.7). They were housed in a field bag fastened to the lower shelf for protection from sudden inclement weather and dust. Use of the WMGS was limited to flat to moderate slopes. It was selected for its size, transportability, and maneuverability in tight spaces and around various terrain obstacles in terrain. It was also selected to scan in culturally protected sites for its low impact and minimal ground disturbance.

The NaI detector used in the WMGS detection system was developed by RSI and the wheel-mounted frame was designed by the USEPA (Figure 3.11). The system consisted of one RSX-1 detector which contained a single NaI detector enclosed in a carbon fiber casing and partially collimated copper-lined lead shield (Figures 3.8). Schematics of the RSX-1 and the shield are located on Figures B.10 and B.11.

The RSX-1 was connected to a RSI Model RS-701 multichannel analyzer and data storage console. During scanning operations, the RS-701 console housed in the field bag, integrated the measured gamma spectroscopy data with the GPS data (Figure 3.12). The GPS satellite signal was received by a Trimble® Model GeoXH™ GPS receiver mounted and centered on the top of the detector; this receiver was later replaced by a Trimble® Model SPS852 GPS receiver with a Zephyr™ II antenna for increased accuracy. This integrated data was transmitted via wireless router (housed in the field bag) to a Panasonic Toughbook® (Model CF-30 or CF-19) mounted on the top electronics shelf, providing display of real-time data. The operator could simultaneously track scanning progress and view gamma radiation data while scanning. Table 3.5 summarizes the WMGS detection system components and specifications. The RS-701 user manual and RSX-1 specifications are located in Appendix J.

To ensure optimal scanning coverage and to reduce data gaps, a transect width of 24 inches was used. This transect was approximately 85 percent of the calculated FOV (28 inches), for overlap between transects ensuring complete scanning coverage. The computer program RadAssist® was used to track the scanning coverage in real time. This program was installed onto the Panasonic Toughbook®, containing georeferenced aerial maps with survey boundaries, areas of interest, and up-to-date previous gamma scanning coverage. Based on the ground conditions, wheel track marks were also used as an aid to identify previous surfaces scanned.

The detector had a fixed height of 12 inches and the only requirement to achieve uniform scanning was to ensure all wheels remained in contact with the ground while operating. The WMGS was operated at a maximum velocity of two feet per second. Operators were trained to move the detection system at this pace.

3.1.1.4 Single Detector Track Mounted Gamma Scanner

The STGS consisted of a single NaI scintillation detector enclosed in a lead and copper shield. The detector was mounted on a retrofitted CanyCom Model BP419, off-road, dual rubber-track carrier (Figure 3.13 and Photograph A.8). The CanyCom operator's manual and specifications are provided in Appendix J.

The system was motorized with a gas engine requiring a single operator and had hand controls for start, stop, pause, gears, and related drive functions (Figure 3.14). The electronics were stored in a customized metal electronics housing affixed to the vehicle, safe from sudden inclement weather, vehicle roll over, and dust (Figure 3.9). A side profile schematic of the STGS is illustrated on Figure B.8. The detector was mounted on a bracket that acted as a hinge to allow the detector to move vertically for increased maneuverability in uneven terrain (same design as the TMGS) (Photograph A.5). A schematic of the detector plate mounting bracket is located on Figure B.9.

The STGS was selected along with the TMGS to replace the WMGS for greater access to terrain not accessible with the WMGS. The advantage of the STGS over the TMGS was increased maneuverability. The motorized carrier also relieved operator physical stress and fatigue, was capable of scanning a wider range of terrain, offered the ability to ascend and descend moderately steep slopes, and to maneuver around various obstacles in the terrain. Over the course of the project, two modifications were made to enhance the durability of the STGS in rough terrain. The solid rubber tracks were upgraded to a forged steel reinforced rubber track to prevent tracks from ripping, tearing, and stretching; and the stock yokes were upgraded to a 3130 Chromoly metal and, later, forged steel.

In conformance with project health and safety requirements, the STGS was not operated on slopes with a grade greater than 20 percent.

The NaI detector used in the STGS detection system was developed by RSI and the mechanical mounted frames were designed by USEPA. The system consisted of a single RSX-1 detector that contained a single NaI detector enclosed in a carbon fiber casing and copper-lined lead shield (Figure 3.8). Schematics of the RSX-1 and the shield are located on Figures B.10 and B.11.

The RSX-1 detector was connected to an RSI Model RS-701 multichannel analyzer and data storage console. During scanning operations, the RS-701 console, stored in the customized electronics housing, integrated the measured gamma data with the GPS data. The GPS satellite signal was received by a Trimble® Model GeoXH™ GPS receiver mounted to the top center of the detector; this receiver was later replaced by a Trimble® Model SPS852 GPS receiver with a Zephyr™ II antenna for increased accuracy. This integrated data was transmitted via wireless router located in the electronic housing to a Panasonic Toughbook® (Model CF-30 or CF-19) mounted on the top of the electronic housing, providing display of real-time data. The operator simultaneously tracked progress and viewed gamma data while scanning. Table 3.6 summarizes the STGS detection system components and specifications. The RS-701 user manual and RSX-1 specifications are provided in Appendix J.

To ensure optimal scanning coverage and to reduce data gaps, a transect width of 30 inches was used which is approximately 85 percent of the calculated FOV (36 inches), for overlap between transects ensuring complete scanning coverage. The computer programs ArcPad® and RadAssist® (which replaced ArcPad®) were used to track the scanning coverage in real time. These programs were installed onto a Panasonic Toughbook®, containing georeferenced aerial maps with survey boundaries, areas of interest, and up-to-date, previous gamma scanning coverage. Based on the ground conditions, track marks were also used as an aid to determine previous surfaces scanned.

The detectors had a fixed height of 15 inches. The only requirement to achieve uniform scanning was to ensure both tracks and front wheel remained in contact with the ground while operating. To maintain a speed of two feet per second a preliminary test was completed to determine which gear and throttle level met the requirement. During scanning operations, the system never exceeded fourth gear under full throttle while moving forward. While backing up, reverse low was used.

3.1.1.5 Mule-mounted Gamma Scanner

The MMGS system consisted of two RSI RSX-1 NaI scintillation detectors enclosed in a lead and copper shield attached via outriggers to each side of a customized mule saddle and harness called the mule rig (Figures 3.15 and 3.16). The mule rig and outriggers were adjustable in order to maintain an approximately constant detector-to-ground height and to allow modest adjustments when different animals were deployed (due to the size and leg length of each mule). Over the course of the project the mule rig was upgraded from steel to a primarily aluminum based rig, to reduce the weight load on the mule. The system electronics were contained in a weatherproof, electronics housing affixed to a platform attached to the mule rig saddle (Figure 3.17). Figure B.13 includes an overview schematic of the mule rig.

The detector transportation mechanism for the MMGS was a mule (*Equus mulus*). During field operations the mule was led by an equine expert mule handler (Photograph A.9). A field technician provided guidance, computer, and additional support (Photograph A.10). Over the course of the project, a total of seven mules were trained and utilized for field scanning. The MMGS was selected for its maneuverability and ability to scan steep, rough, and vegetated terrain. It was also selected to scan in culturally protected sites for its low impact and minimal ground disturbance where wheeled or tracked vehicles were not allowed to operate.

The NaI detectors used in the MMGS detection system were developed by RSI. The saddle-mounted frames were designed by USEPA. The system consisted of two RSX-1 detectors, which each contained a single NaI detector enclosed in a collimated copper-lined lead shield (Figure 3.8). The mule provided additional shielding on the inner sides of the detector. Schematics of the RSX-1 and the detector attachment schematic are located on Figures B.10 and B.14.

The RSX-1 detectors were connected to an RSI RS-701 multichannel analyzer and data storage console. During scanning operations, the RS-701 console was housed in a weatherproof electronics housing secured to a platform above the saddle and integrated gamma data with GPS data. The GPS satellite signal was received by a Trimble® Model GeoXH™ GPS receiver mounted and centered on the top of the electronics housing; this receiver was later replaced with a Trimble® Model SPS852 GPS receiver with a Zephyr antenna for increased accuracy. This integrated data was transmitted via wireless router, located in the electronics housing, to a Panasonic Toughbook® (Model CF-30 or CF-19) carried by the field technician, providing display of real time data. The field technician was able to both track progress and view gamma data while the mule was lead through the survey area. Table 3.7 summarizes the MMGS detection system components and specifications. The RS-701 user manual and RSX-1 specifications are provided in Appendix J.

To ensure optimal scanning coverage and to reduce data gaps, a transect width of 90 inches was used. This transect was approximately 85 percent of the calculated FOV (104 inches), for overlap between transects ensuring complete scanning coverage. The computer programs ArcPad® and RadAssist® were used to track MMGS coverage in real time. These programs were installed onto the Panasonic Toughbook®, containing georeferenced aerial maps with survey boundaries, areas of interest, and up-to-date gamma coverage. The field technician could view current coverage as well as previously scanned surfaces.

In addition to utilizing computer software, the field technician followed behind or ahead of the MMGS marking the ground with environmentally safe spray paint. The mule handler used these marks as a guide while leading the mule (Photograph A.10).

The detector height, measured from the ground, of the tallest mule was approximately 35 inches. To ensure both detectors remained uniform to the ground, the detection system and mule harness straps were adjusted periodically.

The mules were voice trained and responded to commands given by the handler. To maintain a scan velocity of 3 feet per second during field operations, the mule handler trained the mules to walk at a slow pace. The MMGS was not as sensitive to scanning velocity as the other detection systems, mainly due to its increased operating height. Occasional excursions beyond the maximum scan velocity were deemed acceptable because it was not always possible to control the mules and limit their movement precisely (as could be done with motorized or human propelled systems).

3.1.1.6 Hand Held Gamma Scanner

The HHGS was used to survey difficult-to-access surfaces where which other detection systems were unable to access. The HHGS system consisted of a Ludlum™ Model 44-20 NaI detector with a Ludlum™ Model 2241-3 survey meter. Two field operational configurations were created for the HHGS.

The first configuration consisted of a light-weight frame assembled from aluminum bar stock (Figures 3.18 and 3.19). The detector was enclosed in a polyvinyl chloride (PVC) protective tube and affixed to an aluminum bar with a counter balance of a bag containing the survey meter (Photograph A.12). A side view schematic of the HHGS I is illustrated on Figure B.15. The aluminum frame fastened onto a modified backpack frame worn by the operator to aid in distributing the weight of the device. The backpack contained the Trimble® Model SPS852 receiver, batteries, and the wireless router. A Zephyr™ II antenna was attached to the backpack frame (Figure 3.20). A handheld computer (Panasonic Toughbook® U-1) was mounted on an aluminum bar attached perpendicularly to the frame for the operator to track scanning coverage.

For the second configuration, the detector was carried by a field operator from a handle attached to the PVC protective tube (Figures 3.21 and 3.22). An overview schematic of the HHGS II is located on Figure B.16. The computer (Panasonic Toughbook® CF-19) was attached to a backpack worn by the operator with the display visible for a second field technician. The Trimble® Model SPS852 GPS receiver, batteries and wireless router were housed in the backpack (Photograph A.13). The operator or field technician could view current scanning coverage as well as previously scanned surfaces. Detector count rate was not visible in real time due to software limitations.

The Ludlum™ Model 44-20 was a 3-inch diameter by 3-inch long NaI cylindrical detector (Figure 3.23). A photomultiplier tube and associated electronics were sealed inside an aluminum case and then placed in a PVC protective tube (Figure 3.24). A side view schematic of the Ludlum™ Model 44-20 detector is presented on Figure B.17.

During scanning operations, the gamma data from the Ludlum™ Model 44-20 was transmitted to the portable computer by a USB connection. The GPS was connected to a wireless router, also housed in the backpack, and powered by portable rechargeable batteries. The GPS transmitted data to the computer then merged with detector gamma data in real time using ArcPad®. ArcPad® was configured to provide the operator with a display tracking real time scanning coverage. Table 3.8 summarizes the HHGS detection system components and specifications. To ensure optimal scanning coverage and to reduce data gaps, a transect width of 24 inches was used. This transect was roughly 50 percent of the calculated FOV (48 inches), for overlap between transects ensuring complete scanning coverage. In addition, while surveying, the detector was slowly moved in an arc from left to right to overlap adjacent transects.

The scanning height of the HHGS was 18 inches. Some fluctuations in height were expected due to uneven terrain. An 18-inch weighted chain was attached to the detector to serve as a height guide for the operator. The frame was adjustable for differing heights of personnel to maintain correct proper scanning height. The HHGS was operated at a maximum velocity of 1 foot per second. Operators were trained to move the detection system at this pace.

3.1.1.7 In Situ Gamma Spectrometer

The ISGS consisted of a Canberra Model 5020 broad energy germanium detector. The detector was housed in a non-shielded metallic cover with a window facing the ground. The detector electronics were connected by data cables to an Inspector™ Model 2000 multichannel analyzer which was set at distance of at least 10 feet from the detector (Figure 3.25).

To minimize the weight and bulk, the detector was not collimated. Positioned above the detector was the Dewar, a cylindrical cryogenic storage container filled with liquid nitrogen. The liquid maintained proper detector operating temperature and occasionally a thermal blanket was used to insulate the detector when used in direct sunlight in hot weather. The detector was mounted on an adjustable tripod 30 centimeters (cm) above the ground surface (distance from ground to bottom of detector face); this height was measured at each location and the detector height adjusted if necessary.

The ISGS collected static measurements at locations of interest (Photograph A.14). The detector had much greater resolution than the NaI detection systems (Photographs A.15 and A.16) which allowed for enhanced identification and estimation of radionuclide concentrations in surface soil. The 90 percent efficiency FOV for the ISGS was defined as a uniformly contaminated planar source of 4 meter (m) diameter, 30 cm height and 40 cm depth. The ISGS FOV was defined differently than the gamma scanning detection systems which were based on a conservative 50 percent efficiency FOV. The ISGS was calibrated to a specific contaminant distribution which differs from actual field conditions; thus, radionuclide concentrations were not as accurate as analytical laboratory soil sample results. Since the ISGS detects contamination over a much larger volume of soil than possible from soil sampling and analysis, the ISGS results were more representative of wide spread contamination.

The ISGS was used to further investigate, characterize, and provide radionuclide-specific information for 87 PGRAYs. It was primarily used at PGRAYs suspected of having site-related contamination, but was also used at some PGRAYs to assist in classification. The resolution of the ISGS compared to the NaI based detection systems provided more definitive spectral identification of potential contamination. Frequently the ISGS confirmed the presence of site-related contamination, which was predominately cesium (Cs)-137.

The Inspector™ 2000 recorded the gamma spectroscopy data and its digital signal processing technology was capable of identifying many radionuclides with high resolution. A Trimble® Model SPS852 GPS receiver was used to determine the GPS coordinates of each measurement. The Gamma Acquisition and Analysis function of the Genie™ 2000 software was used to control data collection. This program was installed onto a Panasonic Toughbook® (Model CF-74). The ISGS detection system inventory lists and specifications are presented in Table 3.9.

3.1.1.8 Troxler™ 3430 Nuclear Moisture/Density Gauge

The Troxler™ 3430 nuclear moisture density gauge was a portable instrument used to determine soil moisture (Figure 3.26). Measurements were used to verify soil moisture did not exceeded 15 percent, which was an operating requirement for gamma scanning activities, in accordance with the SAP (HGL and TPC, 2010a).

The main compartment of the Troxler™ 3430 contained sealed radioactive sources, detectors, shielding, electronic modules, and a battery pack. An americium-241 and beryllium neutron source and a helium-3 detector tube were used to measure soil moisture content. The Cs-137 source for density measurements was not used for this project.

The instrument face had a digital display and keypad allowing the operator to read data and control instrument functions. The main compartment had dimensions of approximately 1 foot by 0.5 feet by 0.5 feet and weighed approximately 15 pounds (lbs), with an arm length of 1.5 feet.

Accessory equipment such as the scraper plate, reference block, and battery charger were stored with the instrument. The scraper plate was a metal plate with two approximately 6-inch tube handles used to clear and level the test surfaces. The reference block was a dense plastic block used for daily instrument checks. The Troxler™ 3430 Nuclear Moisture Density operator manual and specifications are located in Appendix J.

3.1.1.9 Global Positioning Systems

Initially the Trimble® Model GeoXH™ GPS receiver was used for GPS data collection (Figure 3.27). The ERGS II was an exception as it used the Trimble® Model AgGPS 332 receiver with an attached Tornado™ external GPS antenna (Figure 3.28). These units had an accuracy of about 1 m. The Trimble® GPS units were connected to the respective RSI console and replaced the external GPS antenna. During scanning operations, the RSI interface console integrated the measured gamma data with GPS data. The GPS satellite signal was received by an internal antenna in the GeoXH™ which was mounted above the centerline of the NaI detector for any particular detection system. Post-process merging of data was not required.

The GPS unit was later upgraded to the Trimble® Model SPS852 GPS receiver with a Global Navigation Satellite System capability (Figure 3.29). This upgrade substantially increased the maximum satellite coverage by including the Russian GPS satellite system. Accuracy correction was provided by a 900 megahertz (MHz) radio signal using Real Time Kinematic. A Trimble® Model SPS852 GPS base station, with the precision base upgrade, was installed on the roof of the project office (Figure 3.30). This base station relayed accuracy corrections to the receiver units, via 900 MHz radio signals, allowing for a real time GPS accuracy of 10 cm. To maintain the radio signal during scanning operations in the NBZ, a Trimble® Model SNB900 radio repeater was set up in the field at the Study Area boundary (Figure 3.31).

Post-process merging of data was required for the Trimble® Model SPS852 GPS receiver data. To enable merging of measured gamma data with GPS data, each RSI console utilized an internal GPS receiver for data synchronization. Thus, gamma data was recorded with the same synchronized time stamps as the unattached SPS852 receiver, ensuring the GPS coordinates were correctly aligned to detector data. The two datasets were later merged using GPSMerge, a software program developed by HGL. This program is described in Section 3.1.2. Table 3.10 summarizes the GPS systems. The user guides for the GeoXH™ GPS, Real-Time H-Star, Trimble® Model SPS852 Receiver, and SNB900 radio repeater are provided in Appendix J.

3.1.2 Detection System and Instrumentation Software

Several software programs were required for operating the detection systems, and data processing and analysis as listed below:

- ArcGIS
- ArcPad®
- Genie™ 2000
- GPSMerge
- Oasis Montaj®
- Quality Control Manager
- RadAssist®
- Trimble® – SPS Operator

Details of each software program are summarized in the following sections. Figures 3.32 through 3.36 are schematics of the data collection and merging process for all detection system configurations.

3.1.2.1 ARCGIS®

ArcGIS® version 10.0 by ESRI was a modeling and analysis program which was used as the primary data analysis program at the beginning of the study. It collected the raw data produced by the RadAssist® program in comma separated variable format as an input to form a database. This database was then used for statistical analysis as well as mapping for both PRGAY identification and presentation purposes.

3.1.2.2 ArcPad®

ArcPad® version 10.0 R2 (Build 30) by ESRI was a navigation and data collection program. It was used for field navigation and collection of location information on detection systems which employed the Trimble® Model SPS852 GPS receiver. ArcPad® displayed in real time the location of data collection points over a map layer. This was the primary indicator of survey surface coverage in the field. The program also recorded the location information and exported it as a shapefile compatible with the GPSMerge program.

3.1.2.3 Genie™ 2000

Canberra Industries' Genie™ 2000 version 3.2.1 was a data analysis program for spectral analysis. This program was used to analyze static measurements collected by NaI detection systems and the ISGS. The evaluation of data from these systems required establishing standardized analysis sequences. The ISGS was used in accordance with Field Operating Procedure (FOP) 1.1.0, Use of the In-Situ Gamma Spectrometer.

3.1.2.4 GPSMerge

GPSMerge software was developed by HGL as a data processing tool. Its function was to combine the high accuracy GPS data recorded with ArcPad® with the RSI proprietary binary output format (RSIBIN) of the RadAssist® software. Formatting of the RSIBIN file was maintained to retain compatibility with the data analysis program Oasis Montaj®.

3.1.2.5 Oasis Montaj®

Oasis Montaj® is a geospatial modeling and analysis program by GeoSoft®. It was found to accept a much higher data volume and a broader range of data formats than ARCGIS®. The ability of Oasis Montaj® to accept the RSIBIN data format combined with its larger capacity resulted in its replacing ARCGIS® as the primary scanning data analysis tool for the study.

3.1.2.6 Quality Control Manager

QC Manager software was developed by HGL as a QC check for RSI detection systems. This program verified the daily source check was within a 20 percent range of an established baseline. In addition, QC Manager verified the system test result, full width at half maximum (FWHM), was within an acceptable range of 7 to 8 kilo electron volts (keV).

3.1.2.7 RadAssist®

RadAssist® version 3.18.2.0 by RSI was the controlling software for all RSI detection systems. In addition to detection system operation, this program was also used for preliminary data processing and analysis. RadAssist® as used in the study was configured with the following add-ons:

- Live data view: Provided RadAssist® with the ability to display spectral data in real time.
- RS-701 interface: Required for the operation of any detection system which used the RS-701 console.
- RSX5 interface: Enabled direct operation of the RSX-4 detectors bypassing the RS-501 console.
- RS relay server: Allowed the detection system to connect remotely to the manufacturer's network for technical support.

- RS-501 interface: Required for the operation of any detection system which used the RS-501 console.
- Geographic Information System (GIS) data view: Provided the ability to perform basic GIS and navigation functions.
- Upload calibration parameters: Permitted uploading of calibration parameters from detection system to controlling computer eliminating the time consuming task of manually entering a calibration coefficient matrix.
- Field scripting: Enabled RadAssist® to recognize Python scripting within its data processing and analysis functions. By adding this feature, RadAssist® was able to display real-time information which otherwise was available only by post processing.
- Nuclide IDview: Gave RadAssist® the ability to perform a background corrected analysis of a dataset.
- Spectral analysis: Provided program with nuclide identification function in both live data view and Nuclide IDview.

In addition to the add-ons, RadAssist® required ROIs before data collection. These ROIs allowed for enhanced real time radionuclide identification and for more efficient data post processing. To enable these features, the parameters summarized in Tables 3.11 and 3.12 were entered into RadAssist®.

3.1.2.8 Trimble®'s SPS Operator

Trimble®'s SPS Operator was the controlling software for the SPS852 GPS receivers. It was used to configure GPS unit output for compatibility with ArcPad® 10.0 (the navigation and data collection program used with SPS852 GPS units). Communication between the SPS852 GPS unit and ArcPad® 10 required a Transmission Control Protocol/Internet Protocol connection established to pass Trimble®'s National Marine Electronics Association (NMEA) format data string at a rate of 1 hertz. This was accomplished through the input/output configuration window in the SPS Operator.

3.2 DETERMINATION OF SENSITIVITY

Sensitivity tests were conducted to determine operating parameters of the detection systems. Test results were used to establish the FOV, operating height, and operating velocity for each detection system (Table 3.1). The following subsections summarize the tests performed and variables affecting the sensitivity of the detection systems (Appendix E).

3.2.1 Detection System Sensitivity Data Collection

Sensitivity testing provided an estimation of the amount of radioactivity detectable in the field with each detection system configuration. The ISGS was not designed for ground surface scanning; therefore, operating velocity did not apply. Calibration to a specific static height was predetermined by USEPA. The following four laboratory tests were conducted in the project field office.

- Radial matrix efficiency test was designed to establish the FOV for each detection system.
- Detection system height test was performed to compare discrete detector scanning heights to provide baseline information rather than to justify selection of a particular height. Operational height selection was driven by physical considerations encountered in the field that balanced balancing both sensitivity and maneuverability of the detection system.
- Velocity test was designed to compare the detection system scanning efficiency against its static efficiency and determine the maximum velocity for each system.
- Subsurface soil depth sensitivity test was conducted to evaluate the linear attenuation of soil and compare it to the calculated linear attenuation. The subsurface tests were performed to document the capability of each detection system to detect subsurface contamination.

The minimum detectable concentrations for each detection system were calculated and verified from the data generated from these tests.

3.2.2 Variables Affecting Detection System Sensitivities

Several environmental variables could affect measurements. They are listed below in order of importance:

- Physical features (buildings, asphalt, sandstone outcrops, etc.)
- Soil composition (geological formation)
- Soil moisture content
- Atmospheric conditions

NORM is found in rocks and minerals; thus, soil composition can also affect detection system measurements. Soil compositions are dependent on the two main geological formations that underlie and crop out on the site: the Chatsworth Formation and the Santa Susana Formation. Additional information regarding the geological setting is discussed in Section 2.0. Gamma emitting radionuclides are commonly found in sedimentary rocks which can contain NORM. Asphalt and concrete found above or below ground surface could also cause fluctuations in local background gamma radiation due to rocks and minerals in the asphalt and concrete mixtures. The process for establishing localized background surface radiological levels is discussed in Section 7.1, and a discussion of the associated background variations that were observed between subareas within the Area IV Study Area is provided in Section 9.1.

Because water has an attenuating effect on radiation (Appendix G), the project team determined the effect of soil moisture content on gross gamma radiation count rate measurements (HGL and TPC, 2010a). Gamma radiation measurements were collected with the ERGS II and soil moisture readings were measured with a Troxler™ Model 3430 nuclear density gauge as described in the SAP.

Results of the soil moisture study indicated a negative correlation between gamma radiation measurements and soil moisture content. An increase in soil moisture resulted in a slight decrease in gamma measurements; at 20 percent soil moisture the gamma measurement decreased approximately 3 percent. No further inferences could be made based on the data collected. The findings agreed with the American National Standards Institute (ANSI) recommendation of a maximum of 15 percent soil moisture content as the limit for field gamma scanning in accordance with the SAP (HGL and TPC, 2010a).

Data recorded and reviewed from both sources included daily high temperatures (measured in degrees Fahrenheit), dew point, humidity percentage, maximum pressure (inches water) and precipitation (inches). Gamma radiation had a weak negative correlation with barometric pressure; increased pressure results caused a slight decrease in gamma count rates (Appendix G). This weak correlation may have been influenced by high soil moisture content or seasonal variations at the time of study.

Radon levels typically increase shortly after arrival of a low pressure air mass and decrease shortly after the onset of a high pressure air mass. Meteorological data was reviewed and recorded daily to compare increased gamma measurements to weather conditions. Meteorological data was supplied by The Boeing Company's on-site weather station using a Climatronics digital pressure sensor barometer Model #102666 and from the Weather Underground™ website (www.wunderground.com) which used seven nearby weather stations. This public domain website provided real-time weather information for all major cities and was a reliable data source throughout the project.

3.3 SPECIAL TRAINING REQUIREMENTS

The gamma scanning investigation involved using several detection systems and instrumentation which required specialized training and/or certification. Only certified personnel were allowed to operate the equipment requiring specialized training as follows:

- Industrial off-road telehandler
- Track mounted gamma scanners
- Mule and mule equipment
- Troxler™ nuclear density gauge

Due to the presence of state and federally protected species, artifacts with cultural significance, and the concern for health and safety, personnel were required to undergo training on the following topics:

- Natural resources
- Cultural resources
- Snake handling

Poisonous snakes in the Area IV Study Area were relocated on site to a location far away from work zones as required for the health and safety of field personnel. Only personnel who received snake handling training were authorized to capture and relocate snakes.

Certifications, training records, instructional forms, and test results were maintained on site by the site Radiation Safety Officer (RSO) and the Site Safety and Health Officer (SSHO). Additional information regarding these trainings is summarized in the following subsections.

3.3.1 Specialized Equipment Training

3.3.1.1 Industrial Off-Road Telehandler Training

To operate the telehandlers, personnel were required to obtain State of California Occupational Safety and Health Administration (OSHA) certifications (Cal/OSHA General Industrial Safety Order 3649-3669). This training also satisfied federal OSHA certification in accordance with Code of Federal Regulations (CFR) 1910.178. Training for the industrial off-road telehandler was conducted by an OSHA Certified Trainer.

An instructional presentation on safety and operation of the equipment was provided by the SSHO. Field training consisted of identification of equipment controls and the proper usage of equipment attachments and functions. Personnel received instruction on proper operating procedures for equipment and identifying vehicle's capabilities during gamma scanning field activities and stability on uneven terrain. Emphasis was placed on safety by training personnel to identify potentially hazardous environmental conditions and procedures for utilizing the telehandler to prevent harm to the operator and equipment. The operator was required to pass a written and driving exam. Upon completion of training and exams, personnel were required to complete 40 hours of supervised operation to receive Cal/OSHA certifications.

3.3.1.2 Track Mounted Gamma Scanner Training

The STGS and TMGS required field and classroom instruction which was provided by the SSHO. Classroom instruction consisted of a presentation covering safe handling of the equipment and instrumentation, equipment physical capabilities, and proper operating procedures. After classroom instruction, the SSHO conducted field training consisting of operating tracked systems over varying terrain, and proper loading and unloading of equipment from the transport trailer. Personnel were also trained to identify ideal locations and conditions for using the TMGS and STGS in gamma scanning activities. Before personnel were authorized to operate the track systems, a written exam and a field test were administered.

3.3.1.3 Mule and Mule Equipment Training

Gamma scanning with the MMGS required personnel to interact with mules. Training to work with mules was provided by an experienced mule handler, who was an equine expert. Personnel were trained to identify ideal locations and conditions for using the MMGS in gamma scanning field activities. Personnel were provided training on operating overhead hoist equipment used to raise and lower the MMGS onto the mules (Photograph A.11).

3.3.1.4 Troxler™ Training

Specialized training was provided by the American Portable Nuclear Gauge Association to operate the Troxler™ in accordance with State of California regulations. Personnel received training on operational safety, security and driver awareness, and function-specific training of a nuclear gauge. The course covered aspects of Nuclear Regulatory Commission Regulation 1556 and 49 CFR 172, Subpart H, and was handled in accordance with State and Federal regulations. In addition, personnel received training on selecting representative sample locations.

3.3.2 Site Specific Training

3.3.2.1 Natural Resources Training

Throughout the course of the project, measures were employed to protect natural resources. These measures were detailed in the Site Management Plan (SMP) (HGL, 2010b) written to satisfy environmental protection standards as required by the National Historic Preservation Act; PL89-655, as amended through 2006, 16 USC 470 et seq. Before entering the field for the first time, a Biological Monitor (biologist) conducted training sessions to familiarize personnel with on-site endangered or threatened species and habitats. The Biological Monitor also instructed personnel on procedures to follow if threatened plant species, animal species, or their habitats were encountered, and measures to be employed to prevent damaging or disturbing the resource. The Biological Monitor also inspected each area before any field activities began and flagged protected habitats or plant species. Personnel were trained how to identify and work around the flagged areas during gamma radiation investigation activities (Photograph A.17).

An information sheet was provided to site personnel containing a list of the federal and state species of concern in the Biological Assessment prepared by the USEPA and the Biological Opinion issued by the U.S. Fish and Wildlife Service. Species at risk but not considered endangered or threatened from site activities were also monitored for protection through the joint effort of field personnel and the Biological Monitor (HGL, 2010b).

3.3.2.2 Cultural Resources Training

In addition to natural resources training, personnel were trained by a Cultural Resources Monitor (archaeologist) and a Native American Advisor/Consultant (local Chumash tribe representatives) on recognizing cultural resources which included:

- Archaeological deposits - soils that contained material evidence of human activity including remains of structures, hearths, burials, and other features
- Artifacts - objects made by people such as whole or broken grinding stones, bowls and tools of various kinds
- Rock paintings and carvings tied to the landscape
- Cultural resources also included certain plants and sacred sites (natural features of the landscape recognized in local traditions and places with cultural significance)

To mitigate the potential for disturbing cultural resources within the Area IV Study Area, Cultural Resource Monitors flagged areas designated as a cultural resource (Photograph A.18). Personnel were trained to recognize and avoid these areas. Entry into these areas, if essential, was made only after obtaining prior approval and conducted under the guidance of a monitor (HGL, 2010b).

3.3.2.3 Snake Handling Training

The SSFL is a natural habitat for the protected Southern Pacific Rattlesnake species; thus, special care was taken to protect personnel. Some personnel were trained to handle and relocate rattlesnakes out of harm's way and to protect field personnel. Training consisted of a three-hour class with a herpetologist from Jules Sylvester's Reptile Rentals, Inc. Personnel were taught how to identify rattlesnakes versus non-venomous snakes, how to use snake tongs and hooks to capture snakes, and how to place the snakes into a bucket without harming the reptile or themselves. Personnel with snake handler training were required to relocate snakes. Only personnel who volunteered received snake handling training.

4.0 SAMPLING AND ANALYSIS PLAN AMENDMENTS AND DEVIATIONS

This section summarizes the amendments to and deviations from the SAP which occurred during data collection activities (HGL and TPC, 2010a). The following amendments and deviations were documented in the gamma scanning field logbooks. All logbooks were maintained in accordance with Standard Operating Procedure (SOP) 4.07, Use and Maintenance of Field Logbooks, which are retained by HGL and will be transferred to the USEPA.

4.1 AMENDMENTS

Some strategies and procedures described in the original SAP were modified to accommodate conditions encountered in the field and to improve field operations. These amendments address equipment modifications and changes to procedures for collecting, processing, and evaluating data. Amendments are documented in this report in lieu of making multiple revisions to the SAP. Table 4.1 summarizes affected sections of the SAP and includes a brief description of the amendment and the section in this report with details of the amendment.

Table 4.1
Summary of Amendments to the Final Gamma Radiation Scanning SAP

SAP Section	Amendment Summary	Gamma Scanning Report Section
Section 4.0 – Detection Systems and Instrumentation	When the SAP was completed, detection system design, components and specifications were not fully established. The proposed detection systems were modified prior to data collection.	Section 3.1 and Tables 3.3 through 3.10 describe as-built configurations and specifications of the detection systems.
Section 4.0 – Detection Systems and Instrumentation	The TMGS and STGS were not planned detection systems. They were developed after data collection activities had commenced to increase access to steep terrain with the large volume RSI detectors. These two detection systems provided better ergonomics than the HHGS, and enhanced stability and maneuverability, detector sensitivity, and FOV for steep terrain than the other detection systems.	Sections 3.1.1.2 and 3.1.1.4
Section 4.5 – HPGe	The nomenclature of the HPGe detection system is consistent with industry standards. The name was changed to "In Situ" for field activities as documented in field logbooks.	Section 3.0
Section 4.6 – FIDLER Detection System	The field instrument for detection of low energy radiation (FIDLER) detection system was not used for data collection activities as soil sampling and analyses would provide more accurate measurement of low energy gamma activity.	None

SAP Section	Amendment Summary	Gamma Scanning Report Section
Section 5.1.1 – Definition of Gamma Radiation Anomaly	Radiological Background Reference Area data was not used in the verification process for determination of GRAYs because the background levels at the Radiological Background Reference Areas were greater than those at the Area IV Study Area. Localized background levels were calculated for each subarea for data analysis and evaluation purposes.	Section 9.1
Section 5.1.2 – Identification of a GRAY	In the PGRAY Verification Reports, GRAYs were subcategorized into Verified GRAY, Not a GRAY, and Inconclusive GRAY. The PGRAY sub classifications were developed to help clarify the PGRAY status for selection of soil sample locations.	Section 9.0
Section 5.1.2 – Identification of a GRAYs	Complex modeling of GRAYs with the MicroShield software program was not required as the detection systems provided adequate characterization for identification purposes.	None
Table 5.1 and 5.2 – Surface Attributes and Survey Area Categories	Survey areas were not categorized by the 29 combinations of the three surface attributes. Three attributes were initially used to create 29 combinations: slope gradient, vegetation height, and surface type. During field activities a detector system was predominately selected based on slope gradient. Other attributes considered were soil compaction (unstable surfaces), proximity to buildings, sandstone outcrops, and protected resources, and vegetation exempt from disturbance.	Section 6.3
Table 5.2 – Survey Area Categories	When the SAP was completed, the MMGS was listed as the second most sensitive detection system; however, sensitivity test results indicated it was the least sensitive of the RSI based detection systems.	Section 3.0 and Appendix E
Section 5.2 – Gamma Radiation Scanning Strategy	Maps of the surface attributes, surface type and vegetation height, were not generated for the Area IV Study Area. As discussed above, slope gradient was the predominate attribute utilized in determining accessibility. Only one map was created which incorporated the other surface attributes with the slope gradient.	Section 6.3

SAP Section	Amendment Summary	Gamma Scanning Report Section
Section 5.2 – Gamma Radiation Scanning Strategy	The TMGS and STGS detection systems were not used to rescan surfaces previously surveyed by the MMGS. The TMGS and STGS, which were more sensitive detection systems than the MMGS, were developed after gamma scanning had commenced. Many surfaces that the MMGS had surveyed were accessible with the TMGS or STGS. Due to budgetary and scheduling constraints these locations were not rescanned using the TMGS or STGS; however, the MMGS data was deemed sufficient for detection of PGRAYs in the areas surveyed. All PGRAYs were verified with a more sensitive detection system.	Section 7.5.3
Section 5.2 – Gamma Radiation Scanning Strategy	The nomenclature of "Sub-Survey Areas" was changed to "Survey Sections." The Area IV Study Area was divided into 12 subareas to align with the convention of previous investigations. For gamma scanning, each subarea was further divided into smaller units called Survey Sections. This terminology more easily differentiated gamma scanning areas from the project subareas.	Section 2.1
Section 5.2 – Gamma Radiation Scanning Strategy	Project-specific FOPs were developed to meet project-specific requirements, as existing HGL SOPs were not adequate for the scope of this project.	Appendix I
Section 6.2 – Sensitivity Testing	Detection system sensitivity testing results were not compared to modeled results. Modeled results were not developed because the sensitivity tests were found adequate.	Section 7.2 and Appendix E

4.2 DEVIATIONS

Occasional minor deviations from SAP procedures occurred during data collection activities (HGL and TPC, 2010a). These deviations were related to excursions made to improve scanning measurements and ergonomics, and changes to procedures made to address health and safety concerns. Table 4.2 summarizes the affected procedures and includes a description of the rationale for the deviation from the SAP.

Table 4.2
Deviations from Planned Procedures

Deviation	Rationale for Deviation
SAP, Section 5.5 - Gamma radiation measurements from scanning activities were not compared to soil sample laboratory analytical results to determine a correlation.	A correlation analysis was not possible at the time this report was finalized because all laboratory analytical results were not available for comparison. Data quality was not affected by this deviation.
SAP, Section 7.1 - Instrument field quality control procedures required taking an instrument out of service after three consecutive daily QC failures until the cause of the failure was determined and corrected. The ERGS II failed three QC checks but was used to collect data while the cause of the failure was corrected.	The control interface board on the ERGS II detection system failed for unknown reasons, resulting in a QC failure and an artificial increase in the count rate by a multiple of 2.3. After completing a system diagnostic, the manufacturer recommended applying a correction factor of 2.3 to process the data until a replacement board was obtained. The correction factor was applied to all affected data collected by dividing the count rate measurements by 2.3 to obtain corrected an accurate data. The detection system was operated in this manner for two days before the control interface board was replaced and normal operations restored. Since the data was adjusted to the correct count rate values, the data quality was not affected by this deviation.
Sensitivity Report, Section 3.0 – Each detection system was assigned a maximum velocity which was not to be exceeded during data collection. The maximum velocity was exceeded occasionally in order to operate the detection systems safely.	Due to field conditions, the maximum velocity was exceeded in some circumstances. For example, the MMGS may have exceeded the maximum velocity when descending steep slopes. In these cases, resulting data was evaluated and specific locations were rescanned if data gaps or compromised data was found. Brief excursions above the maximum velocity did not affect data quality.

5.0 QUALITY ASSURANCE AND QUALITY CONTROL

The QA program implemented throughout investigation activities ensured fulfillment of quality control requirements in accordance with the SAP (HGL and TPC, 2010a). Systematic monitoring of QA processes reduced occurrences of errors during gamma data collection. The QC program focused on testing procedures to verify detection systems were functioning correctly and fully operational before data collection commenced, and to ensure collected data were consistent, comparable, accurate, and within specified limits of precision. In summary, QC test results documented that equipment was properly functioning while QA procedures ensured the data collection process was performed consistently within project requirements.

The following subsections summarize development of QC limits, inspection procedures, maintenance activities, equipment damages sustained during field activities, and corrective actions to ensure data quality and functionality of detection systems and equipment.

5.1 DETECTION SYSTEM CALIBRATION

Manufacturers of each detector provided an initial calibration. Annual calibration of all RSI based detection systems was not required or recommended by the manufacturer. Recalibration was recommended only when equipment damage or malfunction was severe enough to require repair by RSI. The HHGS detector required annual calibration which was performed by the manufacturer, Ludlum™ Measurements. Calibration of the ISGS was maintained by USEPA. All calibration sheets are located in Appendix O.

5.2 QUALITY CONTROL CHECKS

Three operational QC checks for each detection system were established at the beginning of the gamma radiation investigation. The mean response was determined in accordance with American National Standards Institute N323A (ANSI, 1997). Detection systems were tested for the following:

- Activity response to known quantities of gamma emitting from sealed radioactive sources (source check)
- Resolution response to known quantities of gamma emitting from sealed radioactive sources (resolution check)
- Ambient background (background check)

QC limits for the source check and resolution checks were established. The background check was a qualitative determination of detector usability and used for background subtraction of the gross count rates obtained during daily QC checks. However, background subtraction was not performed on gamma radiation scanning field data. All RSI detection systems QC procedures are detailed in FOP 2.01, Quality Control for Radiation Solutions Inc. Gamma Detection Systems.

5.2.1 Quality Control Limits for Radiation Solutions Inc. Systems

Upper and lower QC limits for source and resolution checks were established during the initial setup of each detection system and after any repairs or modifications were completed. QC limits were established by performing 20 background baseline measurements, which were used to calculate net source response, and 20 radioactive source measurements.

Background baseline measurements were collected over the course of multiple days at the respective detection system's designated QC test area adjacent to the project office (Building 204). Each measurement was performed at a fixed and consistent geometry for 10 minutes and the average background baseline calculated. RadAssist® was used to initiate and terminate QC data collection, and to log and export the data.

The source and resolution check involved exposing the detection system to a National Institute of Standards and Technology (NIST™) traceable radioactive sealed source with a known activity (see certifications in Appendix N). An approximately 1-microcurie (μCi) "button" source of Cs-137 was used for the ERGS II, TMGS, WMGS, STGS, and HHGS I and II, while the MMGS required approximately 3 μCi Cs-137 source (the detector height required a greater activity to obtain a reasonable response). The source and resolution check procedure was performed at a fixed and consistent geometry for five minutes at the designated QC location. RadAssist® was used to initiate and terminate the measurements, log and export the data.

After completion of 20 measurements, a source check baseline was calculated by subtracting the average background baseline measurements from each source check measurement. Next, the results were averaged to create a source check baseline. The upper and lower QC limits were established at 20 percent above and below the source check baseline.

In addition to establishing a baseline for source response and background, a baseline system resolution test was determined for the RSI detection systems in concurrence with the 20 source checks. This test measured the peak energy resolution of a Cs-137 peak in FWHM. The required resolution was an FWHM between 7 and 8 keV, as recommended by RSI.

To ensure the detection system data was within the established QC limits, data was uploaded into QC Manager, a software program developed by HGL for this project. This program verified the daily source check was within the 20 percent range of the established baseline as well as verifying the system resolution check was within the proper range. QC data graphs for the detection systems are located in Appendix M.

5.2.2 Daily Quality Control Checks for Radiation Solutions Inc. Systems

A daily source check, based on net response, was performed to verify each detection system responded to a known radiation field in a consistent manner. This was accomplished by repeatedly exposing the detection system to the same NIST™ certified Cs-137 source using an identical geometry, and comparing the results to an established baseline in accordance with FOP 2.01, Quality Control for Radiation Solutions Inc. Gamma Detection Systems. If the daily source check failed three consecutive times then the detection system was taken out of service until the cause of the failure was determined and corrected. The NIST™ source certifications are provided in Appendix N.

A daily resolution check was performed to ensure the gamma spectral analysis of each detection system was functioning properly. This was accomplished by exposing the detection system to an NIST™ certified Cs-137 source (the same one used in the daily source check) and verifying the resulting gamma energy peak at approximately 662 keV had an FWHM value between 7 and 8 keV, as defined by FOP 2.01. If the daily resolution check failed three consecutive times then the detection system was taken out of service until the cause of the failure was determined and repaired.

5.2.3 High Voltage Adjustment for Radiation Solutions Inc. Systems

A high voltage adjustment was required if an RSI-based detection system displayed a noticeable shift in gamma spectra or prolonged auto-stabilization. This shift was noted if the detection system failed the Daily System Test or if the potassium-40 peak was not located at 1461 keV as expected. Adjusting the high voltage aligned the potassium-40 peak with the desired energy level. Auto-stabilization typically required 30 seconds to 3 minutes, if this time period was exceeded then a high voltage adjustment was required. The manufacturer's procedure was followed and completion of a high voltage adjustment was noted in the detection system field logbook.

5.2.4 Quality Control Limits for the In-Situ Gamma Spectrometer

Upper and lower QC limits were established during initial setup of the ISGS and after repairs or modifications. QC limits were established by performing 10 radioactive source response measurements and 10 background measurements in accordance with FOP 2.10, Quality Control for the In Situ Gamma Spectrometer. The average measurement and standard deviation were calculated for the peak centroid, net counts, and FWHM for both the 122 keV peak and the 1408 keV peak. The average and standard deviation for background integral counts were also calculated.

5.2.5 Daily Quality Control Checks for the In-Situ Gamma Spectrometer

The source check involved exposing the ISGS to NIST™ traceable radioactive sealed sources with a known activity (see certificates in Appendix N). The sources were two europium-152 sources and one cadmium-109 source, approximately 1 μCi each. The source check procedure from FOP 2.10, Quality Control for the In Situ Gamma Spectrometer, was performed at the designated QC location adjacent to the project office at a fixed and consistent geometry for a five minute static measurement while the background check was a 20 minute static measurement. Genie™ 2000 software initiated and terminated the measurement, and logged and exported the data.

5.3 INSPECTION PROCEDURES AND MAINTENANCE

Subsequent to the daily QC check, visual inspections were performed on each detection system before field use to ensure mechanical and electrical components of the detectors and transportation mechanism were intact. The uniqueness of each detection system required individual inspection and maintenance logbooks to track regular mechanical services performed on the ERGS II, TMGS, STGS, WMGS, and MMGS. Inspections and maintenance for the HHGS and ISGS were documented in the respective field logbooks since these systems were not used daily.

5.3.1 Enhanced Radiation Ground Scanner II

The following tasks were performed by project personnel before using the ERGS II on a daily basis:

- Examining for loose wiring
- Checking battery voltage
- Examining for damage to the polycarbonate window
- Checking structural integrity
- Inspecting tire treads for excessive wear
- Checking fuel level
- Performing visual inspections for fluid leaks
- Visually inspecting telehandlers for structural damage

ERGS II maintenance, such as replacing faulty motherboards and batteries, was recorded on the Gamma Scanning ERGS II Maintenance Log Sheets and in field logbooks. Examples of blank field forms used are provided in Appendix L.

Telehandlers were also inspected daily in accordance with the manufacturer's manuals provided by the rental companies (Appendix J). Inspections performed were recorded on log sheets by telehandler type. Certified mechanics from the rental company performed technical maintenance and repairs. Documentation for maintenance and repairs was recorded in inspection and maintenance logbooks.

In addition to maintenance, upgrades were performed to the tires on the JCB Model 524-50, Skytrak® Model 10054, and Gradall® Model 534D9-45. They were modified from air filled tires to foam filled tires by the rental company to prevent loss of tire pressure caused by punctures and wear from the rough terrain in the Area IV Study Area.

5.3.2 Track Mounted Gamma Scanners

Daily inspections performed on the TMGS and STGS consisted of the following tasks:

- Inspecting air filter
- Checking fuel and oil level
- Inspecting conditions of tracks
- Inspecting conditions of belts and hoses

- Performing visual inspections for fluid leaks
- Checking tightness of all fastener bolts

All inspections were performed by gamma team personnel and were recorded on the Gamma Scanning Equipment Inspections Log Sheets. In addition to daily inspections, maintenance was also performed on the TMGS and STGS on a weekly or as needed basis. Regular maintenance included:

- Changing the oil after 50 hours of operation
- Changing the transmission fluid after 500 hours of operation
- Cleaning the air filter
- Checking for loose wiring

For the TMGS and STGS to function properly in the field conditions present at the Area IV Study Area, upgrades were implemented to improve the reliability, durability, and performance. These upgrades included:

- Replacing the standard engine oil with synthetic oil
- Changing the rubber tracks with rubber tracks reinforced with forged steel
- Replacing the standard yokes with custom-made stainless steel yokes

The yoke and track upgrades were necessitated by reoccurring damage incurred during scanning activities as discussed in Section 5.4.2.

5.3.3 Wheel Mounted Gamma Scanner

Before field activities commenced, the following inspection activities for the WMGS were completed daily:

- Checking for loose bolts
- Checking tire pressure
- Inspecting condition of brake pads

The WMGS was not mechanized; therefore, no additional maintenance logs were required.

5.3.4 Mule-Mounted Gamma Scanner

The following inspections were performed on the MMGS support and transportation equipment before field activities commenced each time the MMGS was used:

- Examining cables for signs of damage and wear
- Examining the hoist for signs of damage and to ensure proper function
- Checking hooks for signs of damage and wear
- Inspecting pulleys to ensure proper function

In addition to the inspections of the equipment, the mules were also examined daily for lesions and general health concerns. The mules were brushed to remove excess sand and dirt from their bodies to prevent sores forming where the harness contacted their skin. Their hooves and legs were also checked for signs of wear.

Once the detection system was mounted onto the mule, the straps and harnesses used to attach the detection system were inspected. It was often necessary to adjust the detectors and tighten the harness straps periodically due to movement while scanning.

An individual mule was utilized for gamma scanning activities a maximum of three to four hours per day and then allowed to rest overnight, at a minimum. Often the mules were allowed a full day of rest between work shifts to prevent fatigue. The mules were provided plenty of water and fed a mixture of seedless hay (which met Bureau of Land Management standards), crimped oats, rolled barleycorn, and various feed supplements three times daily. Animal waste was removed from the stable, stored in a small dumpster bin, and taken off site periodically. Bun bags were employed during field use to ensure no animal waste was left in the Area IV Study Area.

The mules were kept on site during the weekdays in a custom built stable on the northern end of the parking lot at the USEPA field office, Building 204. On weekends, holidays, or when the field office was closed, the mules were kept at an offsite stable. Jack Lilley's Movin On Livestock stables housed three mules (named Sarah, Katie, and Big Kate). Private boarding stables were used to keep three other mules (named Bonny, Betty, and Ellie May).

The project mule handler was responsible for training and conditioning the mules, which took approximately one and a half months to complete. The mules were trained for 20 to 25 hours per week during that time. The mules' training was two-fold. First, their bodies needed physical hardening and increased balance in rough terrain to carry the heavy loads. Second, they were trained to walk at a slower pace (scanning speed as opposed to normal walking speed).

5.3.5 Hand-Held Gamma Scanner

The HHGS I and II were not mechanized; therefore, daily inspection and maintenance was not required. A visual inspection of all equipment was performed to ensure damage had not occurred from previous usage.

5.3.6 In Situ Gamma Spectrometer

Inspections and maintenance performed on the ISGS before field activities commenced each time the ISGS was used consisted of the following:

- Examining the physical integrity of the instrument
- Checking battery charge
- Verifying the Dewar had been filled with liquid nitrogen within 24 hours
- Examining cables for signs of wear and damage

- Checking computer function

Additional maintenance performed on the ISGS was performed by USEPA. QC procedures were performed on the ISGS before field use and recorded in the field logbook.

5.4 EQUIPMENT AND INSTRUMENT DEFICIENCIES AND CORRECTIVE ACTIONS

Deficiencies were observed during data collection. These deficiencies consisted of external damage identified during visual inspections, a loss of communication between the detector(s) and the computer, or a discrepancy in data output. Deficiencies were investigated immediately to isolate the possible cause and corrective actions implemented, if necessary. Data was re-collected in locations when discrepancies resulted in comprised or lost data.

When an event occurred that could have caused damage to a detection system, including the transportation mechanism, gamma survey personnel reviewed the event logs in RadAssist® to confirm the detectors were not damaged. The RadAssist® "RSI alarm" was also reviewed for a flashing indicator signaling a GPS connection was lost. Personnel further examined the detection systems and transportation equipment for cracks, leaks, and any additional breakage that may have occurred. If a detection system was not operating correctly, gamma survey personnel diagnosed the situation, attempted to make the necessary field repairs and resumed data collection activities. When field repairs were not possible, the detection system was returned to the project office for repairs or replacement. All events of damages and repairs were recorded in the respective detection system field logbook.

If repairs could not be completed on site, the equipment was either shipped to the manufacturer or a certified technician would come on site to make the repairs. Further records were maintained, such as equipment repair request forms and billing invoices, to track the repair activities.

5.4.1 Telehandlers

Telehandlers requiring repairs for mechanical problems or damage were as follows:

- JCB® 5,000 lb Loadall Series 524-50
- Skytrak® 10,000 lb Legacy Series 10054
- Gradall® 6,000 lb Model 534D-6

Not all telehandlers used during gamma scanning activities required repairs and thus are not discussed in this section.

5.4.1.1 JCB® 5,000 lb Loadall Series 524-50

Deficiency: The hydraulic fan pump brackets broke; this immobilized the telehandler.
Corrective Action: The brackets were replaced by a qualified technician.

Deficiency: A connector located in the undercarriage was disconnected causing the telehandler to become unresponsive in forward and reverse drive.
Corrective Action: To prevent additional damage to the undercarriage, a skid plate was installed by the rental company.

Deficiency: A hydraulic fluid leak occurred and subsequently all fluids were cleaned up immediately. This affected the stability of the boom, resulting in the inability to maintain a constant detector height of 15 inches above the ground surface.
Corrective Action: An O-ring was installed to prevent further leaking.

5.4.1.2 Skytrak® 10,000 lb Legacy Series 10054

Deficiency: The Skytrak® Legacy Series 10054 engine experienced complications, causing the telehandler to stall and release smoke from the engine compartment. Troubleshooting revealed that two pistons had seized due to overheating of the engine, thus immobilizing the telehandler.
Corrective Actions: The Skytrak® was returned to the Volvo Rental Company and was replaced with the Gradall® 534D-6.

5.4.1.3 Gradall® 6,000 lb Model 534D-6

Deficiency: A small hydraulic leak occurred in the Gradall® Model 534D-6 from a small hole in the hydraulic line. All fluids were cleaned up immediately. This affected the stability of the boom, causing it to gradually lower during QC checks. This resulted in an inability to maintain the detector height of 15 inches above the ground surface.
Corrective Action: The Gradall® 534D-6 was returned to the rental company for repairs and the JCB® 524-50 was used to continue field activities.

5.4.2 CanyCom

Deficiency: The same CanyCom model was used for both the TMGS and the STGS. Both CanyComs experienced rapid deterioration of the rubber tracks, caused by the harsh terrain within the Area IV Study Area. This affected the ability to scan efficiently as the CanyComs were out of commission for frequent track repairs or replacement.
Corrective Actions: The standard rubber tracks were replaced with rubber tracks reinforced with forged steel. This increased the durability and longevity of the tracks.

Deficiency: The standard yokes on the CanyComs were prone to bending and breaking due to the rough terrain. Damaged yokes caused the rubber tracks to come off the idler assembly and impede gamma scanning activities.
Corrective Actions: The yokes were repaired at the project office until stronger yokes were necessary and were replaced with custom-made forged steel yokes.

Deficiency: The forged steel yokes had increased strength but eventually became brittle and failed.
Corrective Actions: A stainless steel yoke was constructed which resisted bending and breakage for the remainder of the project.

Additional repairs such as replacing the clutch belt and the drive belt were necessary to maintain optimal performance of the CanyCom.

5.4.3 Radiation Solutions Inc. Detection Systems

If an incident occurred that could have compromised data then all output data were assessed for errors. If errors or deficiencies were found then the affected locations were rescanned. In addition, the daily QC checks were performed after completing all corrective actions to verify that the detection systems were functioning properly. These procedures verified all measurements were acceptable and detection systems were operating within required QC limits before being returned to service.

5.4.3.1 Enhanced Radiation Ground Scanner II

Deficiency: The polycarbonate window on the bottom of the ERGS II detection system was broken with additional damage sustained to the bottom of one RSX-4 detector carbon fiber case. The carbon fiber case and polycarbonate window was patched while replacements were ordered. They were immediately replaced upon receipt.
Corrective Actions: Daily QC and scanning data was reviewed to ensure data was not compromised; however, no data were compromised. All subsequent occurrences of the detectors that came in contact with the ground surface required visual inspection of the polycarbonate window, spot check of the RadAssist® error log, and documentation of the event in the ERGS II field logs.

Deficiency: The RSX-4 detector hard drive located on the ERGS II became dislodged from its dock on the motherboard. This occurred when the RSX-4 electronics cover was removed on the detector. Therefore, data was lost.
Corrective Actions: The hard drive was firmly reseated and the cover reinstalled. A procedure was implemented that after maintenance requiring removal of the electronics cover, the RSX-4 detector was verified to be operational before being reinstalled in the ERGS II shield. The hard drive never disconnected from the motherboard if properly seated and with the electronics cover installed.

Deficiency: The wireless router failed on the ERGS II causing communication disruptions between the computer and GPS.
Corrective Actions: The wireless router was replaced and installed in a location to reduce heat and vibration stress during operation. Some GPS data was lost and affected surfaces were rescanned or GIS techniques were utilized to associate gamma data with scanned locations.

Deficiency: Batteries located in the ERGS II were discharging unevenly causing loss of power. Battery life was reduced by over depletion of voltage.
Corrective Actions: The battery electronic circuits were converted from series (24 volts) to parallel (12 volts) to help prolong the battery life. Low voltage circuit breakers were installed to prevent overdrawing power from the batteries. This prolonged battery life by limiting low voltage conditions.

Deficiency: Spectral auto-stabilization for one RSX-4 detector located on the ERGS II began to require a longer response time. Temperature differences over the course of several weeks caused the auto-stabilization to drift beyond the software's capability to perform an auto-stabilization.
Corrective Action: A manual high voltage adjustment was performed to return stabilization times to proper working order

Deficiency: Failure of the control interface board in the RS-501 for the ERGS II increased reported count rate by a factor of 2.3.
Corrective Actions: Replaced the control interface board and the count rate returned to expected levels. Data was corrected as described in Section 4.0.

Deficiency: ERGS II RS-501 hard drive failed preventing all data storage.
Corrective Actions: Replaced the hard drive which restored the detection system's ability to store data. Affected surfaces were resurveyed.

5.4.3.2 Track Mounted Gamma Scanners

No deficiencies related only to this detector occurred. Section 5.4.3.6 lists deficiencies common to all detection systems.

5.4.3.3 Wheel Mounted Gamma Scanner

No deficiencies related only to this detector occurred. Section 5.4.3.6 lists deficiencies common to all detection systems.

5.4.3.4 Mule-Mounted Gamma Scanner

Deficiency: Damage to the male electrical connector on the MMGS RSX-1 detectors stopped all data transfer between the detector and RS-701 console.
Corrective Actions: The connector was replaced which restored communication between the two components. The cable connecting the detector with the console was fitted with an angled female electrical connector and protected with padding to reduce future damage.

Deficiency: An RSX-1 detector fell approximately 2 feet to the ground due to a failure in the mule hoist while lifting the mule rig. The detection system was removed from service pending extended evaluation due to the severity of the accident.
Corrective Actions: The mule hoist mechanism was replaced with a 2,000 pound rated hoist to prevent recurrence. The detector was sent to RSI for refurbishment and recalibration, and RSI documented the detector met their performance specifications.

Deficiency: The external electrical connector on the MMGS was damaged, due to the mules coming in contact with objects, on several occasions causing data transfer between the RSX-1 detector and the RS-701 console to cease.
Corrective Actions: The electrical connector was removed from the detector case and Ethernet communication cables rerouted to protect further damage to the connector.

Deficiency: Ethernet port in the wireless router failed, due to the mules coming in contact with objects, in the MMGS detection system causing communication disruptions between the computers and the GPS.
Corrective Actions: Ethernet cable was relocated to a working port. The wireless router was repositioned to reduce stress placed on the cable port. If GPS data was lost then affected surfaces were resurveyed.

5.4.3.5 Hand Held Gamma Scanners

The HHGS I and II were not used for an extended period of time, thus no deficiencies were noted.

5.4.3.6 Deficiencies Affecting Radiation Solutions Inc. Detection Systems

Deficiency: Ethernet cable failures caused communication disruptions with all detection systems. Radiological data was not compromised but real time mapping using ArcPad® and integration of GPS data with the Trimble® Model SPS852 was interrupted.
Corrective Actions: Faulty cables were identified and replaced. To minimize recurrence of cable failure the new cables were rerouted to reduce the stress incurred during equipment operation. If GPS data was lost then affected surfaces were resurveyed.

Deficiency: Loss of power to the wireless router resulted in a loss of communication for several detection systems. Some GPS data was lost and affected surfaces were rescanned or GIS techniques were utilized to associate gamma data with scanned locations.
Corrective Actions: Batteries for the wireless router were not fully charged due to problematic battery chargers. Batteries were recharged with more effective chargers and communication was restored.

Deficiency: The Panasonic CF-19 Toughbook® for the detection system was unable to connect to a wireless connection point if an Ethernet cable was connected to the computer.
Corrective Actions: Ethernet cable was removed. Only one connection point was used with the Panasonic CF-19 Toughbook® during data collection. Some GPS data was lost and affected surfaces were rescanned or GIS techniques were utilized to associate gamma data with scanned locations.

Deficiency: Low battery voltage caused rapid cycling of detectors resulting in intermittent data collection; this affected all RSI detection systems.
Corrective Actions: Batteries were recharged and the data output returned to normal. Low battery charge resulted from faulty battery chargers. The batteries were recharged with replacement chargers and communication was restored. If data was lost then affected surfaces were resurveyed.

5.4.3.7 In Situ Gamma Spectrometer

Deficiency: The ISGS failed to produce a low energy spectral range during QC check.
Corrective Actions: The high voltage board inside the ISGS was defective. Since the USEPA owned the ISGS, it was shipped back to the USEPA for repairs. The USEPA replaced the unit with a new ISGS.

5.4.3.8 Troxler™ Nuclear Density Gauge

Deficiency: Troxler™ nuclear density gauge failed a QC check due to a faulty Geiger Mueller tube.
Corrective Actions: Troxler™ gauge was shipped to the manufacturer for repairs. While the gauge was in repair the project did not require collection of soil moisture measurements due to low moisture (dry season); therefore, gamma data were not compromised.

5.5 AUDITS

Results of audits conducted by project personnel provided the status of compliance with prescribed QA/QC programs. The audits targeted operational activities associated with gamma scanning activities and to verify gamma detection system results were within established limits.

QA/QC audits were performed throughout the course of the project on each detection system except for the HHGS, due to its short period of use. Audits measured the effectiveness of the procedures and checked for adequacy and effectiveness of process controls over instruments, equipment and operators as established by project requirements.

Activities were assessed against specific project requirement in the following documents:

- FOP 1.01, Use of Radiation Solutions Inc. Gamma Detection Equipment (Appendix I)
- FOP 2.01, Quality Control for Radiation Solutions Inc. Gamma Detection Systems (Appendix I)
- SOP 4.07, Use and Maintenance of Field Logbooks (Appendix H)
- SAP (HGL and TPC, 2010a)
- SMP (HGL, 2010b)

An activity-specific QA/QC checklist was developed to facilitate the audit. The Gamma Scanning QA/QC Field Audit Checklist was completed during the audit and an example is provided in Appendix L. Observations, proficiencies, deficiencies, and suggested corrective actions were noted on this form.

The following is a summary of categories reviewed during QA/QC audits:

- General observations
  - Documentation in compliance with approved plans and procedures
  - Training records complete and up-to-date
- Site Management and Protection of Natural/Cultural Resources
  - Vegetation cleared in accordance with SMP

    - Culturally and biologically protected sites properly identified and boundaries delineated
- Calibration and Inspection
    - Equipment calibration records maintained and documented
    - Equipment maintained and repaired
    - Daily inspections conducted and documented in accordance with FOP 2.01, Quality Control for Radiation Solutions, Inc. Gamma Detection Systems
- Logbooks
    - Logbooks completed in accordance with SOP 4.07, Use and Maintenance of Field Logbooks
- Gamma Survey Operations
    - Gamma survey operations conducted in accordance with FOP 1.01, Use of Radiation Solutions, Inc. Gamma Detection Equipment the SAP and the SMP

The audit team interviewed key personnel, reviewed numerous records and documents, and witnessed field work activities as they were conducted. The audit team determined the QA/QC program was implemented correctly and in compliance with all applicable project requirements. No discrepancies were found during the audit processes.

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6.0 AREA IV STUDY AREA ACCESSIBILITY

To meet project requirements of scanning 100 percent of accessible surfaces within the Area IV Study Area various activities were conducted to prepare the site. These included:

- Reconnaissance
- Vegetation removal
- Identification of accessible surfaces

The following subsections discuss the processes involved to prepare the site and determine accessibility prior to gamma scanning.

6.1 RECONNAISSANCE ACTIVITIES

The rugged, complex terrain of the Area IV Study Area combined with the potential for encountering both physical and radiological hazards required that a detailed reconnaissance be performed before conducting data collection activities. Photographs A.22 and A.23 illustrate some of the terrain conditions encountered in Area IV ant the NBZ. The objective of the reconnaissance was to gather sufficient information about subareas or Survey Sections to identify radiological and physical conditions that were potentially hazardous to site personnel or locations that survey activities may negatively impacted biological or cultural resources. During multiple reconnaissance efforts, site conditions were evaluated for potential radiological exposure and contamination, health and safety considerations, identification of cultural resources, and identification of biological resources. The radiological and health and safety reconnaissance were performed first to ensure the safety of field personnel performing the other reconnaissance or data collection activities. The various reconnaissance efforts are described in the following subsections.

6.1.1 Radiological Reconnaissance

The radiological reconnaissance was performed to identify any radiological conditions which could be hazardous to site personnel. This was accomplished through the performance of a general area radiation survey to determine exposure rates were below project health and safety levels and a “stomp and tromp” survey to determine the presence of radiological surface contamination. These activities were performed in accordance with FOP 3.06, Reconnaissance of Survey Areas (Appendix I).

The general area radiation survey consisted of walking over the extent of the subject area with a Ludlum™ Model 19 survey meter, an exposure rate gamma radiation detector, or equivalent, in accordance with FOP 3.01, Radiological Survey Techniques (Appendix I). This survey resulted in the discovery of several areas of elevated radiation levels, but none of the levels recorded posed a health and safety danger to personnel as defined by the project Site Safety and Health Plan (HGL, 2011b). Each specific area of elevated radiation was reported to the RSO. All site personnel were informed of these locations and advised to minimize time spent in those areas in accordance with As Low As Reasonably Achievable radiation protection practices.

The stomp and tromp survey consisted of searching the subject area for locations of potential loose surface radioactive contamination and collecting a sample to determine if contamination was present. The sample was collected by placing a disposable Tyvex bootie over the surveyor's work boot and stomping on the ground surface in accordance with FOP 3.01, Radiological Survey Techniques. The bootie was field surveyed with a Ludlum™ Model 44-9 Geiger-Muller detector to determine whether contamination was detectable.

Drainage paths, areas containing potentially contaminated debris, and areas of elevated general area radiation were the primary sample collection points. No loose surface contamination was identified in the Area IV Study Area.

6.1.2 Health and Safety Reconnaissance

The health and safety reconnaissance was performed to identify any non-radiological hazards in the proposed work area. This involved inspecting the area for any potential hazard such as confined spaces, fall hazards, biological hazards (poisonous snakes, bees, etc), and disposed construction materials in accordance with FOP 3.06, Reconnaissance of Survey Areas. The SSHO was informed and all field supervisors were notified of the hazards before commencing work in these areas. When necessary, the health and safety designee marked the areas with highly visible yellow and black striped flags for ease of identification during field activities.

6.1.3 Biological Reconnaissance

The Area IV Study Area was home to many biological resources (local and federal protected plants and animals). To protect biological resources and comply with biological regulations, Envicom, Inc. qualified Biological Monitors were retained to assist with species identification and protection as outlined in the SMP (HGL, 2010b).

The Biological Monitor performed biological reconnaissance of each subarea to ensure that threatened, endangered, or sensitive species were protected. The Biological Monitor inspected the proposed work area for plant or animal species or critical habitats requiring protection. These areas were clearly marked with bright red-and-white-striped or pink flags tied to stakes cordoning off the resource (Photograph A.17), to alert personnel in accordance with FOP 3-06, Reconnaissance of Survey Areas and the SMP (HGL, 2010b).

During the migratory season various birds were nesting within the Area IV Study Area. The nesting bird areas were identified, flagged and continually examined by the Biological Monitor. These areas were avoided until Biological Monitors confirmed the chicks had fledged and left the nest. Once these areas were cleared by the Biological Monitors, the flags were removed and access for field activities was approved.

Field supervisors were informed of the presence of the sensitive areas and provided a recommendation on conducting work in or around the resource without unnecessarily disturbing the wildlife or habitat. Identified biological resources were continually monitored to ensure field activities had not disturbed the flagged areas. Biological Monitors also continually examine subareas for previously unidentified or seasonal species and habitats, throughout field activities.

Biological Monitors maintained field logbooks that documented all identified species and habitats within each subarea, GPS coordinates, and field conditions. This information was transferred into the project GIS database to produce biological resource maps to aid in planning gamma scanning and other field activities. In addition, an Annual Biological Monitoring Report for 2010 to 2011 was created detailing biological resources identified and measures implemented to protect these resources (Envicom, 2011).

6.1.4 Cultural Resources Reconnaissance

The SSFL was historically occupied by Native Americans and thus cultural resources (archeological sites, natural features of religious significance or objects used by former Native American tribes) were located in the Area IV Study Area. Cultural Monitors and Native American Advisors/Consultants were retained to monitor all ground disturbing activity and provided archaeological monitoring support as necessary during execution of field work. Cultural Monitors were qualified archaeologists and specialized in southern California Native American artifacts and culture. The Native American Advisors/Consultants were local Southern California tribal representatives from the most likely descendents of the former Native American inhabitants of the SSFL as discussed in the SMP (HGL, 2010b). The consultants were required to have knowledge of local customs, traditions and religious practices of the Tatavian and/or Fernandeno Indian Tribes and in particular the Eastern Coastal or Ventureno Chumash Indian Tribe.

Cultural Monitors and Native American Advisors/Consultants performed cultural resources reconnaissance of the survey area which served as the initial evaluation for archeological sites, features and objects. Areas of cultural significance were marked with yellow flags tied to wooden stakes (Photograph A.18) to cordon off protected resources (HGL, 2010b).

Field supervisors were informed of the presence of the sensitive areas and provided a recommendation on conducting work in or around the area without unnecessarily disturbing the cultural resource. During all phases of the investigation, identified sites and artifacts were re-examined to ensure all field activities were conducted in a manner to minimize impact. Continued monitoring also determined the correct designation of all cultural resources. Some sites were removed from the cultural resources list when re-evaluation of the sites determined that identified artifacts or features could not be attributed to former Native American inhabitance.

Cultural Monitors maintained field logbooks that documented all identified artifacts and archaeological features within the Area IV Study Area, GPS coordinates, and field conditions. This information was transferred into the project GIS database to track culturally protected resources and incorporate the information into gamma scanning coverage maps.

In accordance with the Cultural Resources Protection Measures detailed in the SMP, exact locations of cultural resources were kept confidential to ensure the continued preservation of these areas and resources (HGL, 2010b, Appendix F).

6.2 VEGETATION REMOVAL

After reconnaissance activities were completed, the survey areas were prepared for personnel to safely and effectively conduct gamma scanning activities. The preparations included vegetation removal in accordance with the Vegetation Cutting Protocol (HGL, 2010b, Appendix E) and the continued monitoring for protected resources.

Vegetation cutting and trimming activities were performed to allow access for vehicles and equipment, and provided proper clearance for the operations of gamma scanning detection systems at optimum height above the ground surface. The vegetation removal crews adhered to the vegetation cutting protocols described in the SMP (HGL, 2010b, Appendix E).

Vegetation was trimmed or cut to a height of approximately 6 to 18 inches above ground surface using a combination of mechanical and hand tools (Photographs A.19 and A.20). Equipment used for cutting, trimming, and mulching vegetation included mowers, weed trimmers, chainsaws, shovels, clippers, cutters, machetes, and chippers.

Cut vegetation was chipped into mulch and left in place to prevent the repopulation of plant species outside its original location (Photograph A.19). On slopes where the TMGS and STGS were operated, vegetation cuttings presented a safety hazard because the tracks could slip on the cuttings. In these areas, cut vegetation was removed from the slope for disposal. Limited pruning of mature trees took place to allow equipment access under the tree canopies; no mature trees were felled during the vegetation removal process. Limbs of mature trees were trimmed only if the diameter was less than 20 percent of the trunk's diameter.

Poison oak was pervasive throughout the Area IV Study Area. Special care was taken when cutting and removing poison oak, *Toxicodendron diversilobum*, which may cause severe allergic reactions (Photograph A.20). Because mulching and returning poison oak cuttings to localized areas would spread these non-native plants and cause a safety hazard, poison oak cuttings were separated and disposed off site. Crews also encountered poison snakes and wasps, in such cases, the snakes were relocated and wasp nests were not disturbed.

In areas occupied by sensitive species or critical habitats vegetation removal was limited to hand tools and did not cause irreparable damage to protected habitats or species of plants. Care was taken during vegetation removal around the soil structures supporting root systems to ensure root systems were not irreparably damaged.

Clearing of vegetation, at times, revealed previously unidentified protected resources which were flagged and cataloged in accordance with the SMP. Previously unidentified debris was also revealed during vegetation clearance. If debris appeared hazardous or radiation measurements indicated potential contamination then The Boeing Company, Inc. and DOE were informed of the location.

A total of approximately 265.82 acres of vegetation was cut within the Area IV Study Area. This included 221.25 acres within Area IV and 44.57 acres within the NBZ (Figure 6.1). Occasionally vegetation required re-cutting or re-trimming after re-growth occurred before field activities could be completed and for areas that required additional gamma scanning. Within Area IV, 24.35 acres of vegetation was re-cut and 1.74 acres of vegetation was re-cut within the NBZ (Figure 6.1).

6.3 SUBAREA ACCESSIBILITY

Accessible surfaces within the Area IV Study Area were identified through field reconnaissance conducted after vegetation removal and before gamma scanning or other related field activities commenced. The Area IV Study Area accessibility was divided into three types of surfaces:

- Accessible Surfaces
- Inaccessible Surfaces
- Limited Access Surfaces

Accessible surfaces were scanned with the most sensitive detection system capable of accessing the surface. Figures 6.2, 6.3, and 6.4 depict the scanning coverage and inaccessible surfaces within the Area IV Study Area.

6.3.1 Accessible Surfaces

Accessible Surfaces contained no natural or manmade features restricting access or reducing detectability of gamma emitting radionuclides in the ground surface. Scanning activities were conducted in compliance with health and safety standards, and the biological and cultural protection plans. The total accessible surface for the Area IV Study Area was approximately 265.73 acres with 219.63 and 46.10 acres in Area IV and the NBZ, respectively. Table 6.1 provides total acreage scanned for each subarea and Figure 6.5 provides a graphical depiction of the surface scanned by each detection system. Table 6.2 summarizes the scanned acreage by each detection system.

6.3.2 Inaccessible Surfaces

Inaccessible Surfaces contained natural or manmade features which prevented access of all detection systems. These surfaces were not altered to gain access. The main determinant in characterizing these surfaces was slope gradient and the ability to operate the detection systems in accordance with health and safety requirements. Inaccessible surfaces included the surfaces with permanent features such as:

- Sandstone outcrops
- Dangerous terrain conditions (unstable soil, sandstone formations, steep slopes exceeding detection systems capabilities, etc.)
- Sandstone shelters, deemed as culturally Protected Areas
- Culturally sensitive plants
- Natural habitats and protected vegetation identified by the Biological Monitors

Other Inaccessible Surfaces included temporary features which should be scanned at a future date upon removal:

- Immobile equipment (surface utility pipes, heavy equipment, storage tanks)
- Restricted access areas in accordance with The Boeing Company policy (RMHF, outfalls, designated confined spaces, etc.)
- Existing structures

Small portions of the Area IV Study Area were considered inaccessible due to the inability to receive a GPS signal as described in Section 7.2.

The total Inaccessible Surface for the Area IV Study Area was approximately 205.91 acres with approximately 70.29 acres in Area IV and 135.62 acres in the NBZ. Table 6.1 provides a breakdown of the inaccessible acreage for each subarea.

As a comparison, early estimates (October 2010), the total Inaccessible Surface for the Area IV Study Area was 66 acres (28 in Area IV and 38 in the NBZ) compared to the 205.91 actual acres that were inaccessible for the study. Similarly the total Accessible Surfaces estimated to be scanned was 406 acres (262 in Area IV and 144 in the NBZ) compared to the Accessible Surfaces that was actually covered of 265.73 acres. The differences between these early estimates and the actual coverage reflect the difficulty of the terrain in many areas within Area IV and the NBZ (Photographs A.22 and A.23).

6.3.3 Limited Access Surfaces

Surfaces with limited access contained natural or manmade features which attenuated gamma radiation emitted from the surface soil, causing a reduction in the sensitivity or effectiveness of selected detection systems. These surfaces included:

- Concrete surfaces
- Asphalt surfaces
- Structural debris
- Above ground pipes
- Concrete and asphalt culverts
- Other miscellaneous attenuating objects

Additional Limited Access Surfaces were cultural or biologically Protected Areas which restricted use of the most sensitive detection system. These areas were documented as requiring further investigation by gamma radiation scanning when the overlying feature is removed or if access is allowed.

In all cases, USEPA classified limited access surface based on best professional judgment taking into consideration the field conditions encountered at the time data collection activities occurred.

6.3.4 Determination of Accessibility

Light Detection and Ranging (LIDAR) data was obtained from the Ventura County Watershed Protection District to create a detailed map of terrain features and topography. LIDAR is an airborne optical remote sensing technology that measures the distance to the ground with pulsing lasers to produce high-resolution digital elevation maps. The data was processed by ArcMap to create a terrain Digital Elevation Model of the Area IV Study Area. The Digital Elevation Model was used to derive a slope map providing the terrain slope at any given point within the Area IV Study Area. The terrain was then categorized by ranges in slope grade as mild, moderate, and steep (Table 6.3).

Initial accessibility determinations were based on the LIDAR slope gradient data in conjunction with soil compaction (surface stability), site infrastructure, surfaces with tall vegetation, protected resource areas, GPS signal loss (areas the GPS receivers could not receive an adequate signal to record accurate coordinates) locations, and sandstone outcrops. Each detection system was assigned to appropriate categories based on expected capability to access various gradient ranges and based on poorly compacted soil areas, protected resource areas, and proximity to site infrastructure and tall vegetation. The surfaces that each detection system could access were refined as the project progressed, as new detection systems were developed, and to accommodate health and safety considerations.

Detection systems used in the NBZ were selected on a day-to-day basis determined by field reconnaissance of terrain accessibility to achieve the highest possible coverage with the most sensitive detection system.

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7.0 DATA ACQUISITION AND ANALYSIS

This section describes the methodologies for collecting, processing, analyzing, and evaluating complex gamma data as follows:

- Section 7.1 describes the collection and determination of background data.
- Section 7.2 describes tests performed to determine detection capabilities of each detection system.
- Section 7.3 details the procedures employed to normalize gamma data so measurements from multiple detection systems were comparable; this normalization step is an integral component of data analysis.
- Section 7.4 provides an overview of how gamma data, including soil moisture and barometric measurements, were collected.
- Section 7.5 summarizes the collection of gamma radiation data.
- Section 7.6 presents brief descriptions of data processing, with detailed step-by-step procedures located in Appendix K.
- Section 7.7 summarizes the data management procedures employed to manage the extremely large datasets collected and processed for this study.
- Section 7.8 summarizes the PGRAY evaluation process.
- Section 7.9 discusses quality control verification surveys conducted to document data reproducibility.

7.1 BACKGROUND DATA

Establishing an appropriate background was critical to evaluating gamma data. Three off site background areas, called Radiological Background Reference Areas (RBRA), were selected during USEPA's Radiological Background Study (HGL, 2009) as representative background locations for soil sampling and analysis. The Bridle Path RBRA and the Lang Ranch RBRA (Photograph A.21) were surveyed to obtain a representative background dataset for ambient gamma radiation. These locations were selected because they had similar geology, vegetation, and topography to the Area IV Study Area. A third location, the Rocky Peak RBRA, was not surveyed because the detection systems were not permitted to access the area. The Bridle Path RBRA consisted of the Santa Susana Formation whereas the Lang Ranch RBRA consisted of the Chatsworth Formation, which was the predominant formation in the Area IV Study Area. Gamma radiation scanning surveys were performed at the two RBRAs with the ERGS II and the WMGS on June 23 and 29, 2010 and with the MMGS on August 24, 2010. The data from all detection systems were processed and normalized to the ERGS II (Appendix F) as described in Section 7.3. Background data for the TMGS, STGS, HHGS, and ISGS was not collected at the RBRAs. The TMGS and STGS had not been planned or developed at the time background at Lang Ranch was collected. The HHGS detection system was not fully functional at the time of data collection and the ISGS was not available at the time of the background investigation.

Review of the RBRAs gamma radiation scanning data collected during the Area IV Radiological Study indicated that the background level of gamma radiation throughout most of the Area IV Study Area was lower than that of the RBRAs. This likely occurred from slight differences in geological layers and disturbance of soil from site activities, including:

- Soil imported from off site to fill excavations during remediation and construction activities
- Surface and subsurface soil graded and mixed during construction activities
- Surface and subsurface soil mixed with imported soils during construction activities
- Site activities that disturbed the natural, native surface and/or subsurface soil

A more accurate background was determined for each subarea and the NBZ after all gamma scanning data was collected in each subarea. The mean and standard deviation count rate values for each subarea were calculated (details of the calculation process are described in Section 7.6, Data Processing) and compared to scanning results from the respective subarea to determine the location of elevated gamma measurements; e.g. PGRAYs.

7.2 DETECTION SYSTEM SENSITIVITY TESTING

Sensitivity tests for each detection system were conducted at the project field office and in Subarea 5DN before field activities commenced to establish the FOV, operating detector height, and operating velocity (Appendix E). Table 3.1 summarizes the operating parameters. The estimated radioactivity potentially detectable with each detection system was also derived from the test data. The following four sensitivity tests were performed:

- A radial matrix efficiency test to establish the FOV, which was used to determine the width of each survey transect.
- A detection system height test to compare discrete detector scanning heights. Selecting an operating height required consideration of the maneuverability and stability of the scanning system in the field, the detection efficiency, and FOV.
- A velocity test to compare the detection system scanning efficiency to its static efficiency. In particular, the test was conducted to determine the maximum velocity without significant degradation of detection sensitivity.
- A subsurface radioactivity test to determine the approximate depths below ground surface that each detection system could detect known source activities. Although this data was not used during the investigation, it helps identify detection system capabilities. Future data may provide more extensive data analysis with regard to profiling the depth of soil contamination.

The ISGS was not designed for scanning activities; therefore, an operating velocity was not relevant. The ISGS was calibrated by USEPA to an operational height of 30 cm while FOV differed for each gamma spectral energy range. For example, the FOV for Cs-137 with 90 percent efficiency was 4 meters (Appendix O).

7.3 NORMALIZATION DATA

The radiological investigation conducted at the Area IV Study Area utilized seven customized gamma radiation detection systems. Data collected with each detection system was not directly comparable with other detection systems due to design differences, such as operating height, FOV, and number of NaI detectors. For example, the ERGS II count rate was approximately three times greater than the TMGS count rate at the same location. Normalization of the TMGS to the ERGS II was required to compare the two datasets for meaningful data interpretation. Normalization permitted merging data from all detection systems into a single dataset so gamma radiation data maps would clearly illustrate PGRAYs. The normalization process resulted in a statistical ratio of the count rate between the ERGS II and each detection system. The HHGS and ISGS were not included in the normalization process as they did not collect the same type of data as the RSI-based detection systems, thus these datasets were interpreted separately. A summary of the normalization process is described below and full details are provided in the Normalization Report that is included as Appendix F of this document.

Subarea 5C was the first subarea surveyed for gamma radiation by mostly the ERGS II. A review of the survey data indicated two surface areas of approximately 0.34 and 0.27 acres with a relatively homogeneous gamma data distribution in Survey Sections 1 and 6, respectively. The areas had a flat topography allowing easy access for all detection systems. In addition, the ERGS II mean count rate for each area was approximately equal to the ERGS II mean count rate for all of the surfaces scanned in Subarea 5C; i.e., they appeared to represent uncontaminated areas. The areas were designated as the project Normalization Areas. Each Normalization Area is further described and delineated in the Normalization Report, Gamma Radiation Detection Systems (Appendix F).

Each detection system scanned both areas in accordance with applicable operating parameters. Data was statistically analyzed and used to calculate a normalization ratio for each detection system. For example, the ratio of the ERGS II count rate to the TMGS count rate was 3.141 to one; therefore, TMGS data was multiplied by 3.141 to normalize to the ERGS II data. After normalization, the TMGS data was merged with the ERGS II data for final processing to determine the presence of PGRAYs.

7.4 SOIL MOISTURE AND BAROMETRIC PRESSURE DATA

A study was conducted to determine the effects of soil moisture content and barometric pressure on gamma radiation measurements. Results indicated that an increase in soil moisture resulted in a decrease in gamma radiation emitted from surface soil due to the attenuating effect of water on gamma rays.

The study also determined how gamma radiation emitted from surface soil varied with changing barometric pressure and soil moisture content over an extended period of time. Results indicated gamma radiation count rates had a slight inverse correlation with barometric pressure. This minor correlation did not affect the data significantly and was considered negligible during gamma data collection activities. Additional details of the study procedures and results are located in the Sensitivity Report (Appendix E), and the Effect of Soil Moisture on Gamma Radiation Count Rate Measurements Technical Memorandum (Appendix G).

In accordance with the SAP and based on the results of the soil moisture study, gamma radiation data collection activities were conducted only when soil moisture content was below 15 percent to maintain maximum detection capability (HGL and TPC, 2010a). Soil moisture measurements were conducted after precipitation or in areas suspected of moist soil such as groundwater springs, low lying areas, or drainages. Measurements were performed with a Troxler™, Model 3430, nuclear density gauge in accordance with the Radiation Safety Program Manual for Portable Nuclear Gauge Users (TPC, 2010). The results were recorded in field logs and in logbooks then entered onto a Microsoft® Excel spreadsheet. The GPS coordinates for each soil moisture measurement also were collected and stored in a database.

7.5 GAMMA RADIATION DATA

The following subsections summarize the procedures and methodologies for collecting gamma radiation data.

7.5.1 Operating Procedures

The project complexity and continued development and redesign of detection systems required developing and revising FOPs for each detection system concurrent with data collection activities throughout the project. As indicated in audit results, operating procedures were maintained in accordance with each FOP requirement (Appendix I).

7.5.2 Determination of Accessibility

Gamma radiation measurements were only collected within accessible areas. Accessibility was dependent on safe access with a detection system while avoiding Protected Resources. Evaluations of all surfaces within the Area IV Study Area were completed to determine accessibility.

To avoid the attenuation of surface gamma radiation by local vegetation, the accessibility of an area was evaluated after ground surface vegetation had been removed. Field personnel conducting this evaluation considered and recorded the following attributes:

- Possible hazards to equipment and personnel
- Topography
- Soil conditions
- Presence of Protected Resources

These observations assisted in determining the most appropriate detection system for a specific location to achieve the highest sensitivity with consideration for the accessibility factors.

If a location was classified as a Protected Area, a Biological Monitor or Cultural Monitor determined if mechanized equipment was permitted to enter the location without threatening the Protected Area (Photographs A.17 and A.18). These locations required detection systems which caused minimal ground disturbance such as the MMGS or WMGS. In some instances, Protected Areas were redefined after reinterpretation of artifacts identified during preliminary surveys, or seasonal changes occurred that enabled unrestricted access to an area that contained a biological resource. An example of a seasonal change would be as in the case of ground nesting birds; once the nesting season was over, unrestricted access was allowed. In these cases, the location was scanned with the most sensitive detection system appropriate for the terrain.

7.5.3 Equipment Capabilities and Limitations

The ERGS II was the preferred gamma scanning detection system due to its greater sensitivity and larger FOV. The ERGS II was used to survey areas of gentle to moderately sloping topography with minimal presence of boulders or ground disturbance. The gross weight of the telehandler and detector required caution on loose or loosely compacted soil. Other operational considerations were the presence of obstacles, such as low hanging tree limbs, electrical lines or cables, fencing, and trees.

The TMGS or STGS were utilized on surfaces inaccessible by the ERGS II. The TMGS and STGS were capable of surveying slopes of up to 25 degrees and over semi-rocky conditions. In addition, the narrow width and high maneuverability enabled the track mounted detection systems to operate around and over obstacles. The STGS was used instead of the TMGS on steeper and more technical terrain due to the lighter weight and smaller front end. Before the development and acquisition of these two systems, the WMGS had been utilized on these types of surfaces. The WMGS was replaced by the TMGS and STGS to reduce physical demands on the operator, increase access to steep sloped terrain, and because the TMGS offered increased sensitivity.

Before the TMGS and STGS were operational, the MMGS was used to survey surfaces where the ERGS II or WMGS were not capable of accessing. After the TMGS and STGS became operational, the MMGS was used to focus on surfaces inaccessible to all other detection systems. By having the capability of navigating over rocky and steep terrain, the MMGS was often used to survey Protected Areas with minimal ground disturbance. The mules could step over boulders, which allowed the MMGS to access surfaces where mechanized equipment did not have adequate ground clearance. In addition, the mules were able to survey under tree canopies, between sandstone outcrops, and in drainages.

When no other detection system could access a location, the HHGS systems were used. These locations consisted of very rocky conditions, steep narrow drainages, and locations where vegetation removal was not feasible. With low sensitivity, lack of gamma spectroscopy data, and high physical demands on the operator, the HHGS systems were reserved as a last resort.

7.5.4 Scanning Survey Approach

Operation of each detection system required two field personnel: one operator and one field technician who provided safety and technical assistance. In accordance with the SMP (HGL, 2010b), Cultural and Biological Monitors were present during ground disturbing gamma data collection activities to ensure the protection of identified protected resources.

During scanning, transects were overlapped to ensure complete (100 percent) coverage. As discussed in Section 3.1.1, transects were set at 85 percent or less of the FOV for each detection system as a margin of error, thus ensuring 100 percent surface coverage.

Linear transects were implemented for the TMGS, STGS, and WMGS. On flat or gently sloped terrain, the operator traversed a predefined transect, turned around and returned on the adjacent transect following the track or wheel marks from the previous transect. On steep and rugged terrain, where the detection system could not be turned around safely, the detection system was backed down the adjacent transect following the track of the previous transect.

The ERGS II and the MMGS executed diminishing circles. First, the outer boundary of a survey area was scanned. Next, the operator continued scanning in consecutively smaller circles or a spiral pattern until 100 percent of the accessible surface was scanned. This approach increased efficiency and allowed for easier maneuverability. The visual map feature in RadAssist® or ArcPad® was used for the ERGS II, and a marking system was used to maintain proper transects. The MMGS relied on a field technician to mark a transect with spray paint (water soluble, biodegradable, environmentally safe). The field technician walked in front of the MMGS and defined the outer limits of the survey area. The mule handler then led the MMGS using the markings as a guide, circling inward until the area was completely scanned.

The HHGS detection systems were used to survey NBZ locations that had very restricted access. The surveyor's path and resulting surface scanned was dictated by surface obstacles (trees, boulders, etc.) and topography (drainages, steep slopes). This resulted in gamma surface coverage without defined transects and final coverage was based field conditions.

At the end of each day, the collected gamma and GPS data was downloaded from each detection system and uploaded onto the project computer server for processing and PGRAY identification.

7.5.5 Equipment Decontamination

Field equipment was examined for removable contamination in accordance with FOP 3.10, Routine Radiological Surveys, using the swipe method as directed in FOP 3.01, Radiological Survey Techniques. Swipes were then analyzed for contamination in accordance with FOP 1.04, Operation of the Model 3030 Alpha Beta Sample Counter. If the results were above the established contamination limits in FOP 3.02, Decontamination of Equipment, the equipment was decontaminated in accordance with FOP 3.02.

Over the course of the project no incidences of radioactive contamination above established contamination limits were detected on any equipment. Although decontamination was not required, the equipment was often cleaned of particulate matter.

7.5.6 Functional Use and Application of Computer Programs

The following subsections discuss software used to provide field mapping, data collection, and merging of GPS data with gamma data. Processing of this georeferenced data is described in Section 7.6.

7.5.6.1 ArcPad® Software Program

ArcPad®, developed by ESRI, was used for field mapping and data collection. The software had a number of key capabilities that addressed project requirements.

RadAssist® was not capable of accepting NMEA output from Trimble® Model SPS852 GPS receivers. ArcPad® was used to connect to the NMEA output stream, thus allowing more accurate GPS coordinates to be recorded than provided by previous GPS units. ArcPad®'s mapping capabilities had customizable layers which allowed up-to-date maps of previously scanned surfaces to be uploaded to field computers. In addition, the maps assisted gamma scanning personnel in completing data gaps while avoiding rescanning previously scanned surfaces.

An ArcPad® mapping interface feature in ArcPad® displayed points that corresponded to a single data collection record. The size of the displayed graphical depiction or "dot" was scalable to the transect width of the detection system, thus allowing field personnel to track actual scanning coverage in real time.

ArcPad® was expandable with Visual Basic Script (VBScript) modules to accomplish tasks not built into the software. Two new tasks were added to ArcPad® for this project. The first task was a user accessible module to record data directly from the GPS receiver. The module recorded GPS data each time new GPS coordinates were received and the data was displayed on the field computer for field personnel to view scanning progress. This process was used with all RSI-based gamma detection systems.

The second task was a user accessible module to record data directly from the HHGS Ludlum™ ratemeter. The module recorded a Ludlum™ ratemeter measurement with an associated GPS coordinate. HHGS ratemeter data was recorded in two different auto-ranging count rate scales without modification; these different scales were accounted for in post-processing.

7.5.6.2 Global Positioning System Integration

Two methods for integrating GPS data with gamma data were employed. The first method involved GPS data integration in real time. The second method integrated GPS data during post processing.

For the real time integration, an external Trimble® GPS receiver exported a positional Trimble® Standard Interface Protocol (TSIP) data format via a cable connected to an RSI console. This caused the RSI console to bypass its internal GPS receiver (which had very low accuracy but was necessary for time synchronization) and instead use the external Trimble® GPS receiver (which had a much greater accuracy). Trimble®'s proprietary TSIP data format was the only GPS data format accepted by RSI detection systems in real time mode. At the time of survey activities, TSIP data format was only available on older, less accurate Trimble® models. This limited the type of compatible GPS systems for real-time data processing.

Real-time GPS integration was implemented with the ERGS II for the majority of the project using an external Trimble® Model AgGPS 332 Receiver with an external "SPOT" antenna. A second GPS configuration implemented with all other gamma radiation detection systems used the Trimble® Model GeoXH™ receiver. For both real-time GPS integration methods, GPS measurements were stored with gamma data on the RSI console.

The second and more accurate method of GPS integration was accomplished in post processing. GPS receivers with high spatial accuracy and the required Trimble® Standard Interface Protocol file format output were not available, thus necessitating post processing. The RSI console had an external GPS antenna to receive the Coordinated Universal Time stamp from the GPS signal. This allowed the RSI systems to properly record gamma data collection times for data merging in post processing. ArcPad® software collected the same Coordinated Universal Time stamp with accurate coordinates from the Trimble® Model SPS852 GPS receiver. These two data sources (gamma data and GPS data) were merged with the GPSMerge program in post processing. The resulting data file was then used for spatial analysis and to display maps of the gamma data.

7.5.6.3 RadAssist®

RadAssist® software controlled data collection for all the RSI-based detection systems: the ERGS II, TMGS, WMGS, STGS, and MMGS detection systems. The hardware was assembled, turned on, and visually inspected in accordance with FOP 1.01, Use of Radiation Solutions Inc. Gamma Detection Equipment and the applicable operator's manual.

Each detection system was connected to RadAssist®. If the detection system was configured properly and powered on, then a detection system icon would appear on the computer screen. The user then could select the detection system to activate it.

If no device appeared, a network query was conducted to check for connections. If no device was found after the query, this indicated that a problem in transferring data between the computer and the detection system. The power supplies, Ethernet cables, and wireless routers were checked for proper installation and if the problem persisted, RSI was contacted for technical support. A detailed step-by-step procedure for setup and operation of RSI equipment is provided in the software instructions included in Appendix K.

A system check was conducted to verify proper detector response, and then the daily QC checks were performed in accordance with FOP 2.01, QC for RSI Gamma Detection Systems (Appendix I). Upon completion, the detection system was ready for data collection.

RadAssist® was used as a navigation tool before the incorporation of ArcPad® software and Trimble® Model SPS852 GPS receivers. The RadAssist® "GIS Data View" screen provided a real time, visual representation of the geographical location of the detection system, referred to as a "bread crumb" style display. The "bread crumbs" represented the gamma count rate, which was projected onto aerial images of the Area IV Study Area. A color scale was manually configured so the "bread crumbs" corresponded to the gamma count rates of the selected ROI Channel; thus, the operator could visualize, in real time, changes in gamma count rates and geographical location. The "bread crumb" size was scaled to the FOV of the applicable detection system.

7.6 DATA PROCESSING

The following subsections summarize the procedures and methodologies for processing gamma radiation data. The procedures and software were used to record, merge, and analyze all collected gamma radiation and related data.

7.6.1 Gamma Radiation Scanning Data

The initial format of all gamma radiation data produced by RSI-based detection systems was an RSI proprietary binary format with the file extension ".RFL.gz." Data was recorded on either the RSI RS-501 or RS-701 console. The console stored the last 24 hours of data collected, writing over older data when the storage capacity was reached. Upon completion of daily gamma scanning, a USB 2.0 storage device was attached to the USB port on the RSI console and the files were automatically transferred to the storage device. The data was then recorded in a folder named for the serial number of the console, with the time and date of the data download (see Appendix K for more information).

7.6.1.1 Data Processing with RadAssist®

Raw gamma radiation data was stored on and accessed from the project server. RadAssist® was used for data processing as described in Appendix K. Program ROIs and calibration coefficients were configured as described in Tables 3.11 and 3.12, respectively. A detailed step-by-step procedure is provided in Appendix K.

7.6.1.2 Global Positioning System Merge

The GPSMerge software program was used to combine high accuracy GPS coordinate data recorded by ArcPad® with RSIBIN binary output gamma radiation data from RadAssist®. The program was not used for other data processing. A detailed step-by-step procedure is provided in the software instructions in Appendix K.

7.6.1.3 Determination of a Representative Background

A representative background dataset was critical in determining and delineating PGRAYs. The ideal background dataset accurately reflects the gamma levels of local native soil and rock formations without the influence from potential contamination; that is, elevated measurements. Calculation of optimal background required exclusion of non-representative scanning data to avoid skewing the background dataset (increasing the mean count rate) which would result in a higher investigation level, thus possibly not identifying PGRAYs during data analysis. For example, road surfaces made of asphalt, concrete pads, invalid data (zero count rate values), and elevated measurements were excluded from the background dataset.

The mean and standard deviation background count rate was calculated for each subarea in two phases. First scanning data was parsed into scanning intervals which represented all data collected by a specific detection system each time data collection started until data collection stopped. Subsequently a subarea may have had hundreds of scanning intervals. Second each scanning interval dataset was imported into Microsoft® Excel for data analysis in a three step process as follows:

Step One: The respective normalization ratio for each gamma scanning detection system was applied to the respective scanning interval datasets (count rate values).

Step Two: All normalized scanning interval datasets were reviewed to temporarily exclude outlier measurements. Outliers met one of more of the following criteria:

- high standard deviation relative to the subarea sample population
- low (less than 6,000 cps) or high (greater than 20,000 cps) mean values which represented count rates below or above typical mean values by 50 percent or greater
- very high maximum count rates greater than 20,000 cps

Step Three: The mean count rate and standard deviation for the background dataset was calculated from the remaining scanning intervals not excluded.

After the background mean and standard deviation values were determined, the temporarily excluded measurement data were recombined with the background dataset to form a complete gamma radiation dataset for the particular subarea. This dataset was processed in Oasis Montaj® to produce a colored map with data gradation as summarized in Table 7.2.

For Subarea 3, NBZ Northwest, and NBZ Northeast, professional judgment was applied to the development and application of background statistical values. Subarea 3 consists of less than two acres of accessible surface and is bounded on three sides by Subarea 6 which had more than 42 acres of accessible surface. As a result, the data from Subarea 3 was combined with Subarea 6. Therefore, the background values for Subarea 6 were applied to Subarea 3. Similarly, most accessible Survey Sections of the NBZ Northwest were not contiguous and may not have provided a representative subarea background. The NBZ Northwest borders Subareas 8N and 7 with most NBZ Northwest Survey Sections adjacent to either subarea. Consequently, the NBZ Northwest background values were calculated from those of Subareas 8N and 7. Although the NBZ Northeast borders Subarea 6 using a Subarea 6 background investigation level for the NBZ Northeast was problematic. No roads or man-made operations were found in the NBZ Northeast. All scanning data formed the background dataset; no data were excluded from the NBZ Northeast background dataset.

7.6.1.4 Oasis Montaj®

Oasis Montaj®, made by GeoSoft®, is a software program designed for processing and visually illustrating large datasets. Processing gamma radiation scanning data involved four primary steps.

1. Merged datasets were imported into Oasis Montaj® by manual commands and a custom Oasis Montaj® script to efficiently process multiple datasets simultaneously. The custom script created a database file, derived dataset statistics, and generated map files. A batch check was executed to ensure all records of the original dataset were captured, which verified the numbers of records in the file prepared for input matched the final number of records in Oasis Montaj®.
2. Data from each detection system was normalized to the ERGSII using the previously determined normalization ratios. Additional details can be found in the Normalization Report in Appendix F.
3. Datasets were inspected to identify data outliers and errors. Each dataset was screened with limit checks, profile checks and visual map inspections. The limit check consisted of comparing statistical parameters of each dataset to the statistical parameters of other datasets within the same subarea to identify data outliers. The profile check identified irregularities in data collection patterns by comparing GPS profiles generated for the longitude and latitude of each dataset. If an error was attributed to a GPS signal loss, the data was manually corrected or removed. GPS signal losses occurred when a GPS antenna could not receive a GPS signal due to overhead physical obstructions such as buildings or tree canopy. If a problem occurred with a GPS signal loss it would was visible when comparing the two profiles. The visual map inspection involved viewing various graphical representations of the data in the Oasis Montaj® map interface. This tool allowed personnel to identify data outliers and errors spatially. If the data outliers and errors were erroneous, then the dataset was removed.
4. This final step involved inspecting and correcting gamma radiation scanning coverage maps created from data processed through the previous three steps. To accommodate the varying FOVs of the different detection systems, each detection system's scanning surface coverage was calculated separately. The results for each detection system were then interpolated, in Oasis Montaj®, for the respective scanned surface. The interpolated data for each detection system was finally combined and applied to a map with the data from the most sensitive detection system taking precedence over less sensitive datasets; i.e., if data overlapped between detectors then the data from the most sensitive detector was displayed on the map. Figures 6.2, 6.3 and 6.4 illustrate the final coverage generated from this process.

Gamma scanning coverage produced in Oasis Montaj® was compared to RSI recorded coverage to verify completeness of data, and confirmed with field personnel ensuring no data was missed during the data extraction process. Coverage maps were provided to field survey teams both as hard copies as well as digitally for use in RadAssist® or ArcPad® to maximize coverage efficiency.

7.6.1.5 Data Processing with Genie™ 2000

Genie™ 2000 software was used to analyze static measurement data collected by both the NaI and ISGS detection systems. Analysis of data from static measurements was only performed on computers with a 32-bit operating system. The RSI detection system data was collected using RSI products which resulted in a comma separated variable (CSV) data output. This CSV data was then opened in Microsoft® Excel, summed by channel, transposed into a single column, and then saved as an MS-DOS text file to conform to the Genie™ 2000 data format requirements. The ISGS data was obtained using a Canberra Model 5020 Broad Energy Germanium detector which recorded as a Canberra proprietary format with a ".CNF" file extension accepted by Genie™ 2000.

7.6.1.6 Record Keeping

Record keeping included maintaining daily field log sheets for each detection system to record daily activities including detection system QC results, background analyses, and data collection start and stop times. These logs were scanned and stored in electronic project files to assist in data processing.

The management of gamma radiation data followed the same procedures for the project duration with the exception of one added step after the ArcPad® GPS data collection process was initiated. Gamma scanning data was downloaded from the detection system and stored on the project server in an "intake" folder. Then, the data was processed using RadAssist®. These files were exported from RadAssist® into a binary format called RSIBIN with a template file imported into Oasis Montaj®. The RSIBIN format contained information about the detector, collection times, GPS coordinates, ROIs, and 1024 channels of gamma spectral data. The associated template file held a description of the data columns contained in an RSIBIN file with instructions for Oasis Montaj® on how to load the data and define the data type for each column. The RSIBIN file and template were uploaded to the server into a second directory for additional processing. With the addition of the ArcPad® data collection process, the RSIBIN formatted data was merged with the improved GPS location data obtained from the Trimble® Model SPS852 GPS receiver. The GPSMerge software program created a merged dataset of the gamma and GPS data, as described in Section 3.1.2.4.

7.6.2 Hardware Minimum Requirements and Performance

Minimum requirements specified by GeoSoft® to run Oasis Montaj® Version 7.2 software (Table 7.1), which was designed to process large quantities of data, did not provide sufficient computing power to compile the immense quantities of gamma radiation data collected during the investigation. Upgrades were implemented that included a faster read/write access hard disk drive, adding to existing server capabilities, and implementing a RAID 5 storage configuration which improved data processing.

7.6.3 File Management

Map file naming nomenclature assisted in the record keeping process by allowing users to quickly view gamma scanning coverage by detection system type, Survey Section, and date in the file name. Nomenclature consisted of detection system name_location_and_collection date yearmonthday. For example, the nomenclature for an Oasis Montaj® map file name collected by the ERGS II detection system in Survey Section 42 on January 23, 2011, was recorded as "ERGS II_SS42_20110123."

Data was maintained on the project server and incrementally backed up each week. The server was comprised of a RAID 5 configuration with an external real time back up drive. The real time backup drive was collocated with the project server while the incremental backup drive was stored at an alternate location, locked in a fireproof safe. Further details of the server and backup processes are described in the SMP (HGL, 2010b).

7.7 ASSOCIATED DATA MANAGEMENT AND ANALYSIS

Various types of non-gamma data and information were collected during the investigation in support of and to document gamma data collection and interpretation activities, which consisted of the following:

- Digital photographs
- GPS data
- Soil moisture measurements
- Meteorological data
- Field logs and logbooks

All data was uploaded and stored on the project server.

7.7.1 Digital Photographs

Digital photographs were collected during all phases of the project including detection system development, site reconnaissance, site preparation, and field activities. Photographs documented the instrumentation construction process, PGRAY locations, objects of interest, and equipment damage and repairs. Photographs also aided in documenting the location and terrain of each subarea, Protected Areas, obstacles within survey areas, and operation of detection systems (Appendix A).

Photographs were recorded onto a photograph log when taken and included date, time, photograph number, subarea, cardinal direction, and a detailed description of the photograph. Photographs were uploaded and saved to the site server daily. Nomenclature used for photograph folders consisted of date taken in month-day-year format, subarea of subject, and a brief description separated by an underscore. For example, photographs taken of a PGRAY in Subarea 5D South on August 1, 2011, were saved in a folder as "08-01-2011_5DS_PGRAY".

7.7.2 Global Positioning System Data

GPS data was collected at every second to record the geographical location of acquired data, either scanning or static, as well as date and time of data acquisition. During gamma scanning activities, the RSI console integrated GPS coordinates with gamma data. After the GPS system was upgraded to a Trimble® Model SPS852 GPS receiver with higher accuracy the GPS coordinates were recorded separately through ArcPad®. The higher accuracy GPS data was saved as a shapefile located on the field computer assigned to a specific detection system. The shapefile was then uploaded to the project server for integration with gamma data using GPSMerge as described in Section 7.6.1.2. A separate shapefile with GPS coordinates was created daily for each detection system.

7.7.3 Soil Moisture Data

Soil moisture content was collected using a Troxler™ Model 3430 to determine if the project requirement of less than 15 percent soil moisture was met in the desired survey area. Field personnel collected three measurements at locations in the planned survey area. If the average of the three soil moisture measurements exceeded 15 percent, then no data collection activities were performed on that day. On subsequent days, measurements were collected at the highest, lowest and middle elevations of the survey area until all soil moisture measurements were below 15 percent. Once the soil moisture content was documented to be less than 15 percent, data collection commenced in the area the measurement was collected. Only surfaces that met the 15 percent soil moisture criteria were scanned.

Soil moisture data was recorded on a separate data sheet at each location and included GPS coordinates, wet and dry density, moisture count, percent moisture, and subarea location. The data sheets were uploaded to the project server for storage then imported into a Microsoft® Excel file.

7.7.4 Meteorological Data

Meteorological data was collected daily to study the atmospheric effects on gamma data as well as documented daily atmospheric conditions. Meteorological data was supplied by The Boeing Company and from the Weather Underground™ website (www.wunderground.com) which used nearby weather stations.

Data recorded and reviewed from both sources included daily high temperatures (measured in degrees Fahrenheit), dew point, humidity percentage, maximum pressure (inches water), and precipitation (inches). This data was entered into a Microsoft® Excel database and stored on the project server.

7.7.5 Field Logbooks and Log Sheets

Field logbooks were maintained for each detection system to record daily field activities in accordance with project SOP 4.01 Documentation – Field Activity Reports and SOP 4.07 Use and Maintenance of Field Logbooks (Appendix H). This data was collected to document scanning locations, work progress, names of field personnel, weather conditions, terrain conditions, and type of data collection performed; i.e., initial gamma scanning, static count, re-scan, etc. Completed logbooks were submitted to the project QA officer and were stored in the project files.

Field log sheets were also used by field personnel to record daily activities including detection system QC, background analyses, and the start and stop times of detection systems. Log sheets were scanned and uploaded to the project server and referenced when processing RadAssist® gamma data. Nomenclature for log sheets consisted of detection system name and date of data collection separated by an underscore. As an example, data collected using the TMGS on April 23, 2010, was recorded as "TMGS_100423."

7.8 POTENTIAL GAMMA RADIATION ANOMALY DATA EVALUATION

Upon completion of data collection, file management, and processing steps as described in Sections 7.1 through 7.7, gamma radiation data were compiled into a database for each subarea. Gamma data analysis consisted of a three step evaluation process; identification of PGRAYs, verification of PGRAYs, and classification of PGRAYs as "Not a GRAY" or "Confirmed GRAY" with a recommendation to conduct or not conduct soil sampling.

The first step was to collect, process, and review gamma radiation scanning data to identify PGRAYs. Next, gamma static measurements were collected, processed, and analyzed to determine if the PGRAY consisted of only NORM or if radionuclides of concern were detected. Finally, the PGRAY was classified as a Not a GRAY or a Confirmed GRAY depending on the verification results. Soil sampling was recommend for all Confirmed GRAYs but not for all Not a GRAYs. Figure 7.1 illustrates the PGRAY evaluation process with additional details described in the following sections. A PGRAY Verification Report was prepared for every PGRAY to summarize the results of the data evaluation process. The 217 PGRAY Verification Reports are provided in Appendix D.

7.8.1 Identification of Potential Gamma Radiation Anomalies

After all gamma radiation scanning data was collected for a subarea, the data was compiled, processed, and reviewed to identify PGRAYs. First, the data was processed as described in Section 7.6. Next, the data was reviewed to remove data outliers. Finally, PGRAYs were identified through statistical analyses and delineated for verification.

7.8.1.1 Removal of Data Outliers from Scanning Datasets

Two types of data outliers occurred; these included transient values and very high values.

Very infrequently the RSI digital signal processor recorded a transient zero value for a single second of data followed by a transient value with double the actual count rate. This was recognized as a software binning or timing error; thus the zero and double count rate data were inspected and removed.

Occasionally, due to statistical fluctuations in gamma radiation, very high measurements were recorded for a single second, which was considered erroneous and did not indicate presence of a PGRAY. This conclusion is supported by the fact that as a detection system scanned over the ground surface of an actual anomaly, gamma radiation should have been detectable for several seconds, not for a single second. These individual data points were visually inspected to determine if the positive increase resembled a gamma energy peak. The single second of data was removed from the dataset if no gamma energy peak was evident; otherwise the data was retained for further evaluation.

7.8.1.2 Statistical Analysis of Scanning Data

Two statistical analyses were performed to identify PGRAYs; one comparing count rate measurements to a subarea specific background count rate value and one comparing radionuclide-specific gamma ROIs to the total gamma spectrum. These complementary methods both resulted in the identification of PGRAYs.

After the background statistical parameters (mean and standard deviation) were determined as described in Section 7.6.1.3, the respective subarea dataset was processed in Oasis Montaj® to produce a colored map with data gradation as summarized in Table 7.2. The data gradations were selected to enhance the visual differentiation in increasing gamma measurements. Next, the map was reviewed to evaluate the location of PGRAYs. A PGRAY Investigation Level (IL) was defined as a set of measurements (a single measurement did not qualify) with a count rate greater than four standard deviations above the respective subarea mean. This IL was deemed sufficiently conservative for use in identifying PGRAYs for further investigation.

Analysis of count rate data does not necessarily result in the identification of all PGRAYs. Normalized count rate data typically ranged from 10,000 to 16,000 cps with a mean and standard deviation, for all the subareas, of approximately 12,800 and 1,000 cps, respectively. Thus, a count rate of 16,800 cps (12,800 plus four times 1,000) would have been identified as a PGRAY given these parameters, whereas values less than 16,800 cps would not have been identified as a PGRAY. Yet, a count rate increase of less than 1,000 cps could have been due to the presence of a specific radionuclide but would have been considered within the noise of the count rate data. Small ranges of energies within the full gamma spectrum (20 to 3,000 keV) were defined to identify specific radionuclides; these small ranges are called ROIs and are summarized in Table 3.11.

A threshold for investigation of an elevated ROI was based on a ratio of the total ROI counts to the total spectrum counts. First a single second of data, the total counts in each ROI and the total counts for the full spectrum was calculated by using RadAssist®. Second a ROI to Spectrum Ratio was calculated for each specific radionuclide by dividing the radionuclide-specific ROI counts by the spectrum counts. These two steps were repeated for each second of spectral data within a subarea. All ROI to Spectrum Ratios for a specific radionuclide were summed and the statistical mean and standard deviation calculated.

ROI to Spectrum Ratios were subject to larger statistical variation than that of the count rate in the entire spectrum. A PGRAY IL was set at the mean plus six times the standard deviation for each radionuclide-specific dataset. For example, the mean and standard deviation for the ROI to Spectrum Ratio for Cs-137 in Subarea 3 was 0.047 and 0.0040, respectively. Therefore, the IL was 0.071. Normalized gamma spectral data was analyzed and reviewed to identify PGRAYs with radionuclide-specific ROI to spectrum ratios exceeding the ILs as summarized in Table 7.3.

These two statistically based PGRAY identification techniques were effective in determining the location and extent of each PGRAY. After PGRAYs were identified, each was verified to determine the classification as described in the next section.

7.8.2 Verification of Potential Gamma Radiation Anomalies

After identification of PGRAYs, static measurements were collected to obtain more accurate spectral data to verify that the determination of a PGRAY consisting of only NORM (thus Not a GRAY) or of radionuclides of concern (thus a Confirmed GRAY) is technically justified. Two static measurement techniques were deployed: one using a RSI based detection system and one using the ISGS. However, not all PGRAYs were measured using both detection systems.

Before initial static measurements were collected, the general area and extent of the PGRAY was identified and loaded onto a laptop computer. Field technicians surveyed the area of interest to determine the exact location for the static measurement. This was accomplished by monitoring the live data stream in RadAssist® to identify the location with the highest count rate. The location was marked, GPS coordinates and field observations were recorded, and photographs taken of the location. For PGRAYS suspected of containing Cs-137, the Cs-137 ROI of RadAssist® was used to identify the location with the highest Cs-137 count rate. Some PGRAY locations were clusters of locally elevated gamma measurements; for these situations, the single highest measurement location (spectrum count rate or Cs-137 count rate) was selected for the static measurement.

The first static measurement utilized the most sensitive RSI based NaI detection system capable of accessing a particular PGRAY location. Sometimes the selected detection system was more or less sensitive than the system used to scan the PGRAY location. A more sensitive system was used when access to the PGRAY was possible yet active scanning was not possible with the same system. For example, a PGRAY may have been identified using the TMGS. The location was accessible by the ERGS II because driving it straight to and from the PGRAY was possible but lateral movement was not. Occasionally a less sensitive detection system was deployed due to discovery of new cultural resources or changes in biological conditions necessitating a low impact detection system. Detection systems used to perform the static measurements were the ERGS II, TMGS, WMGS and STGS. The MMGS was not used for static measurements due to challenges in maintaining the mules stationary for the required measurement time. The HHGS systems were not capable of collecting gamma spectroscopy data and were not used to perform static measurements.

The RSI-based detection system static measurement was performed for a duration dependent on the sensitivity of each detection system. The ERGS II performed a static measurement for 5 minutes with the sensor lowered to 2 inches above the ground surface. The TMGS required 20 minutes while both the STGS and WMGS each required 40 minutes.

The second static measurement was with the ISGS which was deployed because it was capable of collecting significantly higher resolution gamma spectroscopy data than the NaI detection systems. Typically the ISGS was used at PGRAY locations that required additional data to fully characterize the nature of the PGRAY; for example, if the NaI data did not clearly indicate the presence or absence of radionuclides of concern. The ISGS was placed at the location of the greatest total or Cs-137 count rate location at a height of 30 centimeters above the ground surface for 20 minutes. The data was recorded with the Genie™ 2000 software and downloaded for processing. See software instructions located in Appendix K for a detailed step-by-step description of this process. While the ISGS was collecting gamma spectroscopy measurements, GPS coordinates were recorded in the field logs. The complete ISGS data collection procedure is detailed in the FOP 1.10, Use of In Situ Gamma Spectrometer (Appendix I). All field forms, which recorded field activities such as start and stop times for detection systems, site location descriptions, and field conditions, were scanned into a PDF and uploaded to the project server.

The verification spectra were analyzed and reviewed to determine the PGRAY category; containing only NORM or containing radionuclides of concern (site-related contamination). Initially, NaI detection system spectra were processed using RadAssist® to identify spectral peaks. A manual determination was made to verify the presence of radionuclides of concern above background levels. Approximately midway through verification of all the PGRAYs, Genie™ 2000 was used to provide spectral analysis for both NaI detection systems and the ISGS. This was possible after the NaI spectral data was converted to a data file format that could be imported into Genie™ 2000. Genie™ 2000 utilized gamma-energy peak search and nuclide identification algorithms, calibrated to NaI detection systems or to an ISGS detection system, as appropriate. The generated spectra images were included in PGRAY Verification Reports with evaluation comments. ISGS data was processed using Genie™ 2000 and the evaluation of the data was similar to that of the NaI spectral data.

After the verification data was analyzed the PGRAY was classified in the final PGRAY evaluation process as described in the next section.

7.8.3 Classification of Potential Gamma Radiation Anomalies

PGRAYs were classified as Not a GRAY or a Confirmed GRAY based on the results documented in the PGRAY Verification Reports (Appendix D). PGRAYs with only detectable NORM in the dataset were classified as Not a GRAY and soil sampling was not recommended. For PGRAYs with detectable or suspected site-related contamination, the classification was documented as a Confirmed GRAY with soil sampling recommended.

7.9 QUALITY CONTROL VERIFICATION SURVEYS

After completion of scanning 100 percent of accessible surfaces in the Area IV Study Area, a QC verification survey was conducted to determine whether data collection activities were reproducible. These surveys provided data for comparison to initial gamma scanning data. The gamma radiation scanning detection systems involved in the verification QC surveys included the ERGS II, TMGS, STGS, WMGS, and MMGS. The HHGS was not included in this survey as it only scanned a very small area (less than 1 acre) and EPA deemed it unnecessary to document data reproducibility. A minimum of five percent of the total acreage scanned by each detection system was rescanned.

7.9.1 Survey Approach

The survey approach was based on the following criteria:

- Each detection system scanned surfaces initially scanned by the same detection system
- Each detection system scanned at least five percent of the total surface acreage completed by the respective detection system (Table 7.4)
- All detection systems scanned the Normalization Areas

QC verification data was compared to the initial data collected by each specific detection system; i.e., ERGS II data was compared to ERGS II verification data for the same surface area. The two data sets were expected to match closely, i.e., an area with a PGRAY should have been detected and identified during the QC verification survey. Normalization Area verification surveys enabled re-evaluation of normalization data and confirmation of normalization factors to verify accuracy.

Locations for conducting verification QC surveys were referred to as Quality Control Areas (QCA). Four types of QCAs were selected based on gamma data patterns as follows:

- Confirmed GRAY; meaning PGRAY containing Cs-137
- Not a GRAY; meaning PGRAY containing only NORM
- A surface of uniform count rate; meaning measurements were approximately at background
- A surface with distinct data patterns; meaning gamma data was greater than background but no PGRAYs or GRAYs were present

Scanning Confirmed GRAYs and Not a GRAYs allowed data comparison between detection systems to verify data normalization provided consistent results; that is each system verified the presence of a Confirmed GRAY or Not a GRAY. If necessary, vegetation was removed from QCAs prior to data collection, but surfaces not requiring vegetation removal were given a higher priority in the selection process to reduce expenditure of resources.

7.9.2 Data Processing and Analysis

QC verification scanning data was processed in the same manner as initial scanning data. Maps were created which delineated the initial dataset versus QCA data. Most of the initial data was collected with less accurate GPS which was accounted for when processing and comparing the two datasets.

The same statistical parameters used to evaluate the initial datasets were calculated for the verification datasets for comparison. The initial and verification datasets were also visually compared to determine reproducibility of patterns in gamma radiation data. Inconsistencies in atmospheric conditions and GPS accuracy were noted during the data evaluation. The relative differences in data for each detection system were accounted for by comparison of the normalized datasets (Appendix F).

8.0 VERIFICATION AND VALIDATION

8.1 DATA VERIFICATION AND VALIDATION

Each process for collecting gamma measurements, processing data, assembling data into a database, and producing isopleth maps to display the gamma data was confirmed and validated before implementation. These verification and validation steps included:

- Establishing the FOV of each detection system and ensuring overlap between transects during scanning.
- Verifying file transfer from detection systems to project server.
- Verifying that GPS and gamma data were merged properly and if gamma data did not have an associated GPS coordinates then GPS interpolation was performed correctly.
- Comparing scanning coverage between field logs and collected data.
- Completing a statistical evaluation of local background gamma data for each subarea, and validation by examination of the database and the subarea isopleth maps.
- Verifying reproducibility for collecting, processing, and analyzing gamma data.

These verification and validation steps combined with using FOPs, performing QC checks of detection systems, and conducting field procedural audits formed the overall QC system for gamma radiation data collection activities to ensure the integrity of the gamma scanning data collected during the investigation.

8.2 EVALUATION OF DATA QUALITY OBJECTIVE

The primary DQO for gamma radiation scanning was to identify Confirmed GRAYs in the Area IV Study Area, which would then be subject to soil sampling and analysis to determine the nature and extent of site-related contamination. This objective was met through the development and application of various data collection, processing, and assessment methods. The critical tasks required to locate GRAYs is discussed in detail in the sections identified in Table 8.1.

Table 8.1
Tasks Required to Achieve the Gamma Scanning Data Quality Objective

Objective	Tasks	Section	Comment
Identify Confirmed GRAYs	Gamma Scanning	5.2	Performing detection system daily QC checks
		7.6.1.4	Verifying scanning coverage
	Data Processing	7.6.1.3	Conducting data integrity checks
			Verifying data transfer
		7.6.3	Conducting file management and backup
	Data Evaluation	7.8	Determining PGRAY locations and evaluating PGRAYs as Not a GRAY or as a Confirmed GRAY
		7.1 and 9.1	Establishing local background
	Data Verification	7.9	Selecting criteria and collecting QC verification scanning data
		9.2	Evaluating QC verification results

9.0 GAMMA RADIATION RESULTS

The primary purpose for the gamma radiation survey was to determine locations of potential site-related radiological contamination. Gamma radiation data was evaluated to identify PGRAYs. All PGRAYs were investigated to determine a classification of Confirmed GRAY (presence of site-related contamination) or Not a GRAY (presence of only NORM). Confirmed GRAYs were recommended for soil sampling and analysis. No soil samples were recommended for Not a GRAYs. This information was provided to the project's soil investigation team for consideration in the selection of soil sample locations.

Gamma scanning commenced in July 2010 and was completed in January 2012, including the QC verification surveys. Data processing, review, and evaluation were performed soon after gamma data was collected; these activities were completed concurrently with gamma scanning efforts until completion of the investigation. Gamma data was displayed on maps with color-coded isopleths for evaluation to identify PGRAYs. In addition, gamma spectra were reviewed to identify radionuclides of concern. Once PGRAY locations were identified and delineated, the location with the highest measurement within the PGRAY was located to perform one or two static measurements with an RSI-based NaI and/or the ISGS detection systems, depending on the specific PGRAY. Static measurement data were evaluated to determine whether a PGRAY indicated the presence of site-related contamination or contained only NORM.

A key component of data evaluation was producing maps to graphically illustrate and interpret gamma data. Gamma data maps utilized color schemes as summarized in Tables 7.2 and 7.3. These color schemes are based on mean count rate in cps and standard deviations (sigma) above the mean for all scanning data collected in each subarea. Only gamma measurements above the mean were of importance for identifying PGRAYs; therefore, no color gradations were created for measurements below the mean.

All gamma data was normalized (except HHGS and ISGS data) as detailed in the Normalization Report (Appendix F). The HHGS data did not require normalization as only a very small area was scanned with the detection system. ISGS data did not require normalization as the data were not compared to gamma scanning data. Background subtraction was not performed on any gamma data because gross count rates and specific ROI ratios were compared to local background values (Table 9.1). Gamma data is reported as a count rate in cps, which is the sum of counts in all spectral channels ranging from approximately 20 to 3,000 keV, or as an ROI-to-spectrum ratio, which is the ratio of the counts within a specific ROI to the sum of counts in all spectral channels (approximately 20 to 3,000 keV). Count rates and ROI to spectrum ratios were calculated for each second of data collected. Gamma scanning data presented in this section represent normalized, gross count rate results in unit of cps unless stated otherwise.

9.1 BACKGROUND RESULTS

Establishing an appropriate background value was critical to evaluating gamma data. As described in Section 7.1, background locations (RBRAs) representing the two geologic formations within the Area IV Study Area were scanned to determine representative background gamma radiation levels (HGL, 2011d). Background data results are summarized in Table 9.1. These locations were thought to be representative of site conditions. Scanning in the Area IV Study Area commenced in Subarea 5C, which lies entirely within the Chatsworth Formation, and gamma scanning results indicated measurements were typically less than the Lang Ranch RBRA (also Chatsworth Formation) measurements.

The Lang Ranch RBRA mean count rate was approximately 14,000 cps with a standard deviation of approximately 400 cps, as collected by the ERGS II (Table 9.2). The Subarea 5C mean count rate was approximately 12,700 cps with a standard deviation of approximately 700 cps. The difference between the mean and standard deviation values between both areas is likely a result of several variables. First, the Lang Ranch RBRA was a relatively uniform 1-acre survey area, whereas Subarea 5C was approximately 20 acres of industrial land with surface developments and engineered structures such as roads, buildings, and utilities. Second, the surface and subsurface soil in Subarea 5C was highly disturbed by grading, excavations, and backfilling of excavations which changed the natural characteristics of the soil. Last, the presence of sandstone was evident throughout Subarea 5C, above (outcrops) and below the ground surface, to a greater degree than observed at the RBRA. The Lang Ranch RBRA overall did not have these features and represented an undisturbed natural environment. Thus, a larger survey area with numerous surface improvements, significant soil disturbance, and the presence of sandstone can cause increased variability in measurements as noted above.

Applying the Lang Ranch values as background to the Subarea 5C data, greater than 90 percent of the subarea was less than or equal to the mean (14,000 cps) and less than 10 percent of the area contained gamma data greater than the mean; this indicated a positive skew in the distribution of Subarea 5C results. Applying a Subarea 5C specific background to the gamma scanning results provided a distribution much closer to a normal distribution with approximately 50 percent of the measurement values at more than or equal to the mean (12,700 cps). Figure 9.1 illustrates Subarea 5C gamma scanning data compared to the two reference background datasets; the Lang Ranch RBRA background dataset and a Subarea 5C specific background dataset.

After gamma scanning data collection was completed in each subarea, the data was normalized then evaluated. Data evaluation included calculating the number of seconds of data, the mean, minimum, maximum, and standard deviations of transects completed within the subarea. Each transect dataset was evaluated and compared to the entire subarea dataset and the same statistical parameters. To differentiate elevated measurements from background, a representative background reference dataset was developed using a uniform set of statistical parameters. A representative local subarea background reference was formed excluded data for the following reasons:

- high standard deviation relative to the sample population
- low or high mean values; e.g., mean values below 6,000 cps or above 20,000 cps which represent count rates below or above typical mean values by 50 percent or greater

- very high maximum count rate; e.g., maximum values above 20,000 cps, which could skew the representativeness of the dataset

Background statistical values (mean and standard deviation) from the remaining dataset were computed. This evaluation process provided representative background data based on the conditions of each subarea. Although certain data were excluded from calculations of local subarea background, these data were not excluded from subsequent data analyses or evaluations.

An example of data excluded from a subarea background statistical dataset is illustrated in Figure 9.1. A road west of Building 4462 had elevated measurements as indicated with the red and sienna colors. The elevated measurements follow the outline of the asphalt road surface composed of aggregate containing rocks with concentrated levels of NORM. The individual scanning datasets for this road section were excluded from the background dataset for Subarea 5C. Other road and concrete surfaces north and south of Building 4462, as well as several other elevated measurements were also excluded. These elevated measurements eventually were identified as PGRAYs. The data from roads and concrete in Subarea 5C had some of the highest and lowest gamma radiation count rates in the subarea. In subsequent subareas, roads and concrete surfaces were scanned as one Survey Section as much as practical.

A subarea count rate IL was then calculated as described in Section 7.8 and summarized in Table 9.1. Although the investigation level (14,800 to 20,000 cps) for identification of a PGRAY varied throughout the Area IV Study Area the mean count rate was relatively consistent and ranged from 12,000 to 14,000 cps with standard deviations ranging from 600 to 1,500 cps. The greater range in standard deviation reflected the variability in the Area IV Study Area surfaces, which varied dramatically depending on the specific location. More stringent ILs would have likely resulted in numerous false positive PGRAYs with the area with a high standard deviation.

Two general areas had a high standard deviation as compared to the remainder of the Area IV Study Area, Subareas 5D-South with 8-South and the two subareas of the NBZ. Both the Santa Susana Formation and the Chatsworth Formation underlies the 5D-South and 8-South subareas and the different bedrock formations likely contributed to the relatively high standard deviation at 1,500 cps. Another example is in the NBZ-Northeast and NBZ-Northwest, which had two of the highest mean (14,000 and 13,000 cps, respectively) and standard deviation (1,500 and 1,000 cps, respectively) values. Note that the datasets for Subarea 5D-South and Subareas 8-South as well as Subarea 6 and Subarea 3 were combined based on similar geological, physical and operational history.

Statistical data for gamma spectral ROI to Spectrum Ratios for Cs-137 and cobalt (Co)-60 were generated from the same subarea datasets as the count rate values (Table 9.1). In a similar process to the count rate data, the Cs-137 and Co-60 ROI to Spectrum Ratio data were evaluated for each subarea. An investigation level for was calculated as described in Section 7.8.1.2. The mean Cs-137 and Co-60 ROI to Spectrum Ratios were relatively consistent with a range of standard deviation values with a greater range. The ILs for Cs-137 and Co-60 were relatively consistent throughout the subareas.

9.2 QUALITY CONTROL SURVEY RESULTS

QC surveys were completed to document results obtained through data collection, processing, and analysis was reproducible. Thirty-five QC scanning surveys were conducted with all RSI-based detections systems, then processed and analyzed following the same data collection methodologies followed during the investigation. Evaluation of reproducibility was accomplished by comparing gamma data maps from the initial survey to maps created from the QC survey. The comparison maps of the initial scanning data with the adjusted QC verification survey data are illustrated on Figures C.1 through C.28 in Appendix C.

Differences were expected in the count rates measured by the same detection systems when scanning the same surface area on different days. This was attributed to soil moisture differences and the fluctuation of background gamma radiation. As summarized in Section 7.4, barometric pressure was not found to have a significant influence on gamma radiation measurements. For example, the initial data may have been collected during the dry season (typically May to November) whereas the QC surveys were collected during the beginning of the wet season from November 2011 through January 2012. QCAs were not selected with consideration of the dates in which the initial scanning measurements were collected, thus field moisture conditions potentially affected data reproducibility. All detection systems re-scanned the Normalization Areas (refer to Section 7.3) to account for these seasonal fluctuations (Figures C.1 through C.10). Consideration for the random nature of radioactive decay was considered insignificant, thus was not accounted for in data analysis.

Data collected in the Normalization Areas during the QC verification scanning surveys were compared to normalization data collected from the initial survey. If necessary, QC datasets were adjusted based on the percent difference from the initial dataset to account for the variables discussed above. For example, if the initial normalization survey data for the WMGS had a mean count rate of 2,000 cps and the QC data had a mean count rate of 2,200 cps (an increase of 10 percent from the initial dataset) then the QC data was adjusted by increasing the measurement values by 10 percent.

Figures 9.2 and 9.3 illustrate series of gamma data maps for the ERGS II and WMGS, respectively. The series of maps represent gamma data for the two Normalization Areas (SS-1 and SS-6) located in Subarea 5C. The first set displays the initial scanning results, the second set displays the QC scanning results, and the third displays the adjusted QC scanning results. The color gradations are the same for each set of maps, which were based on the initial dataset. The amount of green area displayed differs in the QC scanning results because the mean count rate was shifted due to slightly different soil conditions than encountered during the initial scanning data collection. After the QC dataset is adjusted, the map coloration matches more closely to the initial map, thus indicating the correction factor was appropriate.

Both sets of maps in Figures 9.2 and 9.3 are characterized by green, gray, and very small white uncolored areas. The uncolored areas represent locations where the GPS signal was lost or the GPS antenna was tilted at an angle due to a steep slope gradient, so the recorded coordinates did not represent the exact location of measurements (as observed in Figure 9.3). The Normalization Areas were selected for the relatively homogeneous gamma radiation levels and accessibility. Slight differences between scanning coverage are attributed to the fact that separate surveys followed different transects during data collection. These slight variations in the dataset did not affect the data evaluation and analysis.

Overall, the data are reasonably comparable taking into consideration the previously stated variables affecting the data. In the QC survey adjusted illustrations, portions of the data are slightly elevated in comparison to the initial data. However, these are within the tolerance of typical measurement uncertainty thus are minor discrepancies and do not negate demonstration of reproducibility. In the process of assessing QC data, two additional factors contributed to uncertainty in the results.

- **Differences in GPS spatial accuracy:** The GPS receivers used during the QC surveys were more accurate than the GPS receivers used during the original surveys. This was evident in some of the comparison maps in Appendix C with slight variations in feature locations. GPS inaccuracy was most noticeable in locations adjacent to features with steep vertical relief such as sheer sandstone walls, the sides of buildings, and similar physical obstacles that presented occasional difficulties in obtaining a clear GPS satellite signal.
- **Changes in surface conditions:** Changes in surface conditions resulted from soil sampling efforts. For example, asphalt surface was removed at PGRAY 6-37 to access the soil for sample collection with a drill rig (Figure C.17). After sample collection, boreholes were backfilled with homogenized drill cuttings and capped with bentonite clay. These activities could have attributed to the QC survey indicating a larger extent of Cs-137 contamination (because the asphalt did not attenuate the gamma radiation as much as before soil sampling).

Appendix C contains data comparisons figures for all detection systems included in the QC verification survey. The initial scanning results are illustrated with the adjusted QC scanning results. Comparison of QC scanning data indicates the locations of PGRAYs were verified, as well as the lack of PGRAYs. The graphical shapes and color gradations depicting QC gamma datasets were similar to the initial datasets. No major discrepancies in the QC data were found and minor discrepancies were acceptable for the purposes of demonstrating reproducibility within the tolerance of expected uncertainty. Results for all QCAs indicate gamma data were reproducible and valid indicators, within the limits of gamma radiation detection capabilities, of the presence of gamma emitting radionuclides at surface and near surface locations in the Area IV Study Area.

9.3 POTENTIAL GAMMA RADIATION ANOMALIES AND RESULTS

The purpose of the gamma radiation scanning survey was to identify areas of elevated gamma radiation in the surface and near surface soils of the Area IV Study Area. Gamma radiation data results were used as one of several lines of evidence to guide the selection of soil sample locations (further information regarding soil sampling and analysis plans and data reports are found in separate project documents). Although gamma data generated in this investigation provides an indication of potential site-related contamination, soil sample analytical results provide more definitive confirmation of radiological contamination.

PGRAY evaluations resulted in two categories: Not a GRAY and Confirmed GRAY. A Not a GRAY was verified to contain only NORM, whereas results for a Confirmed GRAY indicated field detectable concentrations of site-related contamination. A summary of results for each PGRAY are found in the PGRAY Verification Reports in Appendix D.

The following subsections describe the location and classification of PGRAYs identified in each subarea of the Area IV Study Area. Subareas with more than 20 PGRAYs were subdivided into groups based on proximity to former site operations and to each other for ease of explanation and identification.

9.4 OVERVIEW OF AREA IV STUDY AREA ANOMALIES

A total of 217 PGRAYs were identified in the Area IV Study Area; of these 70 were identified as Confirmed GRAYs (Table 9.3). Of the 70 Confirmed GRAYs, 30 were located in Subareas 6, 38 in Subarea 7, and one each in Subareas 8-South and the NBZ-Northwest. The 147 Not a GRAYs were generally influenced by sandstone outcrops. The rocky outcrops likely contained either higher uranium, thorium, and potassium concentrations or the detector-to-surface geometry, which occurs when a detection system is partially surrounded by or enclosed by multiple surfaces, from sandstone faces combined with the ground surface resulted in elevated measurements above the ILs.

Figure 9.4 presents the all gamma scanning results collected from the Area IV Study Area. Locations of PGRAYs, PGRAY boundaries, static measurement locations, and locations with detected Cs-137 are presented in individual subarea maps. PGRAY boundaries were developed to delineate the boundaries of potential contamination and to combine clusters of multiple elevated measurements into a single PGRAY for verification measurements as visually represented by linear or polygonal features on the figures.

Gamma results varied widely throughout the Area IV Study Area. Maps of gamma results depict graphical features, such as PGRAYs and patterns of gamma radiation measurements above the ILs, representing the magnitude of gamma measurements. Overall results are summarized in Table 9.4 and below.

- Subarea 3 had only two small areas identified as PGRAYs; both were classified as Not a GRAY.

- Subarea 5A had a variety of scattered elevated measurements generally near sandstone outcrops with 24 PGRAYs identified as all Not a GRAY.
- Subareas 5B, 5C, and 5D-North were also relatively featureless with only small areas of elevated measurements and six PGRAYs in each; all were classified as Not a GRAY.
- Subareas 5D-South and 8-South were relatively featureless with a ridgeline of elevated measurements and with 12 PGRAYs in the southern portion of Subarea 5D-South and none in 8-South; all were classified as Not a GRAY.
- Subarea 6 had the highest number of PGRAYs with 60 which were located in drainages adjacent to sandstone outcrops and in areas of former site operations. Of these, 30 were classified as Confirmed GRAYs containing Cs-137.
- Subarea 7, where the RMHF was located, contained many elevated measurements with 42 PGRAYs delineated. Of these, 38 were identified as Confirmed GRAYs with Cs-137.
- Subarea 8-North had several series of sandstone ridges and valleys containing scattered areas of elevated gamma measurements that formed 32 PGRAYs, of which, one was a Confirmed GRAY.
- The NBZ-Northeast contained one PGRAY classified as Not a GRAY and NBZ-Northwest had 26 PGRAYs with only one classified as a Confirmed GRAY.

Some PGRAYs were identified based on only RSI NaI detection system static measurements. The ISGS was also used to collect static measurements to either supplement or verify NaI detector derived data. ISGS gamma spectroscopy data was used as additional verification data. ISGS results provided more accurate identification or lack of identification of Cs-137 concentrations above the soil radiological trigger level (RTL) of 0.2 picocuries per gram (pCi/g); this decision level was developed by the project's soil investigation team as an indication of locations considered contaminated and requiring remediation. The ISGS spectra are included in the PGRAY Verification Reports (Appendix D). The preface to Appendix D provides additional information regarding the format and interpretation of the PGRAY Verification Reports.

The following subsections describe the results in each Subarea, which were further divided into smaller groups (A, B, C, etc.) for convenience of explanation and identification. All PGRAYs are classified as Not a GRAY unless otherwise indicated as a Confirmed GRAY.

9.4.1 Subarea 3 Anomalies and Results

No Confirmed GRAYs were identified in Subarea 3 and only two PGRAYs identified. Gamma spectral data indicated the presence of only NORM. Both were located in the northeast portion of the subarea east of a Southern California Edison electrical substation near sandstone outcrops. The measurements were likely affected by the geometry of the adjacent sandstone outcrops. Results are summarized in Table 9.4 and illustrated on Figure 9.5.

9.4.2 Subarea 5A Anomalies and Results

No Confirmed GRAYs were identified in Subarea 5A. All 24 PGRAYs were classified as Not a GRAY as verified by gamma spectral data which indicated the presence of only NORM. The majority of the PGRAYs were along the northern boundary adjacent to large sandstone outcrops. Results are summarized in Table 9.4 and illustrated on Figure 9.6, which is subdivided into three groups (A through C). The PGRAY locations are summarized below:

<u>Group A: Western portion of Subarea 5A, west of 12th Street and north of G Street</u>

- PGRAYs 5A-1 and 5A-2 were approximately 100 to 150 feet west of 12th Street and down gradient to the RMHF, which is located in Subarea 7.

<u>Group B: Northern portion of Subarea 5A, east and north of G Street</u>

- PGRAYs 5A-3 through 5A-20 were either immediately adjacent to sandstone outcrops or closely aligned with sandstone formations.
- PGRAYs 5A-3 through 5A-12 were located north of the Kinetic Energy Water Boiler reactor building complex, L-85 Reactor building complex, and the AE-6 Reactor building (formally known as the Water Boiler Neutron Source).
- PGRAYs 5A-13 through 5A-20 were located northeast of the Systems Nuclear Auxiliary Power AE-6 Reactor building complex.

<u>Group C: Southern portion of Subarea 5A, south of G Street</u>

- PGRAY 5A-21 was located in an open grassy field in proximity to a probable drainage basin south of an unpaved access road.
- PGRAYs 5A-22 through 5A-24 were located south of PGRAY 5A-21 in the same grassy field but adjacent to sandstone outcrops which likely affected measurements.

9.4.3 Subarea 5B Anomalies and Results

No Confirmed GRAYs were identified in Subarea 5B. All six PGRAYs were classified as Not a GRAY as verified by gamma spectral data that indicated the presence of only NORM. Each PGRAY was associated with either the presence of sandstone outcrops or very shallow sandstone formations. Results are summarized in Table 9.4 and illustrated on Figure 9.7. The PGRAY locations are summarized below:

- PGRAY 5B-1 was located in the northwest portion of the subarea and adjacent to a sandstone outcrop southeast of Building 4358.
- PGRAY 5B-2 was located 30 feet northwest of a high voltage relay tower.
- PGRAY 5B-3 was located in a field approximately 10 feet south of an electrical high-voltage line tower with numerous sandstone outcrops located 30 feet south.

- PGRAY 5B-4 was located down slope to the west of PGRAY 5B-3 in a relatively open field with a large sandstone outcrop 5 feet south.
- PGRAY 5B-5 was located 75 feet west of the corner of 17th and G streets and 20 feet southeast of the preexisting foundation of Building 4007. It was on shallow soil eight feet north of a large sandstone outcrop.
- PGRAY 5B-6 was located in the southeast corner of the subarea at the base of a large sandstone outcrop.

9.4.4 Subarea 5C Anomalies and Results

No Confirmed GRAYs were identified in Subarea 5C. All six PGRAYs were classified as Not a GRAY as verified by gamma spectral data which indicated the presence of only NORM. A majority of the PGRAYs were located in the western and central portion of Subarea 5C. Two PGRAYs (5C-1 and 5C-2) were located in Subarea 8-North, but adjacent to Subarea 5C; however, these were included in the Subarea 5C results for convenience. Results are summarized in Table 9.4 and illustrated on Figure 9.8. The PGRAY locations are summarized below:

- PGRAY 5C-1 consisted of two gravel piles located in the southwestern portion of the subarea on a downward slope immediately northwest of Building 4100. Verification results indicated the elevated radionuclides were NORM likely from mineral constituents of the gravel.
- PGRAY 5C-2 was adjacent to a wall of sandstone outcrops and was located in the northwestern portion of the subarea and south of the "million dollar hole."
- PGRAY 5C-3 was adjacent to a biologically sensitive vernal pool area.
- PGRAYs 5C-4, 5C-5, and 5C-6 were measurements of surface asphalt and concrete surrounding a complex encompassing Buildings 4460, 4461, 4462 and 4463 in the central portion of Subarea 5C. Verification results indicated the elevated radiological concentrations were NORM and likely associated with the mineral constituents in the asphalt.

9.4.5 Subarea 5D-North Anomalies and Results

No Confirmed GRAYs were identified in Subarea 5D-North. All six PGRAYs were classified as Not a GRAY as verified by gamma spectral data which indicated the presence of only NORM. Results are summarized in Table 9.4 and illustrated on Figure 9.9. The PGRAY locations are summarized below:

- PGRAYs 5DN-1 and 5DN-2 were clustered in the south-central section of the subarea. The geometry of these locations with undulation of the natural and disturbed terrain likely contributed to the elevated measurements.
- PGRAYs 5DN-3 and 5DN-4 were located at the base of a massive sandstone outcrop and reflect both the sandstone content and physical geometries of the location.

- PGRAYs 5DN-5 and 5DN-6 were in an open area on the eastern boundary of the subarea.

9.4.6 Subarea 5D-South Anomalies and Results

No Confirmed GRAYs were identified in Subarea 5D-South. All 12 PGRAYs were classified as Not a GRAY as verified by gamma spectral data which indicated the presence of only NORM. The PGRAYs were located in the southern portion of the subarea along a hillside and ridgeline. Results are summarized in Table 9.4 and illustrated on Figure 9.10. The PGRAY locations are summarized below:

- PGRAYs 5DS-1 and 5DS-2 were located in the southwestern portion located on the ridge and foot slope of the hillside.
- PGRAYs 5DS-3 and 5DS-4 were located adjacent to low-lying sandstone outcrops.
- PGRAYs 5DS-5 through 5DS-12 were located along the hillside and ridgeline in the south-central to southeastern portion of the subarea.

9.4.7 Subarea 6 Anomalies and Results

In Subarea 6, 30 Confirmed GRAYs containing Cs-137 above the RTL of 0.2 pCi/g were identified in Subarea 6, and 30 PGRAYs identified were classified as Not a GRAY. Results are summarized in Table 9.4 and illustrated on Figure 9.5, which is subdivided into seven groups (A through G). The PGRAY locations are summarized below:

Group A: North and west of the SRE

- PGRAYs 6-1 through 6-5, and 6-7, 6-8, and 6-9 (Confirmed GRAYs) were located at the northwest edge of a flat area, extending into a culvert, and down gradient of a ledge.
- PGRAYs 6-6, 6-10, 6-11, and 6-18 were located along sandstone outcrops north of the SRE complex.
- PGRAY 6-19 (Confirmed GRAYs) was located directly north of the former SRE.

Group B: SRE footprint, the SRE tarp area, and south of the SRE

No PGRAYs were located in the immediate footprint of the former SRE. The area covered by a tarp to the northeast of the SRE complex was not scanned as it was deemed inaccessible.

- PGRAY 6-12 (Confirmed GRAY) was located on the edge of the SRE complex access road.
- PGRAYs 6-13 through 6-17 and 6-20 were located in the southwestern portion of the subarea amongst massive sandstone outcrops.

Group C: North central portion

- PGRAYs 6-23, 6-24, 6-27, 6-31, 6-32, 6-34, and 6-35 were either located on shallow bedrock with exposed flat sandstone outcroppings, at the base of, or between sandstone boulders or outcrops.
- PGRAY 6-26 (Confirmed GRAY) was located in the footprint of Building 4724.
- PGRAYs 6-28 and 6-29 (both Confirmed GRAYs) were located between two sandstone outcrops directly east of Building 4688.
- PGRAY 6-60 (Confirmed GRAY) was located northeast of the SRE complex in an intermittent pond (the SRE pond).

Area D: Central portion

- PGRAYs 6-21 (Confirmed GRAY), 6-22, and 6-25 were located southeast of the SRE complex. The terrain was relatively flat containing sandstone outcrops.
- PGRAY 6-30 was located near sandstone rock outcrops east of PGRAY 6-25.
- PGRAY 6-33 was located near a large sandstone rock outcrop north of the storage yard associated with Building 4064.
- PGRAY 6-36 (Confirmed GRAY) was located over asphalt on the west roadside of G Street.
- PGRAY 6-37 (Confirmed GRAY) was located over fractured asphalt in a turnout on the eastern portion of G Street.
- PGRAY 6-38 (Confirmed GRAY) was located in a relatively flat roadside area east of G Street.
- PGRAY 6-39 was located near PGRAY 6-38 to the southeast.
- PGRAY 6-40 (Confirmed GRAY) was located east of G Street in a field down gradient from the turnout where PGRAY 6-37 (Confirmed GRAY) was located.

Area E: Northeast portion known as the Old Conservation Yard

- PGRAY 6-45 (Confirmed GRAY) was located within the Old Conservation Yard near the former Building 4313.
- PGRAY 6-46 (Confirmed GRAY) was located south of the access road in a drainage area between the Old Conservation Yard and Barrel Storage Yard.
- PGRAY 6-55 was located on a moderate slope at the base of a massive sandstone outcrop west of an Edison power station. The elevated measurements likely resulted from environmental geometry caused by the adjacent sandstone outcrop.
- PGRAY 6-57 was located in a relatively flat field north of G Street.

Area F: Central eastern portion known as the New Conservation Yard

- PGRAY 6-43 (Confirmed GRAY) was located along the south side of F Street adjacent to an unpaved access road in a water drainage pathway sourced by the open storage areas north of its locations.
- PGRAY 6-47 (Confirmed GRAY) was located west of Buildings 4113 and 4623 on the side of a paved road in close proximity to F Street.
- PGRAYs 6-48, 6-49, 6-52, 6-56, and 6-58 (all Confirmed GRAYs) were located in and along a water drainage pathway in relatively open field.
- PGRAYs 6-44, 6-50, and 6-51 were located along an unpaved access road amongst boulders and massive sandstone outcrops.
- PGRAY 6-59 was located in a desolate location in the southeast portion of the subarea at the base of a sandstone outcrop. The elevated measurements were likely the result of the physical geometry of the adjacent sandstone outcrops.

Area G: Southeast portion

- PGRAYs 6-41, 6-42, and 6-54 were located between or at the base of sandstone outcrops.
- PGRAY 6-53 was located in an open field on the southern boundary of the subarea.

9.4.8 Subarea 7 Anomalies and Results

In Subarea 7, 38 Confirmed GRAYs containing Cs-137 above the RTL of 0.2 pCi/g were identified in Subarea 7 with 4 PGRAYs classified as Not a GRAY. Results are summarized in Table 9.4 and illustrated on Figure 9.11, which is subdivided into five groups (A through E). The PGRAY locations are summarized below:

Area A: Southwest portion

- PGRAY 7-1 was located at the base of a massive sandstone outcrop. The elevated measurements were likely the result of the surface geometry caused by the sandstone outcrop.

Area B: Area west of the RMHF

- PGRAY 7-2 (Confirmed GRAY) was located among sparse sandstone boulders downgradient and west of the RMHF.
- PGRAY 7-6 (Confirmed GRAY) was located in a drainage pathway downgradient of the RMHF.
- PGRAY 7-42 was located at the base of a sandstone outcrop adjacent to a dirt road down gradient of the RMHF.

- PGRAYs 7-3 and 7-4 (both Confirmed GRAYs) were located in proximity to the RMHF holdup pond.
- PGRAY 7-5 (Confirmed GRAY) was located on the upper hillside leading to the RMHF.

Area C: Area adjacent to the RMHF

- PGRAYs 7-7, 7-8, 7-9, and 7-17 (all Confirmed GRAYs) were asphalt surfaces adjacent to the fence of the RMHF. ISGS results indicated the presence of Co-60 at PGRAY 7-17.
- PGRAYs 7-11 through 7-13, 7-15, and 7-16 (all Confirmed GRAYs) were located on or at the base of a hillside (which contained numerous sandstone boulders) north of the RMHF.
- PGRAYs 7-10, 7-14, 7-18, and 7-21 (all Confirmed GRAYs) were located south of the RMHF adjacent to the RMHF fence. ISGS results indicated the presence of Co-60 at PGRAY 7-21.
- PGRAY 7-19 (Confirmed GRAY) was located north of the RMHF along the northern boundary of the subarea which abuts the southern boundary of the NBZ-Northwest.
- PGRAY 7-20 (Confirmed GRAY) was located on the hillside down slope south of the RMHF.
- PGRAY 7-22 (Confirmed GRAY) was located northeast of the RMHF and adjacent to the RMHF fence.

Area D: Area north and east of the RMHF

- PGRAYs 7-23 through 7-36, 7-38, and 7-39 (all Confirmed GRAYs) were located east of the RMHF on a leveled summit with various paved and unpaved access roads with sparse sandstone outcrops.

Area E: Northern panhandle

- PGRAYs 7-37 and 7-41 (both Confirmed GRAYs) are located to the west of a paved access road leading to the northernmost hill summit.
- PGRAY 40 was located downhill near the SSFL boundary.

9.4.9 Subarea 8-North Anomalies and Results

One Confirmed GRAY was identified in Subarea 8-North. Thirty-one PGRAYs were classified as Not a GRAY as verified by gamma spectral data which indicated the presence of only NORM. Subarea 8-North has several ridges and ravines and many exposed sandstone outcrops with considerable vertical relief. Results are summarized in Table 9.3 and illustrated on Figure 9.12, which is subdivided into three groups (A, B, and C). The PGRAY locations are summarized below:

Area A: Western portion, and west and north of the Former Sodium Disposal Facility

- PGRAYs 8N-1 through 8N-9 were located near the boundary with the NBZ-Northwest amongst rows of exposed sandstone beds trending northwest to southwest and dipping to the northwest. The vertical and, in some instances, overhanging geometries of the sandstone outcrops likely contributed to elevated measurements.

Area B: Central and southern portions

- PGRAYs 8N-10 and 8N-12 through 8N-18 were located amongst sandstone outcrops and west of Building 4009. The elevated measurements were likely caused by the geometries of the numerous sandstone outcrops.
- PGRAY 8N-11 (Confirmed GRAY) was located amongst sandstone outcrops and west of Building 4009.

Area C: Northeast portion

- PGRAYs 8N-19 through 8N-32 were located near sandstone outcrops that transitioned into a steep narrow drainage into the NBZ. Elevated measurements were affected by the environmental geometry caused by the sandstone outcrops and the drainage topography.

9.4.10 Subarea 8-South Anomalies and Results

No PGRAYs were identified in Subarea 8-South. Approximately 30 percent of the area was inaccessible due to steep terrain and Protected Biological Resources, predominately Braunton's milkvetch, *astragalus brauntonii*. Results are illustrated on Figure 9.10.

9.4.11 Northern Buffer Zone-Northeast Anomalies and Results

No Confirmed GRAYs were identified in NBZ-Northeast. One PGRAY, P1D-1, was located in the southwest portion of the subarea along the border of Area IV in NBZ Survey Section P1D. The PGRAY was found at the base of a large sandstone outcrop. The enclosed geometry likely caused the elevated measurements and presence of only NORM was confirmed. Results are summarized in Table 9.4 and illustrated on Figure 9.13.

9.4.12 Northern Buffer Zone-Northwest Anomalies and Results

One Confirmed GRAY containing Cs-137 above the RTL of 0.2 pCi/g was identified in the Northern Buffer Zone- Northwest with 25 PGRAYs classified as Not a GRAY. All PGRAYs were located in proximity to sandstone outcrops or at the base of sheer sandstone cliff faces. The elevated levels were very likely due to surface geometries of adjacent sandstone features. Results are summarized in Table 9.4 and illustrated on Figure 9.14. The PGRAY locations are summarized below:

- PGRAY P1I-1 was located in the southwest of the subarea in a ravine north of an unpaved access road in Priority 1I.
- PGRAY P1A-1 was located adjacent to parallel exposed sandstone beds trending northeast and dipping to the northwest expanding into Subarea 8-North.
- PGRAYs P1A-2 through P1A-5 were located adjacent to a sandstone outcrop trending northeast to southwest along the border of Area IV. The physical surface geometry caused by the adjacent sandstone outcrops likely resulted in the elevated measurements for these PGRAYs.
- PGRAYs P1B-1 and P1B-2 were located at the base of large sandstone outcrops, which were likely the cause of the elevated measurements.
- PGRAYs P1C-1 through P1C-16 and P1C-18 were located adjacent to sandstone outcrops, which was likely the cause of the elevated measurements.
- PGRAY P1C-17 (Confirmed GRAY) was located adjacent to a sandstone outcrop.

9.5 CONCLUSIONS

The gamma radiation scanning survey met the objective to scan 100 percent of accessible surfaces in the Area IV Study Area with the most sensitive detection system capable of accessing the location. In addition, locations of elevated gamma emitting radionuclides in surface or near surface soils were identified, delineated, and differentiated between NORM and site-related contamination in accordance with the SAP (HGL and TPC, 2010a). These objectives were met through the development and deployment of innovative gamma radiation detection systems in addition to traditional methods, such as hand held gamma scanning instruments and in-situ gamma spectrometry. The resulting gamma radiation data was digitally mapped using high-resolution geo-referenced databases that provides visual representations of the gamma results depicting location classified as PGRAYs as either Confirmed GRAYs or Not a GRAY.

Approximately 265.73 acres out of 471.64 acres were scanned within the Area IV Study Area. A total of 217 PGRAYs were identified, of which 70 were classified as Confirmed GRAYs and 147 as Not a GRAY. Most Confirmed GRAYs were located in Subareas 6 and 7 with one in Subarea 8-North and one in the NBZ-Northwest; all had detected Cs-137 above the 0.2 pCi/g RTL decision level used to evaluate soil sample results as site-related contamination which requires remediation.

The results were used in conjunction with geophysical data and HSA findings to guide the selection of targeted sample locations for soil sampling and radiochemical analyses. All Confirmed GRAYs were sampled during the soil sampling investigation. Soil sample results are presented in separate documents prepared for each subarea.

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TABLES

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Table 3.1
Operating Parameters for Gamma Detection Systems

Detection System	FOV Width (inches)	Transect Width (inches)	Operating Height (inches)	Maximum Velocity (feet/second)
Enhanced Radiation Ground Scanner II	86	72	15	2
Dual Detector Track Mounted Gamma Scanner	56	48	15	2
Wheel Mounted Gamma Scanner	28	24	12	2
Single Detector Track Mounted Gamma Scanner	36	30	15	2
Mule Mounted Gamma Scanner	104	90	35	3
Hand Held Gamma Scanner	48	24	18	1
In Situ Gamma Spectrometer	4 meters	NA	30 centimeters	NA

Notes:

FOV - field of view

NA - not applicable

Table 3.2
Telehandlers Utilized with the ERGS II Detection System

Make	Model Number	Load Capacity (pounds)	Advantages	Disadvantages	Usage Duration	Reasoning for Ceasing Usage
Gradall®	534D9-45	9,000	Boom reach of 45 feet. High ground clearance of 20 inches.	Poor maneuverability due to rear wheel drive. Large size resulted in restricted access.	February to December 2010	The lease expired.
JCB®	524-50	5,291	Enhanced maneuverability due to compact size and additional steering modes (four-wheeled and crab steering). Foam filled tires reduced punctures. Enclosed cab increased operator comfort.	Low load capacity resulted in short boom reach (9 to 12 feet) and decreased off-road performance with foam filled tires because of weight and traction.	January to December 2011	Ignition complications requiring repairs during the month of August, then the lease expired.
JCB®	535-140	8,000	Temporary replacement for JCB® 524-50.		August 2011	JCB® 524-50 was repaired.
SkyTrak®	10054	10,000	Boom reach of 54 feet (used on Radioactive Materials Handling Facility hillsides). Foam filled tires reduced punctures.	Decreased maneuverability and accessibility caused by size and weight. Poor performance due to engine and overall condition of equipment.	July 2011	Engine complications occurred.
Gradall®	534D-6	6,000	Temporary Replacement for Skytrack® 10054.		July to August	Leak in hydraulic
Xtreme®	XR620-621	6,000	Enhanced maneuverability due to compact size and additional steering modes (four-wheeled and crab steering).	Low ground clearance of ten inches.	January 2012	Gamma scanning was completed.

Table 3.3
Enhanced Radiation Ground Scanner II Specifications

Detection System	
Manufacturer	Radiation Solutions Inc.
Model	(2) RSX-4 (four 4-inch by 4-inch by 16-inch spectral grade NaI)
Detector volume	1,024 in^3 per RSX-4 (totaling 2,048 in^3)
Weight	Approximately 200 pounds per RSX-4 (totaling 400 pounds)
Power	10 to 40 VDC, nominally 12 VDC
Operating temperature	-22 to +113°F
Detector height above ground surface	15 inches
Detector scanning speed	2 feet per second (maximum)
Detector FOV	86 inches
Spectrometer	
Channels	1024
Resolution	3 keV per channel linear response
Gamma energy response	20 keV to 3 MeV with a cosmic window above 3.5 MeV
Dead time	Zero (live time clock adjusts for loss of system measured pile-up rejections to give an apparent dead time ensuring absolute count rate is correct)
Sampling rate	1 per second with capability range of 0.1 to 10 per second
Count rate	Up to 250,000 counts per second
Spectral stabilization	Automatic spectral stabilization at approximately every two minutes to maintain the peak position +/- 0.2 percent over 1024 channels
Control and Data Analysis	
Data Integration	Data from both RSX-4 modules are integrated with the DGPS signal via an RSI RS-501 interface console
Communication	Data transfer from the RS-501 console to computer via ethernet cable and Cisco Link System® E2100L router
Computer	Panasonic Toughbook® Model CF-30 or CF-19
Software	RadAssist® (RSI proprietary) or ArcPad®
Shield	
Construction	0.25-inch stainless steel with 1-inch thick lead, 0.25–inch Lexan (polycarbonate) protective window on bottom
Size	Approximately 49-inch wide by 32-inch long by 9-inch high without forklift handles
Weight	Approximately 1,250 pounds
Forklift Handles	0.25-inch steel sized for standard forks
Differential Global Positioning System (Upgrade)	
Manufacturer	Trimble®
Model	SPS852 base station receiver with Geodetic™ Antenna, upgrades, and internal 900 MHz Radio, and SPS852 receiver (instrument mounted)
Antenna	Zephyr™ II Antenna and Antenna Pole
Differential correction	Real Time Kinematic
Accuracy	10 centimeters
GPS Radio Repeater	Trimble® SNB900, utilized to maintain connection to base station

Table 3.3
Enhanced Radiation Ground Scanner II Specifications

Differential Global Positioning System (Precursor)	
Manufacture	Trimble®
Model	AgGPS332
Antenna	Spot
Differential correction	WAAS
Accuracy	Approximately 1 meter
Miscellaneous	
Battery and Charger	(2) Werker™ SLA battery 12V, 80Ah
	Black & Decker 25 amp simple battery charger with 75 amp engine for 12V SLA battery
Case Fan	6 inch Hoffman™ Case Fan (200/240 CFM, 2670/3200 RPM)
Transportation Mechanism	
Manufacturer & Model	JLG® Skytrack® Legacy Series 10054
	JCB® Loadall Series 524-50
	JCB® Loadall Series 535-140
	JLG® Gradall® Model 534D9-45
	JLG® Gradall® Model 534D-6
	Xtreme® XR620-621
Type	Industrial telescopic forklift equipped with all terrain wheels
Power Train	Hydraulic

Notes:

Ah - ampere hour
amp - amperage
CFM - cubic feet per minute
DGPS - differential global positioning system
°F - degrees Fahrenheit
in^3 - cubic inches
keV - kilo electron volts
lb - pound
MeV - mega electron volts
MHz - megahertz
NaI - sodium iodide
RSI - Radiation Solutions Inc.
RPM - revolutions per minute
SLA - sealed lead acid
VDC - volts direct current
V - volt
WAAS - wide area augmentation system

Table 3.4
Dual Detector Track Mounted Gamma Scanner Specifications

Detection System	
Manufacturer	Radiation Solutions Inc.
Model	(2) RSX-1 (4-inch by 4-inch by 16-inch spectral grade NaI)
Detector volume	256 in^3 per RSX-1 (totaling 512 in^3)
Weight	Approximately 50 pounds per RSX-1 (totaling 100 pounds)
Power	10 to 40 VDC, nominally 12 VDC
Operating temperature	-22 to +113°F
Detector height above ground surface	15 inches
Detector scanning velocity	2 feet per second (maximum)
Detector FOV	56 inches
Spectrometer	
Channels	1024
Resolution	3 keV per channel linear response
Gamma energy response	20 keV to 3 MeV with a cosmic window above 3.5 MeV
Dead time	Zero (live time clock adjusts for loss of system measured pile-up rejections to give an apparent dead time ensuring absolute count rate is correct)
Sampling rate	1 per second with capability range of 0.1 to 10 per second
Count rate	Up to 250,000 counts per second
Spectral stabilization	Automatic spectral stabilization at approximately every two minutes to maintain the peak position +/- 0.2 percent over 1024 channels
Control and Data Analysis	
Data Integration	Data from both detectors are integrated with the DGPS signal via an RSI RS-701 interface console
Communication	Data transfer from the RS-701 interface console to computer via ethernet cable and Cisco Link System® E2100L router
Computer	Panasonic Toughbook® Model CF-19
Software	RadAssist® or ArcPad®
Shield	
Construction	3/8-inch stainless steel with 0.25-inch thick lead lined with copper to shield the 78 keV X-ray peak from the interaction of cosmic radiation with lead or steel, and a 0.25–inch Lexan® (polycarbonate) protective window on bottom
Size	Approximately 7-inch wide by 17-inch long by 7-inch high
Weight	Approximately 43 pounds
Differential Global Positioning System (Upgrade)	
Manufacturer	Trimble®
Model	SPS852 base station receiver with Geodetic™ Antenna, upgrades, and internal 900 MHz Radio, and SPS852 receiver (instrument mounted)
Antenna	Zephyr™ II Antenna and Antenna Pole
Differential correction	Real Time Kinematic
Accuracy	10 centimeters
GPS Radio Repeater	Trimble® SNB900, utilized to maintain connection to base station

Table 3.4
Dual Detector Track Mounted Gamma Scanner Specifications

Differential Global Positioning System (Precursor)	
Manufacture	Trimble®
Model	GeoExplorer® GeoXH ™ handheld 2008 series
Antenna	Internal
Differential correction	Real-Time H-Star™
Accuracy	Approximately 1 meter
Miscellaneous	
Battery and Charger	LiFePO4 Battery 12.8V 20 Ah (256 Wh, 60A rate)
	Solar/DC Charge Controller (120W,10A Rate) for 12V SLA or LFP Battery
	Smart Charger® (10A) for 12.8V LiFePO4 battery Pack (model C12A10) Smart Charger® (6.0A) for 14.8 LI-ion/Polymer Rechargeable battery pack LiMnNi 26650 Battery 14.8V 4Ah (59.2 Wh, 10Arate) with PCM (4.8) Union Battery™ Lead acid 12V, 17Ah (Mx12180)
Transportation Mechanism	
Type	Off-road, rubber track carrier
Model	Retrofitted CanyCom BP419

Notes:

Ah - ampere hour

DGPS - differential global positioning system

°F - degrees Fahrenheit

FOV - field of view

in^3 - cubic inches

keV - kilo electron volts

LFP - lithium iron phosphate

MeV - mega electron volts

MHz - megahertz

NaI - sodium iodide

PCM - protection circuit module

RSI - Radiation Solution Inc.

SLA - sealed lead acid

VDC - volts direct current

V - volt

W - watt

Wh - Watt hour

Table 3.5
Wheel Mounted Gamma Scanner Specifications

Detection System	
Manufacturer	Radiation Solutions Inc.
Model	RSX-1 (4-inch by 4-inch by 16-inch spectral grade NaI)
Detector volume	256 in^3
Weight	Approximately 50 pounds
Power	10 to 40 VDC, nominally 12 VDC
Operating temperature	-22 to +113°F
Detector height above ground surface	12 inches
Detector scanning velocity	2 feet per second (maximum)
Detector FOV	28 inches
Spectrometer	
Channels	1024
Resolution	3 keV per channel linear response
Gamma energy response	20 keV to 3 MeV with a cosmic window above 3.5 MeV
Dead time	Zero (live time clock adjusts for loss of system measured pile-up rejections to give an apparent dead time ensuring absolute count rate is correct)
Sampling rate	1 per second with capability range of 0.1 to 10 per second
Count rate	Up to 250,000 counts per second
Spectral stabilization	Automatic spectral stabilization at approximately every two minutes to maintain the peak position +/- 0.2 percent over 1024 channels
Control and Data Analysis	
Data Integration	Data from detector is integrated with the DGPS signal via an RSI RS-701 interface console
Communication	Data transfer from the RS-701 interface console to computer via ethernet cable and Cisco Link System® E2100L router
Computer	Panasonic Toughbook® Model CF-19
Software	RadAssist® or ArcPad®
Shield	
Construction	3/8-inch stainless steel with 0.25-inch thick lead lined with copper to shield the 78 keV X-ray peak from the interaction of cosmic radiation with lead or steel, and a 0.25–inch Lexan® (polycarbonate) protective window on bottom
Size	Approximately 7-inch wide by 17-inch long by 7-inch high
Weight	Approximately 43 pounds
Differential Global Positioning System (Upgrade)	
Manufacturer	Trimble®
Model	SPS852 base station receiver with Geodetic™ Antenna, upgrades, and internal 900 MHz Radio, and SPS852 receiver (instrument mounted)
Antenna	Zephyr™ II Antenna and Antenna Pole
Differential correction	Real Time Kinematic
Accuracy	10 centimeters
GPS Radio Repeater	Trimble® SNB900, utilized to maintain connection to base station

Table 3.5
Wheel Mounted Gamma Scanner Specifications

Differential Global Positioning System (Precursor)	
Manufacture	Trimble®
Model	GeoExplorer GeoXH handheld 2008 series
Antenna	Internal
Differential correction	Real-Time H-Star™
Accuracy	Approximately 1 meter
Miscellaneous	
Battery and Charger	LiFEPO4 Battery 12.8V 20 Ah (256 Wh, 60A rate)
	Solar/DC Charge Controller (120W,10A) for 12V SLA or LFP Battery
	Smart Charger® (10A) for 12.8V LiFePO4 battery Pack (model C12A10) Smart Charger® (6.0A) for 14.8 LI-ion/Polymer Rechargeable battery pack LiMnNi 26650 Battery 14.8V 4Ah (59.2 Wh, 10A) with PCM (4.8) Union Battery™ Lead acid 12V, 17Ah (Mx12180)
Transportation Mechanism	
Type	Three-wheeled cart manually guided by field technician

Notes:

A - amperage
Ah - ampere hour
DGPS - differential global positioning system
°F - degrees Fahrenheit
in^3 - cubic inches
keV - kilo electron volts
LFP - lithium iron phosphate
MeV - mega electron volts
MHz - megahertz
NaI - sodium iodide
PCM - protection circuit module
RSI - Radiation Solution Inc.
SLA - sealed lead acid
VDC - volts direct current
V - volt
W - Watt
Wh - Watt hour

Table 3.6
Single Detector Track Mounted Gamma Scanner Specifications

Detection System	
Manufacturer	Radiation Solutions Inc.
Model	RSX-1 (4-inch by 4-inch by 16-inch spectral grade NaI)
Detector volume	256 in^3
Weight	Approximately 50 pounds
Power	10 to 40 VDC, nominally 12 VDC
Operating temperature	-22 to +113°F
Detector height above ground surface	15 inches
Detector scanning velocity	2 feet per second (maximum)
Detector FOV	36 inches
Spectrometer	
Channels	1024
Resolution	3 keV per channel linear response
Gamma energy response	20 keV to 3 MeV with a cosmic window above 3.5 MeV
Dead time	Zero (live time clock adjusts for loss of system measured pile-up rejections to give an apparent dead time ensuring absolute count rate is correct)
Sampling rate	1 per second with capability range of 0.1 to 10 per second
Count rate	Up to 250,000 counts per second
Spectral stabilization	Automatic spectral stabilization at approximately every two minutes to maintain the peak position +/- 0.2 percent over 1024 channels
Control and Data Analysis	
Data Integration	Data from detector is integrated with the DGPS signal via an RSI RS-701 interface console
Communication	Data transfer from the RS-701 interface console to computer via ethernet cable and Cisco Link System® E2100L router
Computer	Panasonic Toughbook® Model CF-19
Software	RadAssist® or ArcPad®
Shield	
Construction	3/8-inch stainless steel with 0.25-inch thick lead lined with copper to shield the 78 keV X-ray peak from the interaction of cosmic radiation with lead or steel, and a 0.25–inch Lexan® (polycarbonate) protective window on bottom
Size	Approximately 7-inch wide by 17-inch long by 7-inch high
Weight	Approximately 43 pounds
Differential Global Positioning System (Upgrade)	
Manufacturer	Trimble®
Model	SPS852 base station receiver with Geodetic™ Antenna, upgrades, and internal 900 MHz Radio, and SPS852 receiver (instrument mounted)
Antenna	Zephyr™ II Antenna and Antenna Pole
Differential correction	Real Time Kinematic
Accuracy	10 centimeters
GPS Radio Repeater	Trimble® SNB900, utilized to maintain connection to base station

Table 3.6
Single Detector Track Mounted Gamma Scanner Specifications

Differential Global Positioning System (Precursor)	
Manufacture	Trimble®
Model	GeoExplorer® GeoXH ™ handheld 2008
Antenna	Internal
Differential correction	Real-Time H-Star™
Accuracy	Approximately 1 meter
Miscellaneous	
Battery and Charger	LiFEPO4 Battery 12.8V 20 Ah (256 Wh, 60A)
	Solar/DC Charge Controller (120W,10A) for 12V SLA or LFP Battery
	Smart Charger® (10A) for 12.8V LiFePO4 battery Pack (model C12A10) Smart Charger® (6.0A) for 14.8 LI-ion/Polymer Rechargeable battery pack LiMnNi 26650 Battery 14.8V 4Ah (59.2 Wh, 10A) with PCM (4.8) Union Battery™ Lead acid 12V, 17Ah (Mx12180)
Transportation Mechanism	
Type	Off-road, rubber track carrier
Model	Retrofitted CanyCom BP419

Notes:

A - amperage

Ah - ampere hour

DGPS - differential global positioning system

°F - degrees Fahrenheit

in^3 - cubic inches

keV - kilo electron volts

LFP - lithium iron phosphate

MeV - mega electron volts

MHz - megahertz

NaI - sodium iodide

PCM - protection circuit module

RSI - Radiation Solution Inc.

SLA - sealed lead acid

VDC - volts direct current

V - volt

W - Watt

Wh - Watt hour

Table 3.7
Mule Mounted Gamma Scanner Specifications

Detection System	
Manufacturer	Radiation Solutions Inc.
Model	(2) RSX-1 (4-inch by 4-inch by 16-inch spectral grade NaI)
Detector volume	256 in^3 per RSX-1 (totaling 512 in^3)
Weight	Approximately 50 pounds per RSX-1 (totaling 100 pounds)
Power	10 to 40 VDC, nominally 12 VDC
Operating temperature	-22 to +113°F
Detector height above ground surface	35 inches depending on size of mule
Detector scanning velocity	3 feet per second (maximum)
Detector FOV	104 inches
Spectrometer	
Channels	1024
Resolution	3 keV per channel linear response
Gamma energy response	20 keV to 3 MeV with a cosmic window above 3.5 MeV
Dead time	Zero (live time clock adjusts for loss of system measured pile-up rejections to give an apparent dead time ensuring absolute count rate is correct)
Sampling rate	1 per second with capability range of 0.1 to 10 per second
Count rate	Up to 250,000 counts per second
Spectral stabilization	Automatic spectral stabilization at approximately every two minutes to maintain the peak position +/- 0.2 percent over 1024 channels
Control and Data Analysis	
Data Integration	Data from both RSX-1 detectors are integrated with the DGPS signal via an RSI RS-701 interface console
Communication	Data transfer from the RS-701 interface console to computer via ethernet cable and Cisco Link System® E2100L router
Computer	Panasonic Toughbook® Model CF-19
Software	RadAssist®
Shield	
Construction	3/8-inch stainless steel with 0.25-inch thick lead lined with copper to shield the 78 keV X-ray peak from the interaction of cosmic radiation with lead or steel, and a 0.25–inch Lexan® (polycarbonate) protective window on bottom
Size	Approximately 7-inch wide by 17-inch long by 7-inch high on the front, top and outside of each detector (the side facing the mule will not have shielding)
Weight	Approximately 29.4 pounds each
Differential Global Positioning System (Upgrade)	
Manufacturer	Trimble®
Model	SPS852 base station receiver with Geodetic™ Antenna, upgrades, and internal 900 MHz Radio, and SPS852 receiver (instrument mounted)
Antenna	Zephyr™ II Antenna and Antenna Pole
Differential correction	Real Time Kinematic
Accuracy	10 centimeters
GPS Radio Repeater	Trimble® SNB900, utilized to maintain connection to base station

Table 3.7
Mule Mounted Gamma Scanner Specifications

Differential Global Positioning System (Precursor)	
Manufacture	Trimble®
Model	GeoExplorer® GeoXH™ handheld 2008 series
Antenna	Internal
Differential correction	Real-Time H-Star™
Accuracy	Approximately 1 meter
Miscellaneous	
Battery and Charger	LiFEPO4 Battery 12.8V 20 Ah (256 Wh, 60A)
	Solar/DC Charge Controller (120W,10A) for 12V SLA or LFP Battery
	Smart Charger® (10A) for 12.8V LiFePO4 battery Pack (model C12A10) Smart Charger® (6.0A) for 14.8 LI-ion/Polymer Rechargeable battery pack LiMnNi 26650 Battery 14.8V 4Ah (59.2 Wh, 10A) with PCM (4.8) Union Battery™ Lead acid 12V, 17Ah (Mx12180)
Case Fan	70 mm City Net Case Fan (28.0 CFM at 3700 RPM)
	140 mm Coolmax Case Fan (64.95 CFM, 1000 +/-10% RPM)
Transportation Mechanism	
Type	A mule (Equus mulus) carrying a customized saddle and harness (mule rig) outfitted with detectors led by a trained mule handler.

Notes:

A - amperage
Ah - ampere hour
DGPS - differential global positioning system
°F - degrees Fahrenheit
in^3 - cubic inches
keV - kilo electron volts
LFP - lithium iron phosphate
MeV - mega electron volts
MHz - megahertz
NaI - sodium iodide
PCM - protection circuit module
RSI - Radiation Solution Inc.
SLA - sealed lead acid
VDC - volts direct current
V - volt
W - Watt
Wh - Watt hour

Table 3.8
Hand Held Gamma Scanner Specification

Detection System	
HHGS Systems	2 (dependent on transportation mechanisms)
Manufacturer	Ludlum™ Instruments Inc.
Detector Model	44-20 (3-inch by 3-inch NaI)
Ratemeter Model	2241-3 with RS-232 data port
Detector volume	21.1 in^3
Total weight	Approximately 9.2 pounds
Power	Four D-cell alkaline batteries
Operating temperature	-4 to +122 °F
Sampling rate	1 per second
Sensitivity	Approximately 2,700 counts per minute per micro roentgen per hour (cpm/μR/hr)
Operating point	Optimized for radium-226
Detector height above ground surface	18 inches
Detector scanning velocity	1 foot per second, when possible depending on field conditions and safety
Detector FOV	48 inches
Control and Data Analysis	
Data Integration	Digibox
Communication	Data transfer from the Model 2221 via RS-232 port to digibox then via RS-232 cable to computer, and Cisco Link System® E2100L router
Computer	Panasonic Toughbook® Model CF-U1 or CF-19
Software	USEPA's RAT
Differential Global Positioning System	
Manufacturer	Trimble®
Model	SPS852 Receiver (base station, Building 204) with upgrades and internal 900 MHz Radio and SPS852 Rover (field backpack)
Antenna	Zephyr™ II Antenna and Antenna pole
Differential correction	Real Time Kinetic
Accuracy	10 centimeters horizontally, 50 centimeters vertically
Miscellaneous	
Battery and Charger	LiFePO4 Li-Ion rechargeable battery (12.8 V 3400mAh)
	Powerized LiMnNi charger

Table 3.8
Hand Held Gamma Scanner Specification

Transportation Mechanism	
Configuration I	Fabricated aluminum bar stock frame carried by field technician. Model 44-20 Detector and Model 2241-3 Ratemeter attached on the ends. CF-U1 computer attached on perpendicular bar stock. Field backpack with antenna pole, beacon with SPS852 receiver, wireless router, and batteries inside.
Configuration II	Carried by field technician from handle attached to exterior Model 44-20 detector case. Field backpack with antenna pole and beacon attached with electronics stored inside. CF-19 computer held in backpack visible to second field technician.

Notes:

cpm - counts per minute

°F - degrees Fahrenheit

HHGS - hand held gamma scanner

in^3 - cubic inches

keV - kilo electron volts

mAh - milliampere-hour

MHz - megahertz

μR/hr - microroentgen per hour

NaI - sodium iodide

PVC - polyvinyl chloride

V - volt

Table 3.9
In Situ Gamma Spectrometer Specifications

Detection System	
Manufacturer	Canberra
Detector Model	5020 (Broad energy germanium)
Detector height above ground surface	30 centimeters
Detector scanning velocity	None, detector remains stationary during data collection
Detector FOV	4 meter diameter for Cesium-137
Spectrometer	
Resolution	Variable depending on energy (0.35 keV resolution for 5.9 keV energy and 2.00 keV resolution for 1332 keV energy)
Gamma energy response	30 keV to 3 MeV
Count time	20 minutes, standard verification of PGRAY
Control and Data Analysis	
Data Integration	Inspector™ 2000
Communication	Data cable
Computer	Panasonic Toughbook® Model CF-74
Software	Genie™ 2000
Shield	
Type	unshielded
Differential Global Positioning System	
Manufacturer	Trimble®
Model	SPS852 base station receiver with Geodetic™ Antenna, upgrades, and internal 900 MHz Radio, and SPS852 receiver connected to the 5020 Detector
Differential correction	Real Time Kinetic
Accuracy	10 centimeters
Miscellaneous	
Battery and Charger	Li-Ion l series battery (7.2 V, 6000 mAh)
	BC-V500 portable charger for Info L series Li-Ion battery (1.0 A) for 100-240V
Liquid Nitrogen Storage Vessel	MVE Cryogenics Dura-Tech DOT-4L100
Transportation Mechanism	
Type	A stationary tripod, carried by technician to measurement locations.

Notes:

A - amperage

keV - kilo electron volts

mAh - milliampere-hour

MeV - mega electron volts

MHz - megahertz

PGRAY - potential gamma radiation anomaly

V - volt

Table 3.10
Global Positioning System Specifications

SPS852 Receiver	
Manufacture	Trimble®
Detection System (Upgrade)	ERGS II, WMGS, TMGS, STGS, MMGS, ISGS, HHGS (I & II)
Differential correction	Real Time Kinematic
Accuracy	10 centimeters
Connections and adaptors	Ethernet adaptor and cable
SPS852 Receiver (Base Station)	
Antenna	Zephyr Geo™ II with radio antenna extension
Stand	Tripod
Connections, cables, and adaptors	GPS antenna extension cable,
Upgrades	Internal 900MHz Radio, GLONASS™ , Data Logging 852, Precision Base
SPS852 Receiver (Instrument Mounted)	
Antenna	Zephyr™ II with pole mounted brackets, one foot pole extension
Upgrades	852 to Real Time Kinematic Data Logging 852, GLONASS™
Radio Repeater	
Field Repeater	SNB900 Radio Repeater
GeoExplorer® GeoXH™ Handheld 2008 Receiver	
Manufacture	Trimble®
Detection System (Precursor)	WMGS, TMGS, STGS, MMGS
Differential correction	Real-Time H-Star™
Accuracy	Approximately one meter
Antenna	Internal
Connections, cables, and adaptors	Serial clip, DB9 serial cable
AgGPS332 Receiver	
Manufacture	Trimble®
Detection System (Precursor)	ERGS II
Differential correction	WAAS
Accuracy	Approximately one meter
Antenna	Tornado™

Notes:

ERGS II - Enhanced Radiation Ground Scanner II

GLONASS™ - Global Navigation Satellite System

HHGS - Hand Held Gamma Scanner

ISGS - In-Situ Gamma Spectrometer

MHz - megahertz

MMGS - Mule Mounted Gamma Scanner

RTK - real time kinematic

STGS - Single Detector Track Mounted Gamma Scanner

TMGS - Dual Detector Track Mounted Gamma Scanner

WAAS - wide area augmentation system

WMGS - Wheel Mounted Gamma Scanner

Table 3.11
RadAssist® Regions of Interest

Region of Interest	Start Channel	End Channel
Total Count	2	1022
Potassium	457	523
Uranium	553	620
Thorium	803	937
Man made	2	465
Americium-241	15	24
Americium high	25	34
Cesium-137	200	245
Europium-254	270	445
Cobalt-60	370	465

Table 3.12
RadAssist® Calibration Coefficients

Region of Interest	Total Count	Potassium	Uranium	Thorium	Man made	Americium-241	Americium-high	Cesium-137	Europium-254	Cobalt-60
Total Count	1	0	0	0	0	0	0	0	0	0
Potassium	0	1	0	0	0	0	0	0	0	0
Uranium	0	0	1	0.311	0	0	0	0	0	0
Thorium	0	0	0.0528	1	0	0	0	0	0	0
Man made	0	10.3024	83.2838	66.9645	1	0	0	0	0	0
Americium-241	0	0	0	0	0	1	0.5884	0	0	0
Americium high	0	0	0	0	0	0	1	0	0	0
Cesium-137	0	0.433	3.3595	2.0054	0	0	0	1	0	0
Europium-254	0	1.113	4.4161	3.8054	0	0	0	0	1	0
Cobalt-60	0	0.522	2.4031	0.7204	0	0	0	0	0.5884	1

Note:

Coefficients are displayed as entered into RadAssist.

Table 6.1
Study Area Accessibility

Subarea	Total Acres	Accessible Surfaces (acres)	Inaccessible Surfaces (acres)	Inaccessible Surfaces Categories					
				Tree Canopy (acres)	Structures (acres)	GPS Signal Loss (acres)	Protected Resources (acres)	Rock Outcrop (acres)	Steep Terrain (acres)
Subarea 3	3.91	1.91	2.00	0.19	0.85	0.00	0.00	0.41	0.55
Subarea 5A	38.36	32.39	5.97	1.15	0.36	0.05	0.06	2.38	1.98
Subarea 5B	23.21	19.38	3.82	0.22	2.47	0.09	0.04	0.31	0.69
Subarea 5C	21.92	18.89	3.03	0.05	1.97	0.01	0.01	0.16	0.82
Subarea 5D-North	25.54	24.07	1.48	0.01	1.17	0.02	0.00	0.03	0.24
Subarea 5D-South	45.98	34.81	11.17	0.59	0.02	0.00	0.14	0.11	10.30
Subarea 6	57.26	42.38	14.88	1.55	1.09	0.00	0.09	5.37	6.78
Suabrea 7	16.21	8.52	7.69	0.24	1.89	0.00	0.12	1.90	3.54
Subarea 8-North	35.31	21.58	13.73	2.59	1.31	0.41	0.00	6.15	3.26
Subarea 8-South	22.23	15.71	6.51	0.88	0.00	0.00	1.02	0.33	4.29
NBZ-Priority 1	88.48	37.35	51.13	0.00	0.00	0.00	0.00	15.18	35.96
NBZ-Priority 2	33.30	6.92	26.38	0.00	0.00	0.00	0.00	6.16	20.22
NBZ-Priority 3	59.95	1.83	58.11	0.00	0.00	0.00	0.00	15.29	42.82
Total	**471.64**	**265.73**	**205.91**	**7.46**	**11.14**	**0.59**	**1.48**	**53.78**	**131.46**

Notes:

All data is rounded to two decimals. Calculations were completed with five decimal places. A small amount of round off error may be present in data.

GPS - global positioning system

NBZ - Northern Buffer Zone

Table 6.2
Scanned Acreage by Detection System per Subarea

Subarea	Total Scanned (acres)	ERGS II (acres)	TMGS (acres)	WMGS (acres)	STGS (acres)	MMGS (acres)	HHGS (acres)
Suabrea 3	1.91	1.71	0.13	0.02	0.00	0.04	0.00
Subarea 5A	32.39	20.93	0.00	2.30	0.00	9.16	0.00
Subarea 5B	19.38	14.78	0.00	1.56	0.00	3.04	0.00
Subarea 5C	18.89	15.50	0.00	1.65	0.00	1.73	0.00
Subarea 5D-North	24.07	22.09	0.00	1.24	0.00	0.74	0.00
Subarea 5D-South	34.81	19.75	8.48	0.00	0.61	5.95	0.00
Subarea 6	42.38	30.87	4.00	4.12	0.04	3.35	0.00
Suabrea 7	8.52	4.94	2.33	0.33	0.15	0.76	0.00
Subarea 8-North	21.58	11.54	0.98	0.43	0.00	8.63	0.00
Suabrea 8-South	15.71	9.03	2.20	0.00	0.25	4.22	0.00
NBZ-Priority 1	37.35	14.13	15.12	0.00	5.07	2.61	0.41
NBZ-Priority 2	6.92	1.08	4.26	0.00	0.92	0.65	0.00
NBZ-Priority 3	1.83	0.59	0.83	0.00	0.32	0.02	0.07
Total	**265.73**	**166.97**	**38.35**	**11.64**	**7.38**	**40.92**	**0.48**

Notes:

All data is rounded to two decimals. Calculations were completed with five decimal places. A small amount of round off error may be present in data.

ERGS II - Enhanced Radiation Ground Scanner

HHGS - Hand Held Gamma Scanner

MMGS - Mule Mounted Gamma Scanner

NBZ - Northern Buffer Zone

STGS - Single Detector Track Mounted Gamma Scanner

TMGS - Dual Detector Track Mounted Gamma Scanner

Table 6.3
Detection System Selection Based on Slope Gradient

Slope Gradient	Description	Detection Systems
Predicted		
Mild	Less than 25 percent grade	ERGS II, MMGS, WMGS, and HHGS
Moderate	Greater than 25 percent and less than 40 percent grade	MMGS, potentially WMGS, and HHGS
Steep	Greater than 40 percent grade	HHGS with fall protection
Modified		
Mild	Less than 25 percent grade	ERGS II, TMGS, STGS, MMGS, WMGS, and HHGS (I and II)
Moderate	Greater than 25 percent and less than 40 percent grade	MMGS (at discretion of mule handler and operator) and HHGS
Steep	Greater than 40 percent grade	MMGS (at discretion of mule handler and operator) and HHGS

Notes:

ERGS II - Enhanced Radiation Ground Scanner II

HHGS - Hand Held Gamma Scanner

MMGS - Mule Mounted Gamma Scanner

STGS - Single Detector Track Mounted Gamma Scanner

TMGS - Duel Detector Track Mounted Gamma Scanner

WMGS - Wheel Mounted Gamma Scanner

Table 7.1
System Configuration Minimum Requirements to Run Oasis Montaj®

Parameter	Oasis Montaj Version 7.2 Minimum Requirements	Oasis Montaj Version 7.3 Minimum Recommendations	Initial Project Configuration	Final Project Configuration
Operating System	Microsoft Windows XP Service Pack 3 (32-bit)	Microsoft Windows 7 (32-bit and 64-bit)	Microsoft Windows XP Pro	Microsoft Windows 7 Professional 64 bit
CPU	Dual core processor	Dual core processor Intel Celeron processor is not recommended	Intel Xeon	Intel Xeon 5690
RAM	3 GB	4 to 8 GB	3.23 GB	6 GB
Graphics	Nvidia Professional 256MB 3D (Open GL 2.0) Graphics Card	Nvidia Professional 256MB 3D (Open GL 2.0) Graphics Card	Nvidia Quadro FX 1800 (768 MB)	ATI FirePro 2260 (256 MB)
Data Disk Space	50 GB Data disk space depends on the volume of project data to be processed and the printer driver.	500 GB to 1 TB Data disk space depends on the volume of project data to be processed and the printer driver.	One 451 GB, 7200 RPM	Three 300 GB, 10,000 RPM, RAID 5 Configuration (Total 900 GB)

Notes:
CPU - central processing unit
GB - gigabyte
MB - megabyte
RAID - redundant array of independent disks
RAM - random access memory
RPM - revolutions per minute
TB - terabyte

Table 7.2
Gradations for Count Rate Data

Data Gradations	Gradation Color
Areas not scanned	Uncolored
Less than or equal to the mean	Gray
Greater than the mean to two sigma[1] above the mean	Green
Greater than two sigma[1] to four sigma[1] above the mean	Yellow
Greater than four sigma[1] to six sigma[1] above the mean	Red
Greater than six sigma[1] above the mean	Sienna

Notes:

sigma[1] - standard deviation

Mean and standard deviation calculated from the total data population for each Subarea; in counts per second.

Table 7.3
Data Gradations for Radionuclide-Specific ROI to Spectrum Ratio Data

Data Gradations	Gradation Color
Less than six sigma[1] above the radionuclide-specific ROI to Spectrum Ratio	Uncolored
Greater than or equal to six sigma[1] above the radionuclide-specific ROI to Spectrum Ratio	Blue

Notes:

ROI - region of interest

sigma[1] - standard deviation

ROI to Spectrum Ratio calculated by dividing the total counts for a radionuclide-specific ROI by the total spectrum counts for each one second of spectral data within a subarea. All ROI to Spectrum Ratios were summed to calculate the mean and standard deviation for the specific subarea.

Table 7.4
Summary of Quality Control Verification Survey Acreage

Detection System	Surface Scanned (Acres)	Quality Control Area Required (Acres)	Quality Control Area Completed (Acres)
ERGS II	166.97	8.48	9.32
TMGS	38.35	2.03	2.44
WMGS	11.64	1	1.61
STGS	7.38	0.9	1.07
MMGS	40.92	2.16	4.01
Total	**265.25**	**14.57**	**18.45**

Notes:

ERGS II - Enhanced Radiation Ground Scanner II

TMGS - Dual Detector Track Mounted Gamma Scanner

WMGS - Wheel Mounted Gamma Scanner

STGS - Single Detector Track Mounted Gamma Scanner

MMGS - Mule Mounted Gamma Scanner

Table 9.1
Background Statistics and Potential Gamma Radiation Anomaly Investigation Levels

Subarea	Count Rate (cps)			Cs-137 ROI to Spectrum Ratio			Co-60 ROI to Spectrum Ratio		
	Mean	Standard Deviation	PGRAY IL	Mean	Standard Deviation	PGRAY IL	Mean	Standard Deviation	PGRAY IL
Lang Ranch RBRA	14,000	400	15,600	NA	NA	NA	NA	NA	NA
Subarea 3	13,000	900	16,600	0.0470	0.00400	0.0710	0.0350	0.00300	0.0530
Subarea 5A	13,300	900	16,900	0.0463	0.00313	0.0651	0.0352	0.00274	0.0516
Subarea 5B	12,700	700	15,500	0.0461	0.00278	0.0628	0.0349	0.00250	0.0499
Subarea 5C	12,700	700	15,500	0.0465	0.00399	0.0705	0.0354	0.00382	0.0583
Subarea 5D-North	12,400	600	14,800	0.0457	0.00250	0.0607	0.0340	0.00220	0.0472
Subarea 5D-South	12,000	1500	18,000	0.0464	0.00309	0.0649	0.0334	0.00265	0.0493
Subarea 6	13,000	900	16,600	0.0470	0.00400	0.0710	0.0350	0.00300	0.0530
Subarea 7	13,600	800	16,800	0.0464	0.00383	0.0694	0.0339	0.00320	0.0531
Subarea 8-South	12,000	1500	18,000	0.0464	0.00309	0.0649	0.0334	0.00265	0.0493
Subarea 8-North	12,000	900	15,600	0.0457	0.00334	0.0657	0.0346	0.00307	0.0530
NBZ-Northeast	14,000	1500	20,000	0.0470	0.00400	0.0710	0.0350	0.00300	0.0530
NBZ-Northwest	13,000	1000	17,000	0.0464	0.00383	0.0694	0.0339	0.00320	0.0531

Notes:

Co - Cobalt

cps - counts per second

Cs - Cesium

IL - Investigation Level

NA - not applicable

NBZ - Northern Buffer Zone

PGRAY - potential gamma radiation anomaly

RBRA - radiological background reference area

ROI - region of interest

Table 9.2
Detection System Background Values

Detection System	Lange Ranch RBRA Count Rate (cps)		Bridle Path RBRA Count Rate (cps)	
	Mean	Standard Deviation	Mean	Standard Deviation
Enhanced Radiation Ground Scanner II	14,141	399	16,006	1,080
Dual Detector Track Mounted Gamma Scanner	N/C	N/C	N/C	N/C
Wheel Mounted Gamma Scanner	14,363	487	17,398	861
Single Detector Track Mounted Gamma Scanner	N/C	N/C	N/C	N/C
Mule Mounted Gamma Scanner	14,748	421	17,470	1,244
Hand Held Gamma Scanner	N/C	N/C	N/C	N/C
In Situ Gamma Spectrometer	N/C	N/C	N/C	N/C

Notes:

cps - counts per second

N/C - not collected

RBRA - radiological background reference area

Table 9.3
Summary of Potential Gamma Radiation Anomalies

Subarea	Number of PGRAYs	Number of Confirmed GRAYs	Number of Not a GRAYs
Subarea 3	2	0	2
Subarea 5A	24	0	24
Subarea 5B	6	0	6
Subarea 5C	6	0	6
Subarea 5D-North	6	0	6
Subarea 5D-South	12	0	12
Subarea 6	60	30	30
Subarea 7	42	38	4
Subarea 8-South	0	0	0
Subarea 8-North	32	1	31
NBZ-Northeast	1	0	1
NBZ-Northwest	26	1	25
Total	**217**	**70**	**147**

Notes:

NBZ - Northern Buffer Zone

GRAY - Gamma Radiation Anomaly

PGRAY - Potential GRAY

Table 9.4
Classification of Potential Gamma Radiation Anomalies

PGRAY Number	Classification	Reason	Figure Designation
Subarea 3 PGRAYs (Section 9.3.2 and Figure 9.5)			
3-1	Not a GRAY	NORM	Not Applicable
3-2	Not a GRAY	NORM	Not Applicable
Subarea 5A PGRAYs (Section 9.3.3 and Figure 9.6)			
5A-1	Not a GRAY	NORM	Group A
5A-2	Not a GRAY	NORM	Group A
5A-3	Not a GRAY	NORM	Group B
5A-4	Not a GRAY	NORM	Group B
5A-5	Not a GRAY	NORM	Group B
5A-6	Not a GRAY	NORM	Group B
5A-7	Not a GRAY	NORM	Group B
5A-8	Not a GRAY	NORM	Group B
5A-9	Not a GRAY	NORM	Group B
5A-10	Not a GRAY	NORM	Group B
5A-11	Not a GRAY	NORM	Group B
5A-12	Not a GRAY	NORM	Group B
5A-13	Not a GRAY	NORM	Group B
5A-14	Not a GRAY	NORM	Group B
5A-15	Not a GRAY	NORM	Group B
5A-16	Not a GRAY	NORM	Group B
5A-17	Not a GRAY	NORM	Group B
5A-18	Not a GRAY	NORM	Group B
5A-19	Not a GRAY	NORM	Group B
5A-20	Not a GRAY	NORM	Group B
5A-21	Not a GRAY	NORM	Group C
5A-22	Not a GRAY	NORM	Group C
5A-23	Not a GRAY	NORM	Group C
5A-24	Not a GRAY	NORM	Group C
Subarea 5B PGRAYs (Section 9.3.4 and Figure 9.7)			
5B-1	Not a GRAY	NORM	Not Applicable
5B-2	Not a GRAY	NORM	Not Applicable
5B-3	Not a GRAY	NORM	Not Applicable
5B-4	Not a GRAY	NORM	Not Applicable
5B-5	Not a GRAY	NORM	Not Applicable
5B-6	Not a GRAY	NORM	Not Applicable

Table 9.4
Classification of Potential Gamma Radiation Anomalies

PGRAY Number	Classification	Reason	Figure Designation
Subarea 5C PGRAYs (Section 9.3.5 and Figure 9.8)			
5C-1	Not a GRAY	NORM	Not Applicable
5C-2	Not a GRAY	NORM	Not Applicable
5C-3	Not a GRAY	NORM	Not Applicable
5C-4	Not a GRAY	NORM	Not Applicable
5C-5	Not a GRAY	NORM	Not Applicable
5C-6	Not a GRAY	NORM	Not Applicable
Subarea 5D-North PGRAYs (Section 9.3.6 and Figure 9.9)			
5DN-1	Not a GRAY	NORM	Not Applicable
5DN-2	Not a GRAY	NORM	Not Applicable
5DN-3	Not a GRAY	NORM	Not Applicable
5DN-4	Not a GRAY	NORM	Not Applicable
5DN-5	Not a GRAY	NORM	Not Applicable
5DN-6	Not a GRAY	NORM	Not Applicable
Subarea 5D-South PGRAYs (Section 9.3.7 and Figure 9.10)			
5DS-1	Not a GRAY	NORM	Not Applicable
5DS-2	Not a GRAY	NORM	Not Applicable
5DS-3	Not a GRAY	NORM	Not Applicable
5DS-4	Not a GRAY	NORM	Not Applicable
5DS-5	Not a GRAY	NORM	Not Applicable
5DS-6	Not a GRAY	NORM	Not Applicable
5DS-7	Not a GRAY	NORM	Not Applicable
5DS-8	Not a GRAY	NORM	Not Applicable
5DS-9	Not a GRAY	NORM	Not Applicable
5DS-10	Not a GRAY	NORM	Not Applicable
5DS-11	Not a GRAY	NORM	Not Applicable
5DS-12	Not a GRAY	NORM	Not Applicable
Subarea 6 PGRAYs (Section 9.3.8 and Figure 9.5)			
6-1	Confirmed GRAY	Cs-137	Group A
6-2	Confirmed GRAY	Cs-137	Group A
6-3	Confirmed GRAY	Cs-137	Group A
6-4	Confirmed GRAY	Cs-137	Group A
6-5	Confirmed GRAY	Cs-137	Group A
6-6	Not a GRAY	NORM	Group A
6-7	Confirmed GRAY	Cs-137	Group A
6-8	Confirmed GRAY	Cs-137	Group A

Table 9.4
Classification of Potential Gamma Radiation Anomalies

PGRAY Number	Classification	Reason	Figure Designation
Subarea 6 PGRAYs (Section 9.3.8 and Figure 9.5) (Continued)			
6-9	Confirmed GRAY	Cs-137	Group A
6-10	Not a GRAY	NORM	Group A
6-11	Not a GRAY	NORM	Group A
6-12	Confirmed GRAY	Cs-137	Group B
6-13	Not a GRAY	NORM	Group B
6-14	Confirmed GRAY	Cs-137	Group B
6-15	Not a GRAY	NORM	Group B
6-16	Not a GRAY	NORM	Group B
6-17	Not a GRAY	NORM	Group B
6-18	Not a GRAY	NORM	Group A
6-19	Confirmed GRAY	Cs-137	Group A
6-20	Not a GRAY	NORM	Group B
6-21	Confirmed GRAY	Cs-137	Group D
6-22	Not a GRAY	NORM	Group D
6-23	Not a GRAY	NORM	Group C
6-24	Not a GRAY	NORM	Group C
6-25	Not a GRAY	NORM	Group D
6-26	Confirmed GRAY	Cs-137	Group C
6-27	Not a GRAY	NORM	Group C
6-28	Confirmed GRAY	Cs-137	Group C
6-29	Confirmed GRAY	Cs-137	Group C
6-30	Not a GRAY	NORM	Group D
6-31	Not a GRAY	NORM	Group C
6-32	Not a GRAY	NORM	Group C
6-33	Not a GRAY	NORM	Group D
6-34	Not a GRAY	NORM	Group C
6-35	Not a GRAY	NORM	Group C
6-36	Confirmed GRAY	Cs-137	Group D
6-37	Confirmed GRAY	Cs-137	Group D
6-38	Confirmed GRAY	Cs-137	Group D
6-39	Not a GRAY	NORM	Group D
6-40	Confirmed GRAY	Cs-137	Group D
6-41	Not a GRAY	NORM	Group G
6-42	Not a GRAY	NORM	Group G
6-43	Confirmed GRAY	Cs-137	Group F
6-44	Not a GRAY	NORM	Group F
6-45	Confirmed GRAY	Cs-137	Group E

Table 9.4
Classification of Potential Gamma Radiation Anomalies

PGRAY Number	Classification	Reason	Figure Designation
Subarea 6 PGRAYs (Section 9.3.8 and Figure 9.5) (Continued)			
6-46	Confirmed GRAY	Cs-137	Group E
6-47	Confirmed GRAY	Cs-137	Group F
6-48	Confirmed GRAY	Cs-137	Group F
6-49	Confirmed GRAY	Cs-137	Group F
6-50	Not a GRAY	NORM	Group F
6-51	Not a GRAY	NORM	Group F
6-52	Confirmed GRAY	Cs-137	Group F
6-53	Confirmed GRAY	Cs-137	Group G
6-54	Not a GRAY	NORM	Group G
6-55	Not a GRAY	NORM	Group E
6-56	Confirmed GRAY	Cs-137	Group F
6-57	Not a GRAY	NORM	Group E
6-58	Confirmed GRAY	Cs-137	Group F
6-59	Not a GRAY	NORM	Group F
6-60	Confirmed GRAY	Cs-137	Group C
Subarea 7 PGRAYs (Section 9.3.9 and Figure 9.11)			
7-1	Not a GRAY	NORM	Group A
7-2	Confirmed GRAY	Cs-137	Group B
7-3	Confirmed GRAY	Cs-137	Group B
7-4	Confirmed GRAY	Cs-137	Group B
7-5	Confirmed GRAY	Cs-137	Group B
7-6	Confirmed GRAY	Cs-137	Group B
7-7	Confirmed GRAY	Cs-137	Group C
7-8	Confirmed GRAY	Cs-137	Group C
7-9	Confirmed GRAY	Cs-137	Group C
7-10	Confirmed GRAY	Cs-137	Group C
7-11	Confirmed GRAY	Cs-137	Group C
7-12	Confirmed GRAY	Cs-137	Group C
7-13	Confirmed GRAY	Cs-137	Group C
7-14	Confirmed GRAY	Cs-137	Group C
7-15	Confirmed GRAY	Cs-137	Group C
7-16	Confirmed GRAY	Cs-137	Group C
7-17	Confirmed GRAY	Cs-137, Co-60	Group C
7-18	Confirmed GRAY	Cs-137	Group C
7-19	Confirmed GRAY	Cs-137	Group C
7-20	Confirmed GRAY	Cs-137	Group C

Table 9.4
Classification of Potential Gamma Radiation Anomalies

PGRAY Number	Classification	Reason	Figure Designation
Subarea 7 PGRAYs (Section 9.3.9 and Figure 9.11) (Continued)			
7-21	Confirmed GRAY	Cs-137, Co-60	Group C
7-22	Confirmed GRAY	Cs-137	Group C
7-23	Confirmed GRAY	Cs-137	Group D
7-24	Confirmed GRAY	Cs-137	Group D
7-25	Confirmed GRAY	Cs-137	Group D
7-26	Confirmed GRAY	Cs-137	Group D
7-27	Confirmed GRAY	Cs-137	Group D
7-28	Not a GRAY	NORM	Group D
7-29	Confirmed GRAY	Cs-137	Group D
7-30	Confirmed GRAY	Cs-137	Group D
7-31	Confirmed GRAY	Cs-137	Group D
7-32	Confirmed GRAY	Cs-137	Group D
7-33	Confirmed GRAY	Cs-137	Group D
7-34	Confirmed GRAY	Cs-137	Group D
7-35	Confirmed GRAY	Cs-137	Group D
7-36	Confirmed GRAY	Cs-137	Group D
7-37	Confirmed GRAY	Cs-137	Group E
7-38	Confirmed GRAY	Cs-137	Group D
7-39	Confirmed GRAY	Cs-137	Group D
7-40	Not a GRAY	NORM	Group E
7-41	Confirmed GRAY	Cs-137	Group E
7-42	Not a GRAY	NORM	Group B
Subarea 8-North PGRAYs (Section 9.3.10 and Figure 9.12)			
8N-1	Not a GRAY	NORM	Group A
8N-2	Not a GRAY	NORM	Group A
8N-3	Not a GRAY	NORM	Group A
8N-4	Not a GRAY	NORM	Group A
8N-5	Not a GRAY	NORM	Group A
8N-6	Not a GRAY	NORM	Group A
8N-7	Not a GRAY	NORM	Group A
8N-8	Not a GRAY	NORM	Group A
8N-9	Not a GRAY	NORM	Group A
8N-10	Not a GRAY	NORM	Group B
8N-11	Confirmed GRAY	Cs-137	Group B
8N-12	Not a GRAY	NORM	Group B
8N-13	Not a GRAY	NORM	Group B

Table 9.4
Classification of Potential Gamma Radiation Anomalies

PGRAY Number	Classification	Reason	Figure Designation
Subarea 8-North PGRAYs (Section 9.3.10 and Figure 9.12) (Continued)			
8N-14	Not a GRAY	NORM	Group B
8N-15	Not a GRAY	NORM	Group B
8N-16	Not a GRAY	NORM	Group B
8N-17	Not a GRAY	NORM	Group B
8N-18	Not a GRAY	NORM	Group B
8N-19	Not a GRAY	NORM	Group C
8N-20	Not a GRAY	NORM	Group C
8N-21	Not a GRAY	NORM	Group C
8N-22	Not a GRAY	NORM	Group C
8N-23	Not a GRAY	NORM	Group C
8N-24	Not a GRAY	NORM	Group C
8N-25	Not a GRAY	NORM	Group C
8N-26	Not a GRAY	NORM	Group C
8N-27	Not a GRAY	NORM	Group C
8N-28	Not a GRAY	NORM	Group C
8N-29	Not a GRAY	NORM	Group C
8N-30	Not a GRAY	NORM	Group C
8N-31	Not a GRAY	NORM	Group C
8N-32	Not a GRAY	NORM	Group C
Subarea 8-South PGRAYs (Section 9.3.11 and Figure 9.10)			
No PGRAYs Detected			
NBZ-Northeast PGRAYs (Section 9.3.12 and Figure 9.13)			
P1D-1	Not a GRAY	NORM	Not Applicable
NBZ-Northwest PGRAYs (Section 9.3.13 and Figure 9.14)			
P1A-1	Not a GRAY	NORM	Not Applicable
P1A-2	Not a GRAY	NORM	Not Applicable
P1A-3	Not a GRAY	NORM	Not Applicable
P1A-4	Not a GRAY	NORM	Not Applicable
P1A-5	Not a GRAY	NORM	Not Applicable
P1B-1	Not a GRAY	NORM	Not Applicable
P1B-2	Not a GRAY	NORM	Not Applicable
P1C-1	Not a GRAY	NORM	Not Applicable
P1C-2	Not a GRAY	NORM	Not Applicable
P1C-3	Not a GRAY	NORM	Not Applicable
P1C-4	Not a GRAY	NORM	Not Applicable
P1C-5	Not a GRAY	NORM	Not Applicable

Table 9.4
Classification of Potential Gamma Radiation Anomalies

PGRAY Number	Classification	Reason	Figure Designation
NBZ-Northwest PGRAYs (Section 9.3.13 and Figure 9.14) (Continued)			
P1C-6	Not a GRAY	NORM	Not Applicable
P1C-7	Not a GRAY	NORM	Not Applicable
P1C-8	Not a GRAY	NORM	Not Applicable
P1C-9	Not a GRAY	NORM	Not Applicable
P1C-10	Not a GRAY	NORM	Not Applicable
P1C-11	Not a GRAY	NORM	Not Applicable
P1C-12	Not a GRAY	NORM	Not Applicable
P1C-13	Not a GRAY	NORM	Not Applicable
P1C-14	Not a GRAY	NORM	Not Applicable
P1C-15	Not a GRAY	NORM	Not Applicable
P1C-16	Not a GRAY	NORM	Not Applicable
P1C-17	Confirmed GRAY	Cs-137	Not Applicable
P1C-18	Not a GRAY	NORM	Not Applicable
P1I-1	Not a GRAY	NORM	Not Applicable

Notes:

Co - cobalt

Cs - cesium

GRAY - gamma radiation anomaly

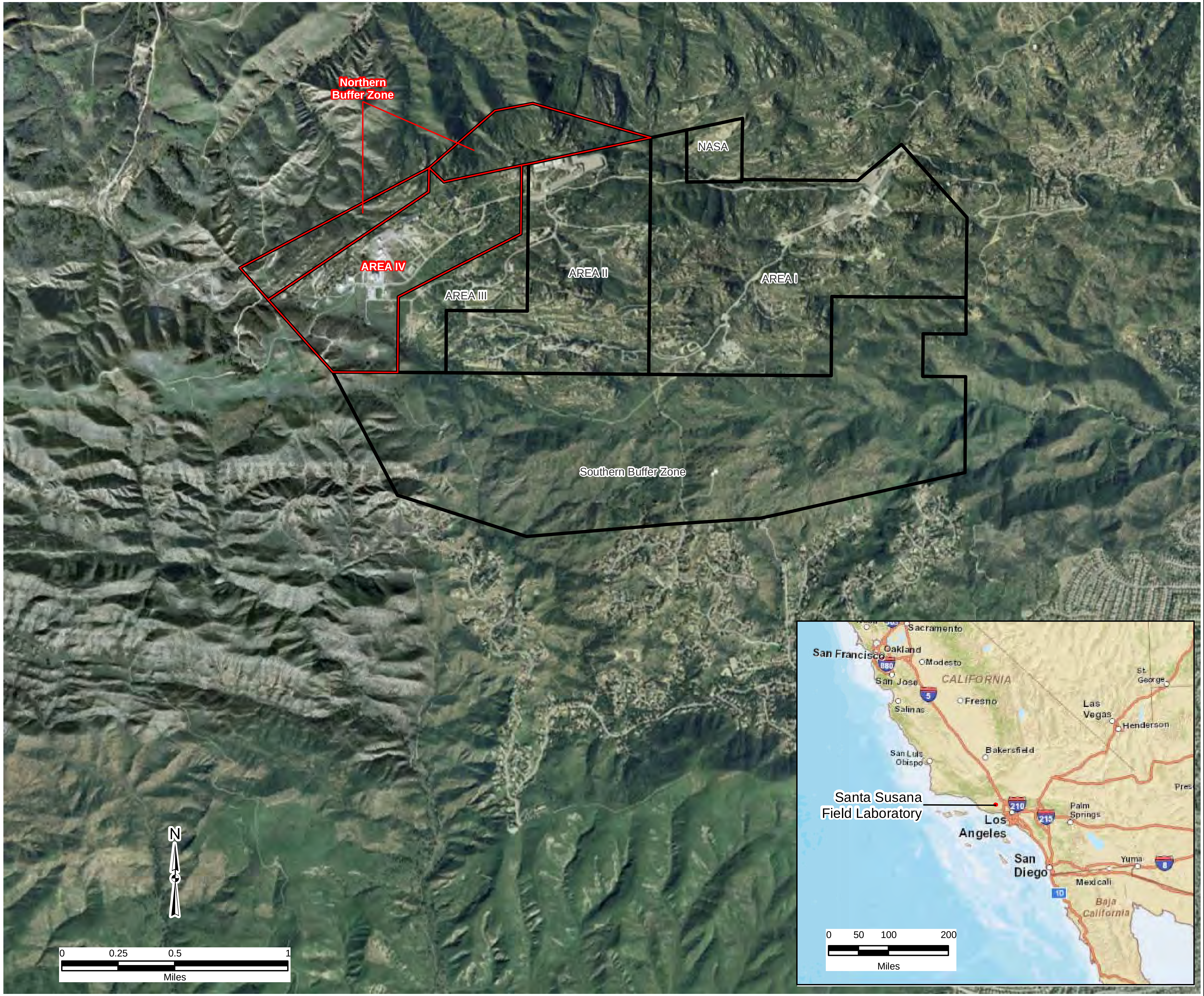
NORM - naturally occurring radioactive material

PGRAY - potential gamma radiation anomaly

FIGURES

Figure 1.1
Site Location Map
Santa Susana Field Laboratory

U.S. EPA Region 9



Legend

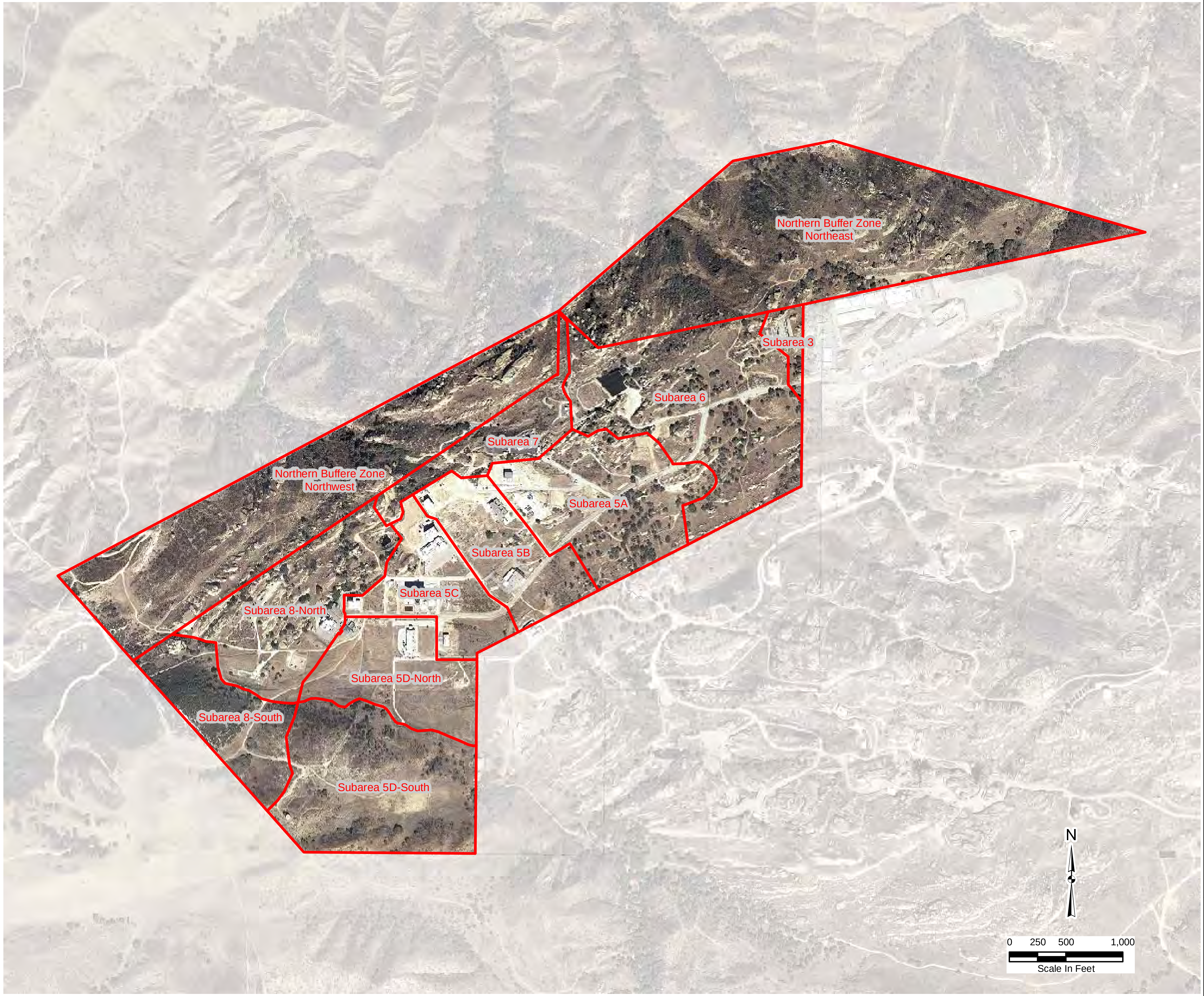
Area IV Study Area Boundary
Property Boundary

Y:\Santa_Susana\EP9038\GammaScanning\Report\(1-1)_SiteMap.mxd
3/24/2012 pbillock
Source: CaSil, NAIP 2009; Boeing 2008

HGL HydroGeoLogic, Inc

Figure 2.1
Area IV Study Area Subareas
Santa Susana Field Laboratory

U.S. EPA Region 9



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Area IV Study Area Subareas

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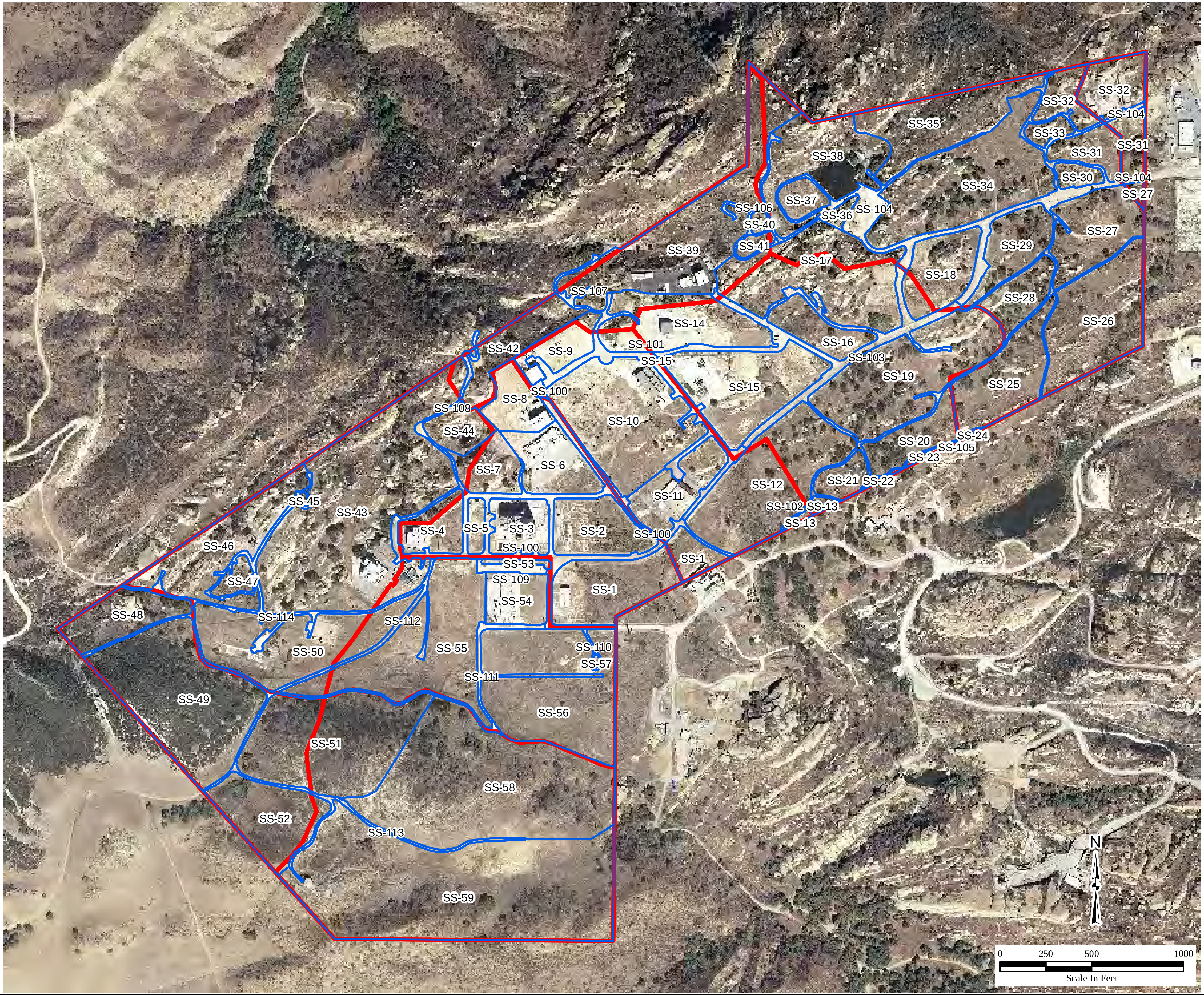
(2-1)_AreaIV_Subareas.mxd
3/24/2012 pbillock
Source: CIRGIS 2007; Boeing 2009

Figure 2.2
Area IV Survey Sections
Santa Susana Field Laboratory

U.S. EPA Region 9



Legend

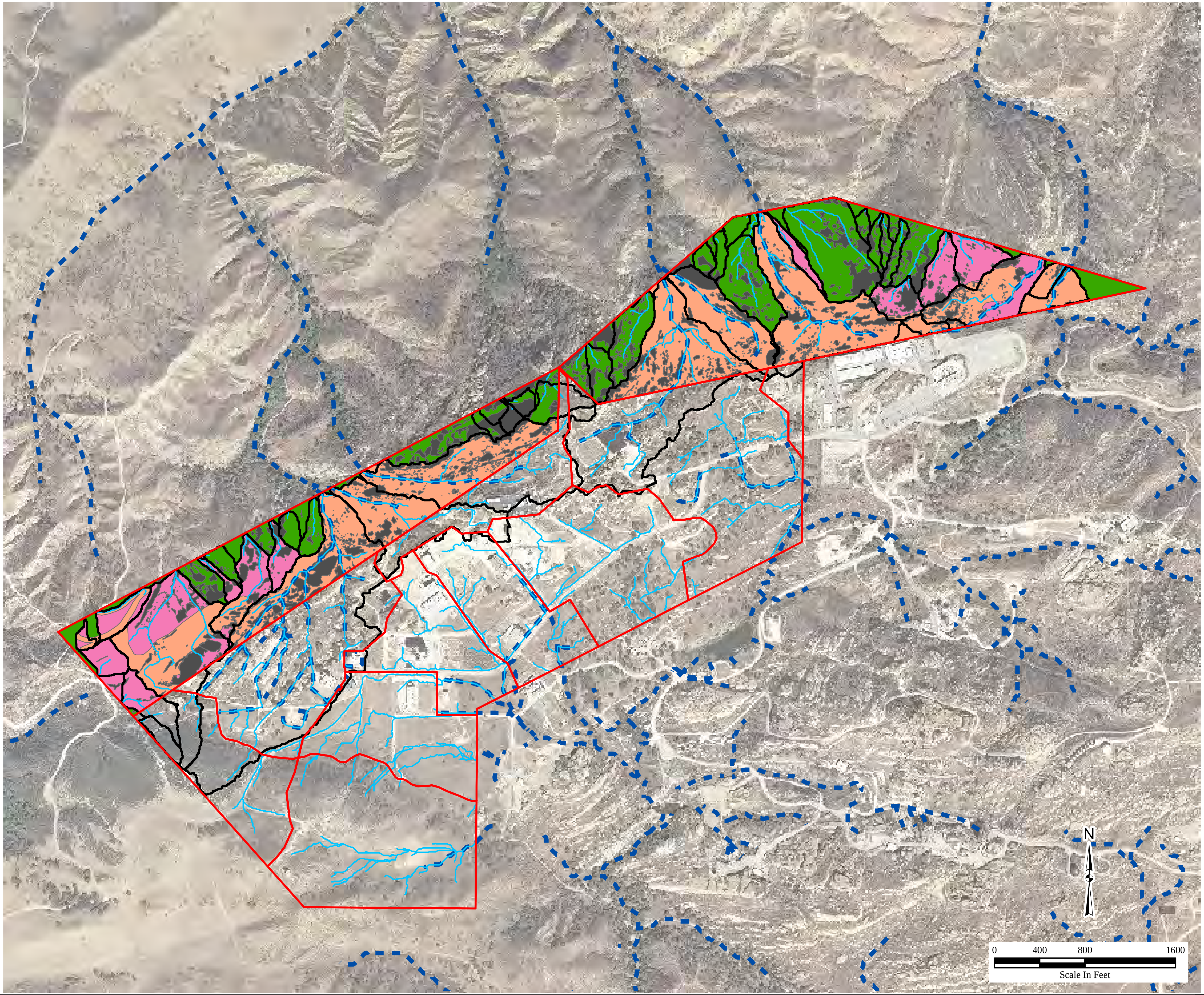
- Survey Sections
- Area IV Subareas

Notes:
SS-## Survey section for areas
SS-### Survey section for roadways

\\Gst-srv-01\Gmap\Santa_Susana\EP9038\GammaScanning\Report\
(2-2)_AreaIV_SurveySections.mxd
6/22/2012 plit
Source: CIRGIS 2007; Boeing 2009; HGL 2010

Figure 2.3
Northern Buffer Zone Priority Areas
Santa Susana Field Laboratory

U.S. EPA Region 9



Legend

Priority Areas

- Priority 1
- Priority 2
- Priority 3
- Watershed Boundary
- Rock Outcrops
- Drainage Pathway
- Intermittent Stream
- Area IV Study Area Subareas

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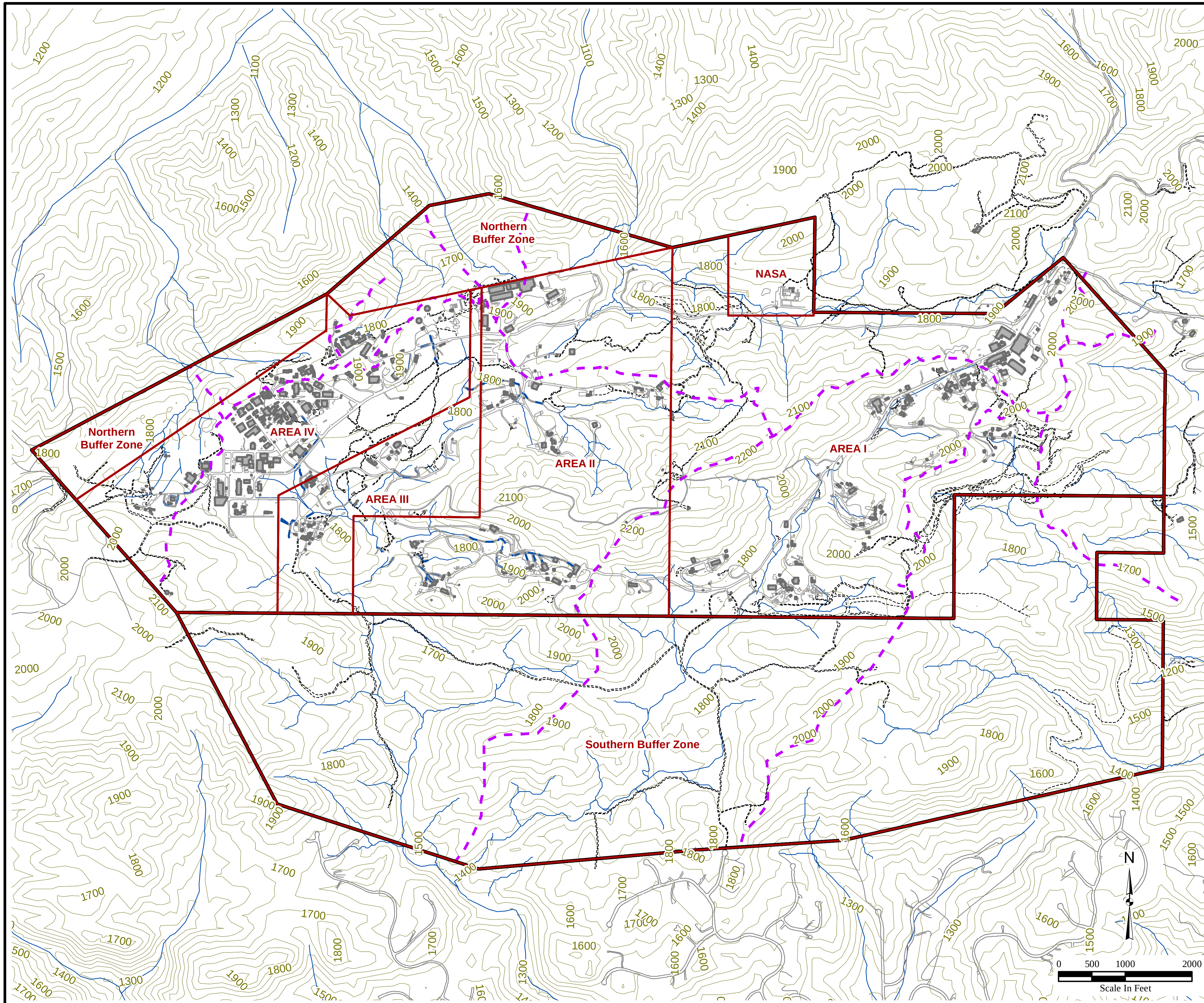
(2-3)_Northern_BufferZone_PriAreas.mxd
6/22/2012 plit
Source:HGL 2010, CIRGIS 2007

Figure 2.4
Topographic Map
Santa Susana Field Laboratory

U.S. EPA Region 9



Legend

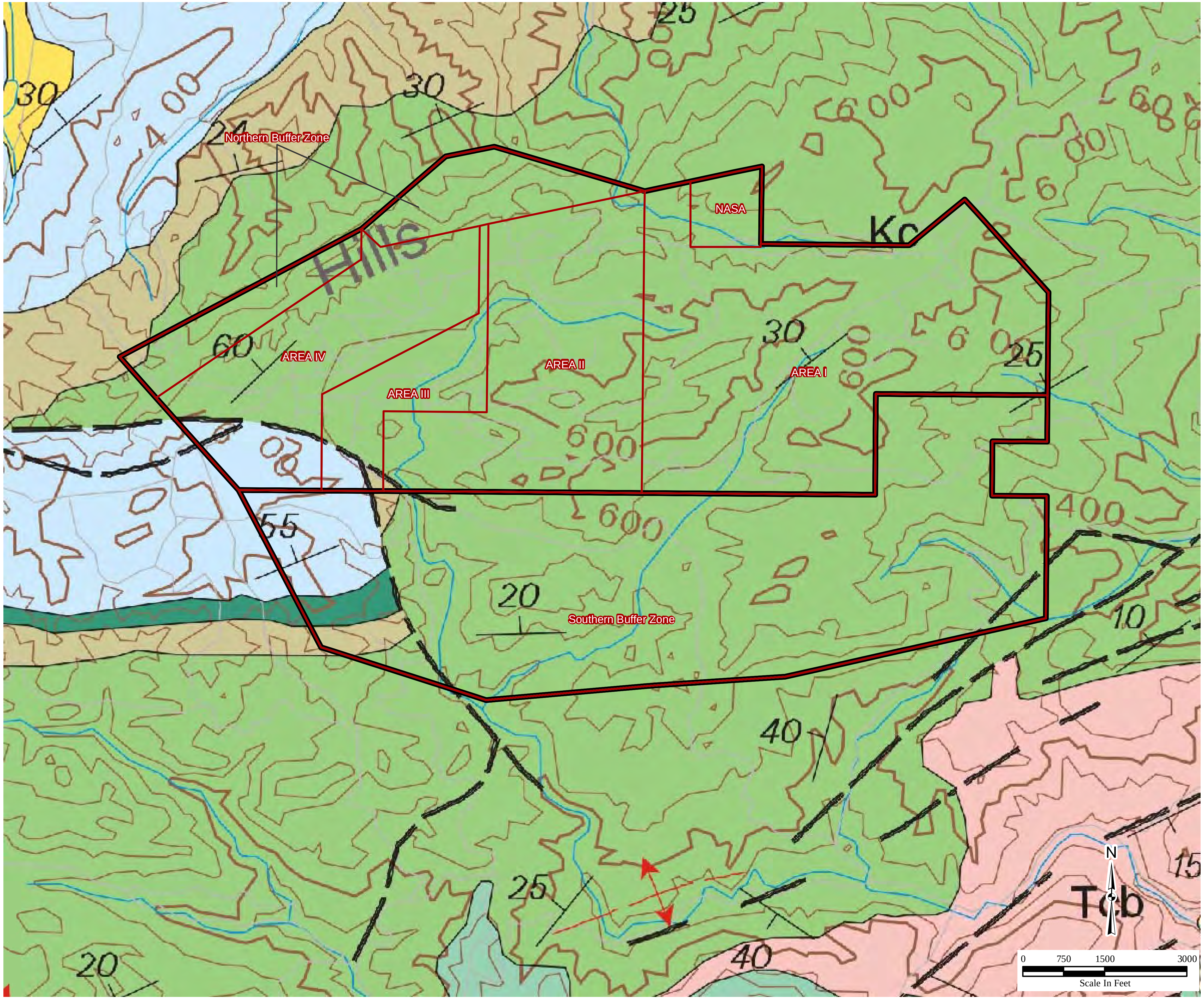
- Property Boundary
- Administrative Boundaries
- Drainage Divide
- Buildings
- Lined Channel
- Unlined Channel
- 50 ft Contours

Y:\Santa_Susana\EP9038\GammaScanning\Report\(2-4)_TopographicMap.mxd
3/24/2012 pbillock
Source: CDM Inc. (2008). Draft Gap Analysis Report, Submitted on June 1, 2008. Prepared for the U.S. Department of Energy

HGL HydroGeoLogic, Inc

Figure 2.5
Geologic Map
Santa Susana Field Laboratory

U.S. EPA Region 9



Legend

Property Boundary

Administrative Boundaries

Geologic Formation

Kc	Chatsworth Formation (late Cretaceous)
Tss	Santa Susana Formation (early Eocene to late Paleocene)
Tlv	Las Virgenes Formation (Paleocene)
Tsi	Simi Conglomerate, Undivided (Paleocene)
Tcb	Calabasas Formation, Undivided (early late Miocene and late middle Miocene)
Tm	Modelo Formation Undivided (late Miocene)
Qof	Old alluvial-fan deposits, Undivided (late to middle Pleistocene)

Y:\Santa_Susana\EP9038\GammaScanning\Report\(2-5)_GeologicMap.mxd
3/23/2012 pbillock
Source: Preliminary Geologic Map of the Los Angeles 30´ x 60´ Quadrangle, Southern California; Yerkes and Campbell; 2005
Coordinate System: NAD83 CA State Plane V

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\
(3-1)_Figure_ERGSII_DetectionSystem.mxd
6/26/2012 plit
Source: HGL 2011

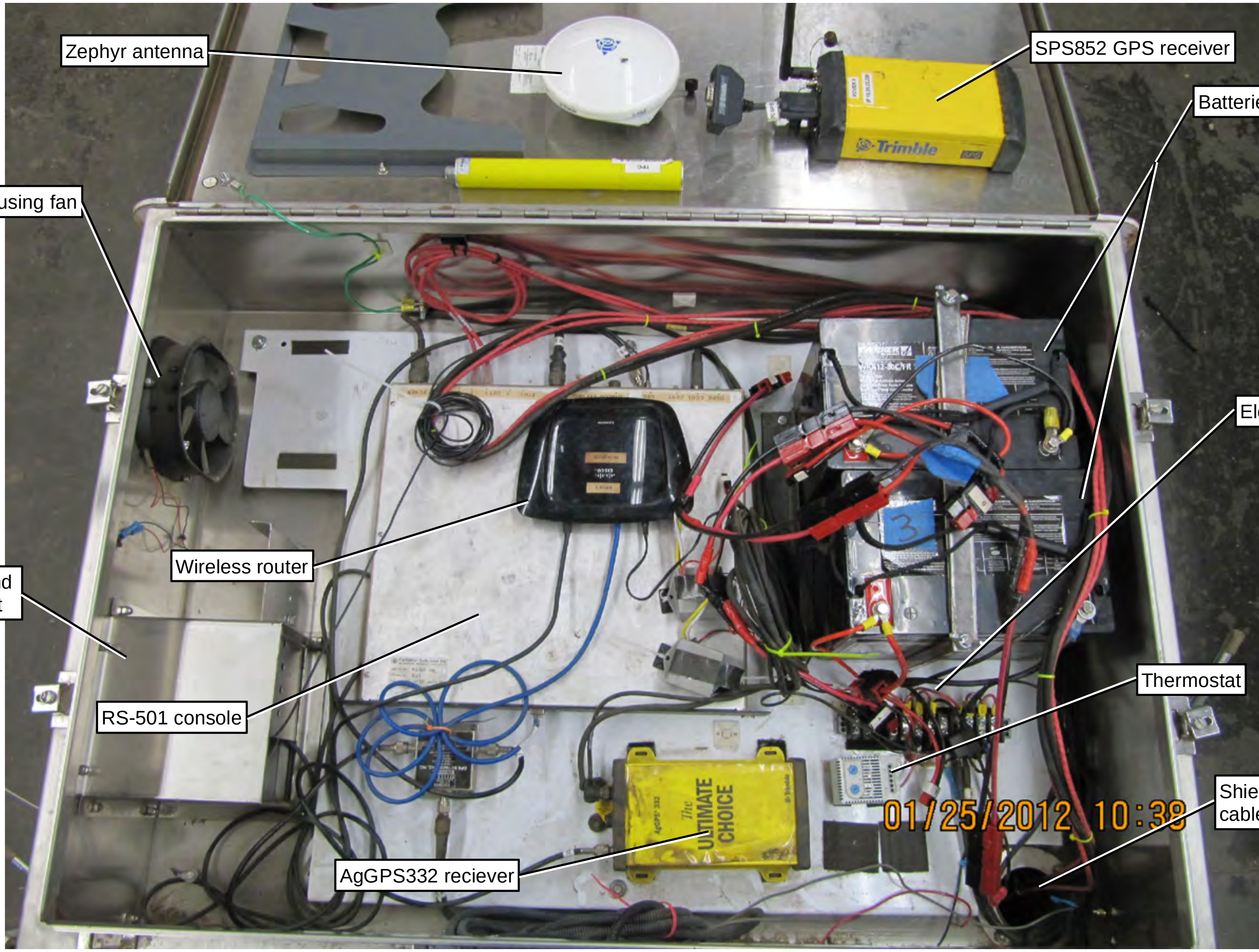
Figure 3.1

Enhanced Radiation Ground Scanner II
Detection System

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-2)_Figure_ Radiation Solutions Inc.RSX_4Detector.mxd
3/25/2012 pbillock
Source: HGL 2011

Figure 3.2

Radiation Solutions Inc. RSX-4 Detector



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6/26/2012 plit
Source: HGL 2011

Figure 3.3

Enhanced Radiation Ground Scanner II Components of Electronics Housing

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(3-4)_Figure_ERGSII_FoamMakers.mxd
6/28/2012 plit
Source: HGL 2011

Figure 3.4

Enhanced Radiation Ground Scanner II
Foam Markers

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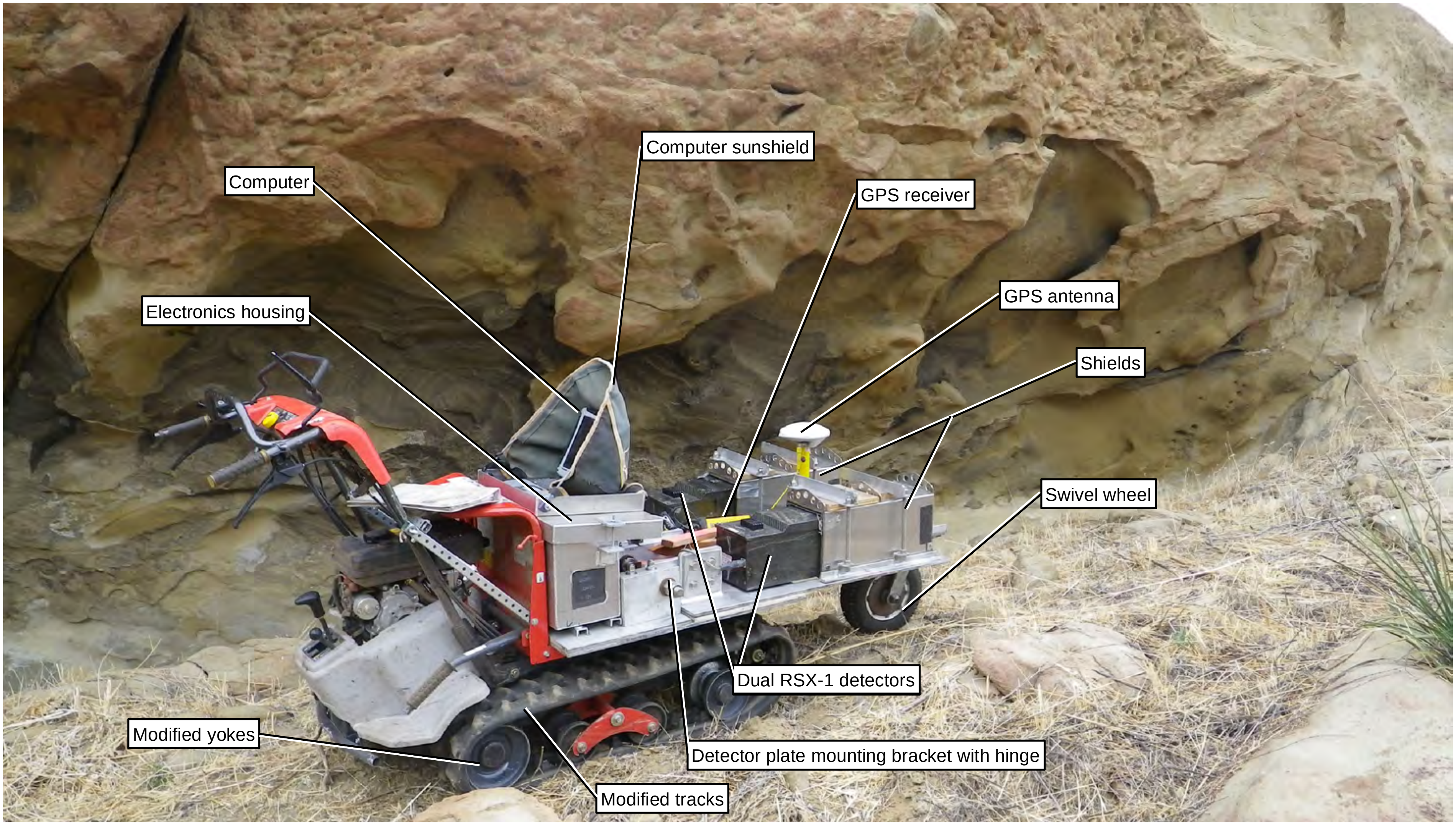
6/28/2012 plit
Source: HGL 2011

Figure 3.5

Enhanced Radiation Ground Scanner II Operating with Guide Chains



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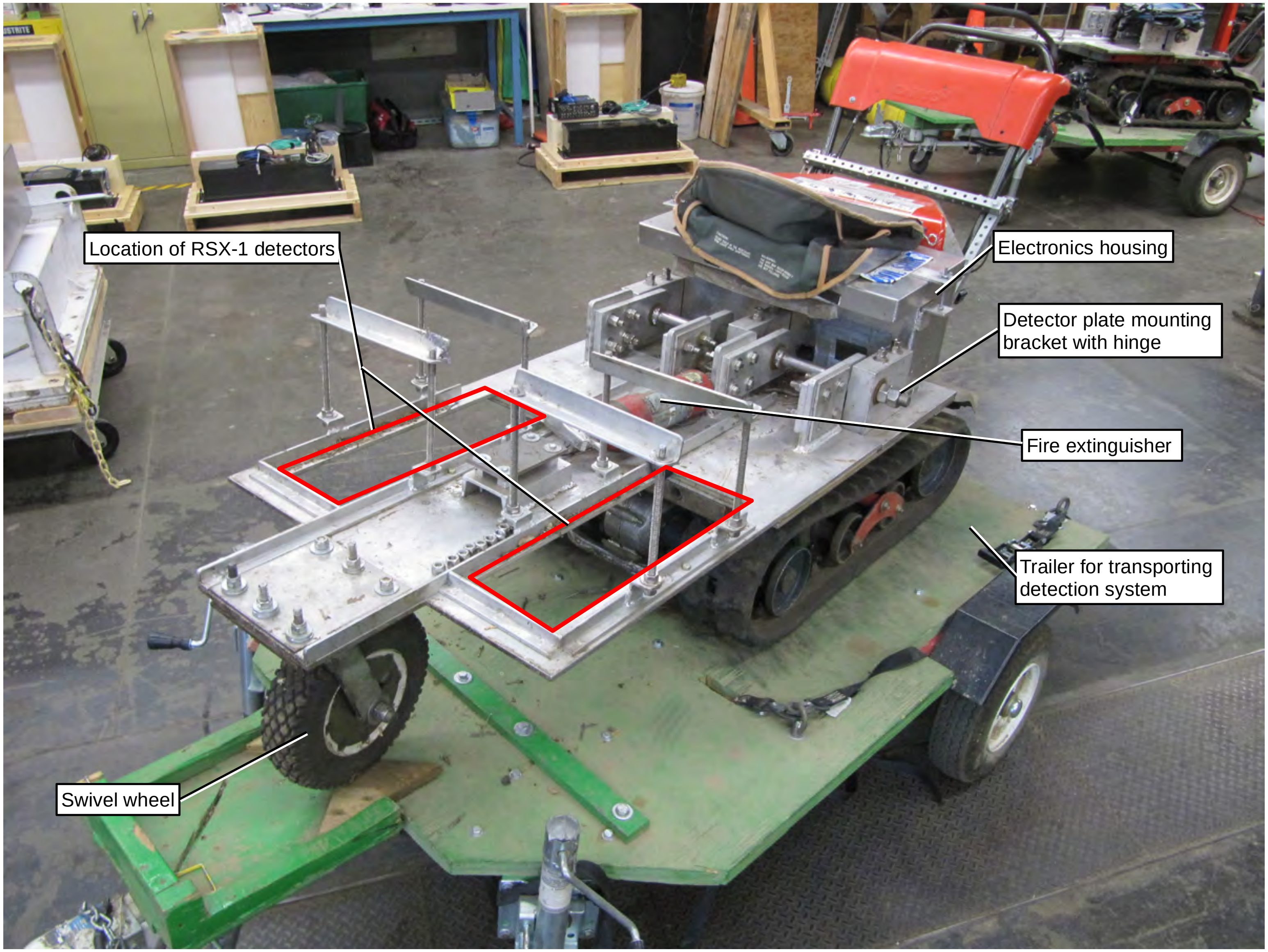
6/28/2012 plit
Source: HGL 2011

Figure 3.6

Dual Detector Track Mounted Gamma Scanner Detection System



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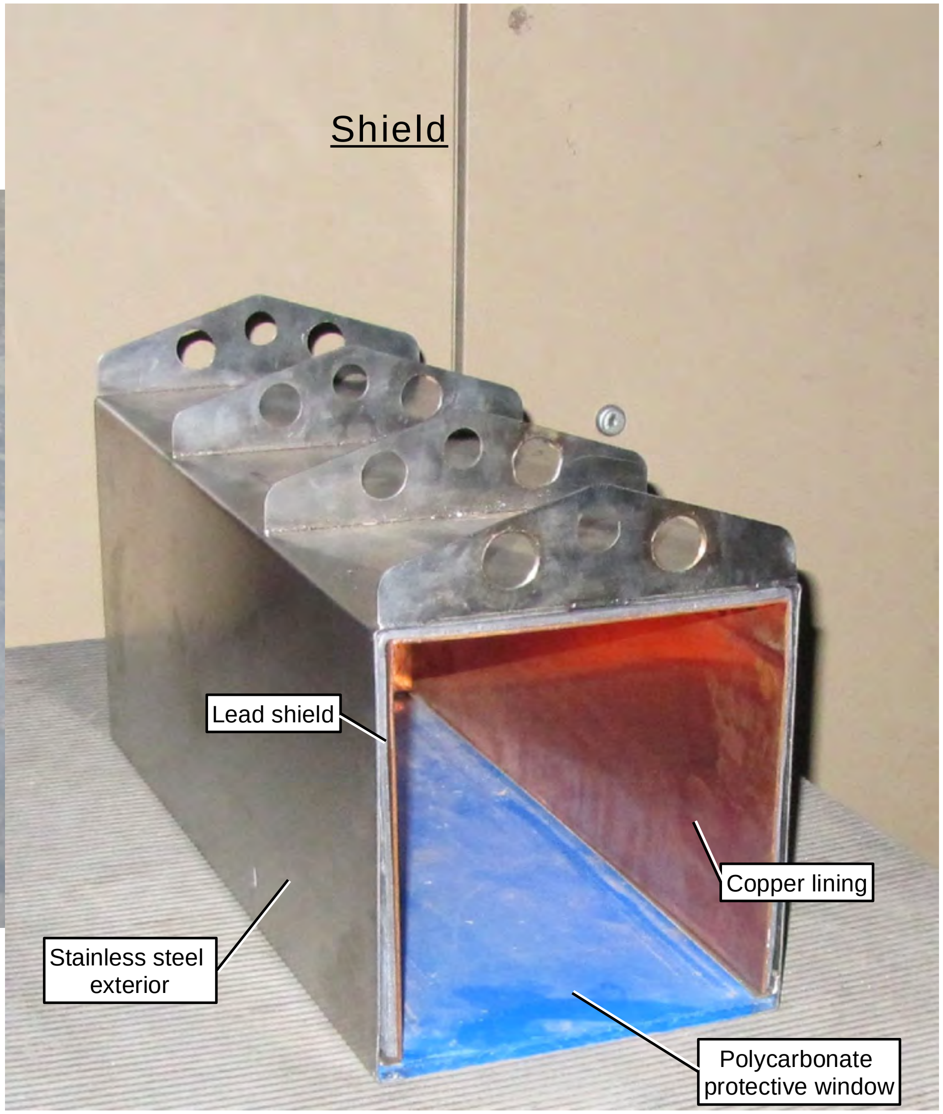
6/26/2012 plit
Source: HGL 2011

Figure 3.7

Dual Detector Track Mounted Gamma Scanner Transportation Mechanism

RSX-1 Detector

Shield



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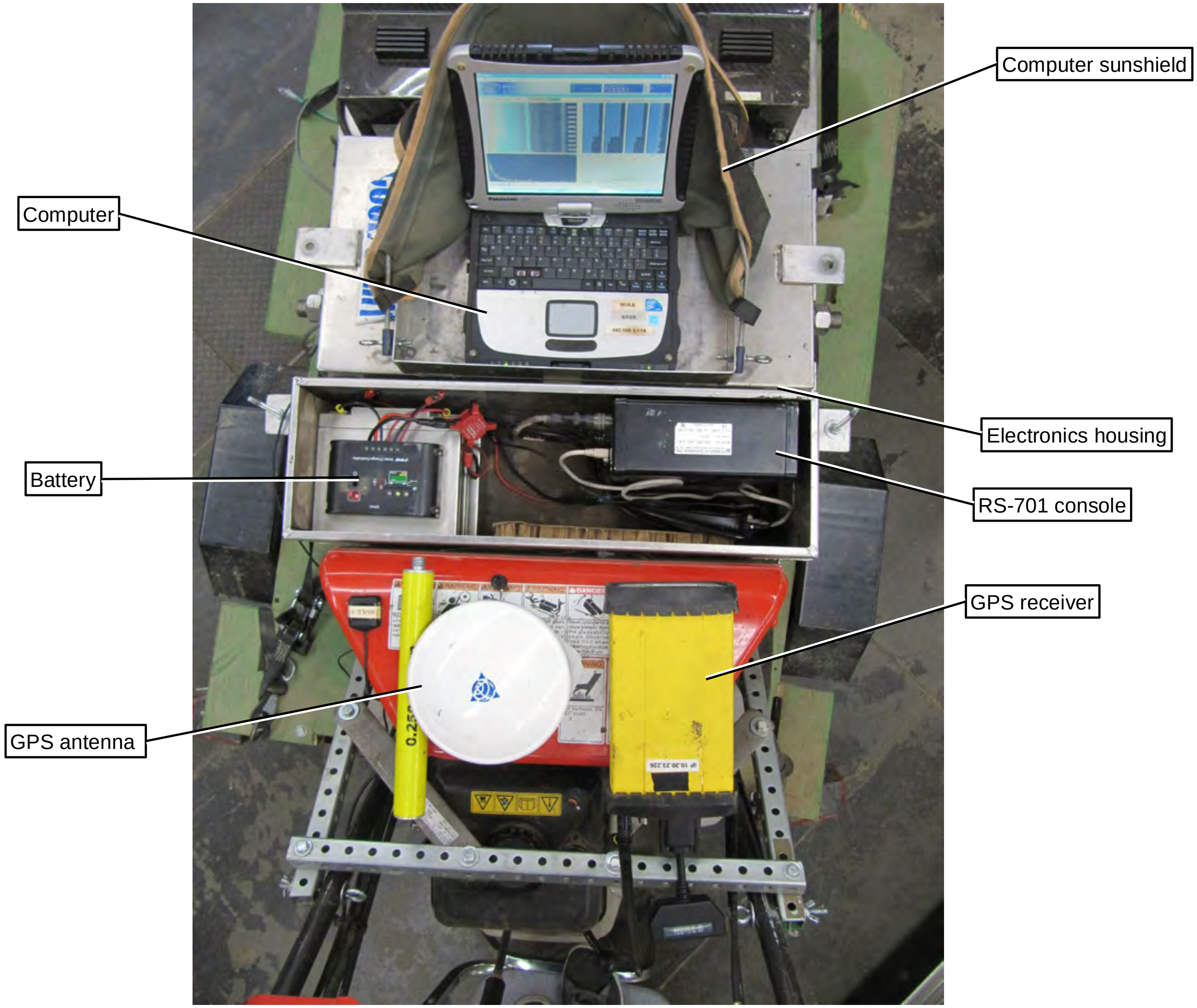
(3-8)_Figure_Radiation_SolutionsRSX_1Detector.mxd
6/26/2012 plit
Source: HGL 2011

Figure 3.8

Radiation Solutions Inc. RSX-1 Detector and Shield



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\
(3-9)_Figure_TMGS_Electronic_Container.mxd
6/26/2012 plit
Source: HGL 2011

Figure 3.9

Dual Detector Track Mounted Gamma Scanner Electronic Components

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\
(3-10)_WMGS_DetectionSystem.mxd
6/26/2012 plit
Source: HGL 2011

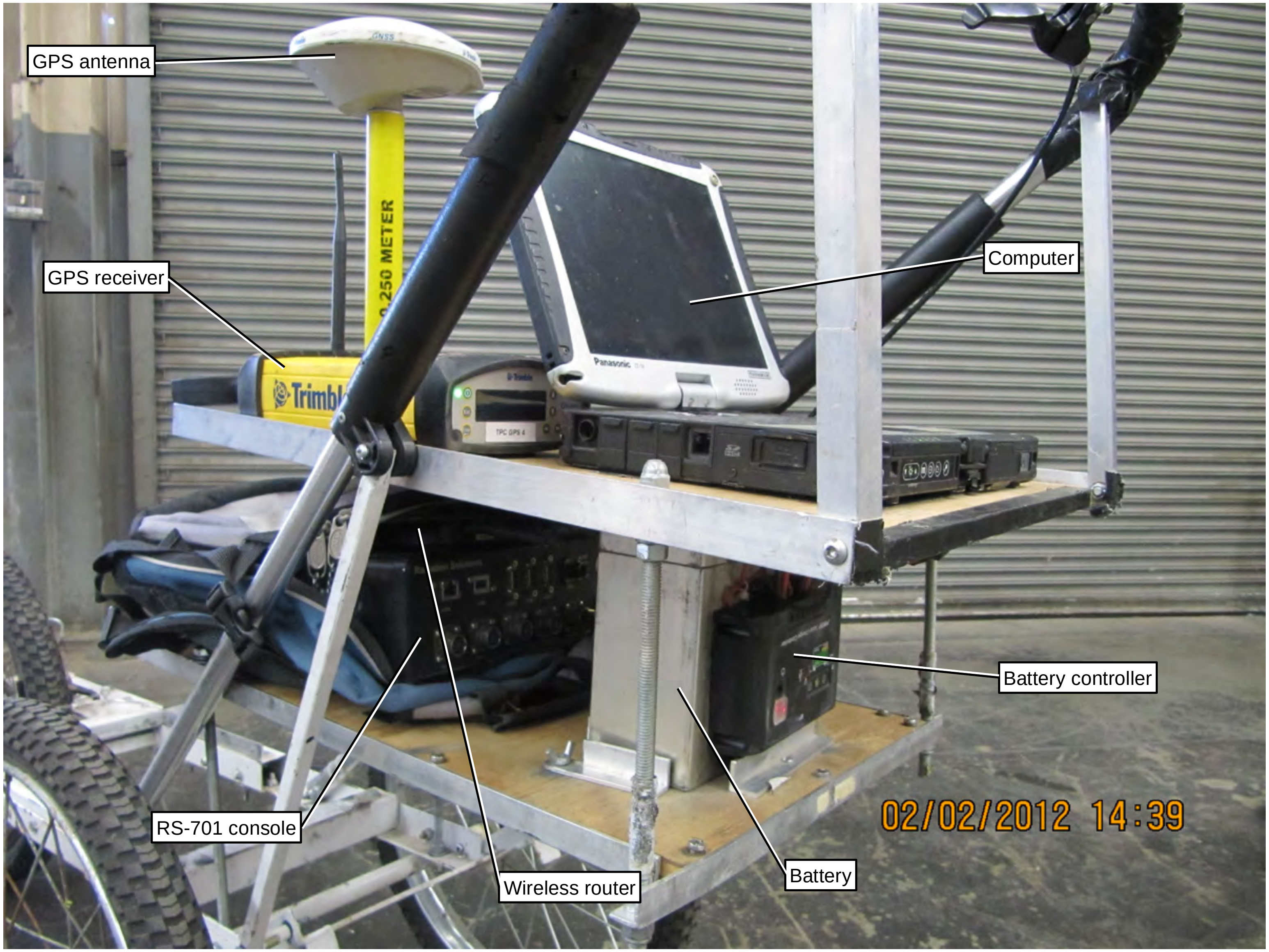
Figure 3.10

Wheel Mounted Gamma Scanner Detection System

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-11)_WMGS_Customized_DetectorTransportation.mxd
3/25/2012 pbillock
Source: HGL 2012

Figure 3.11

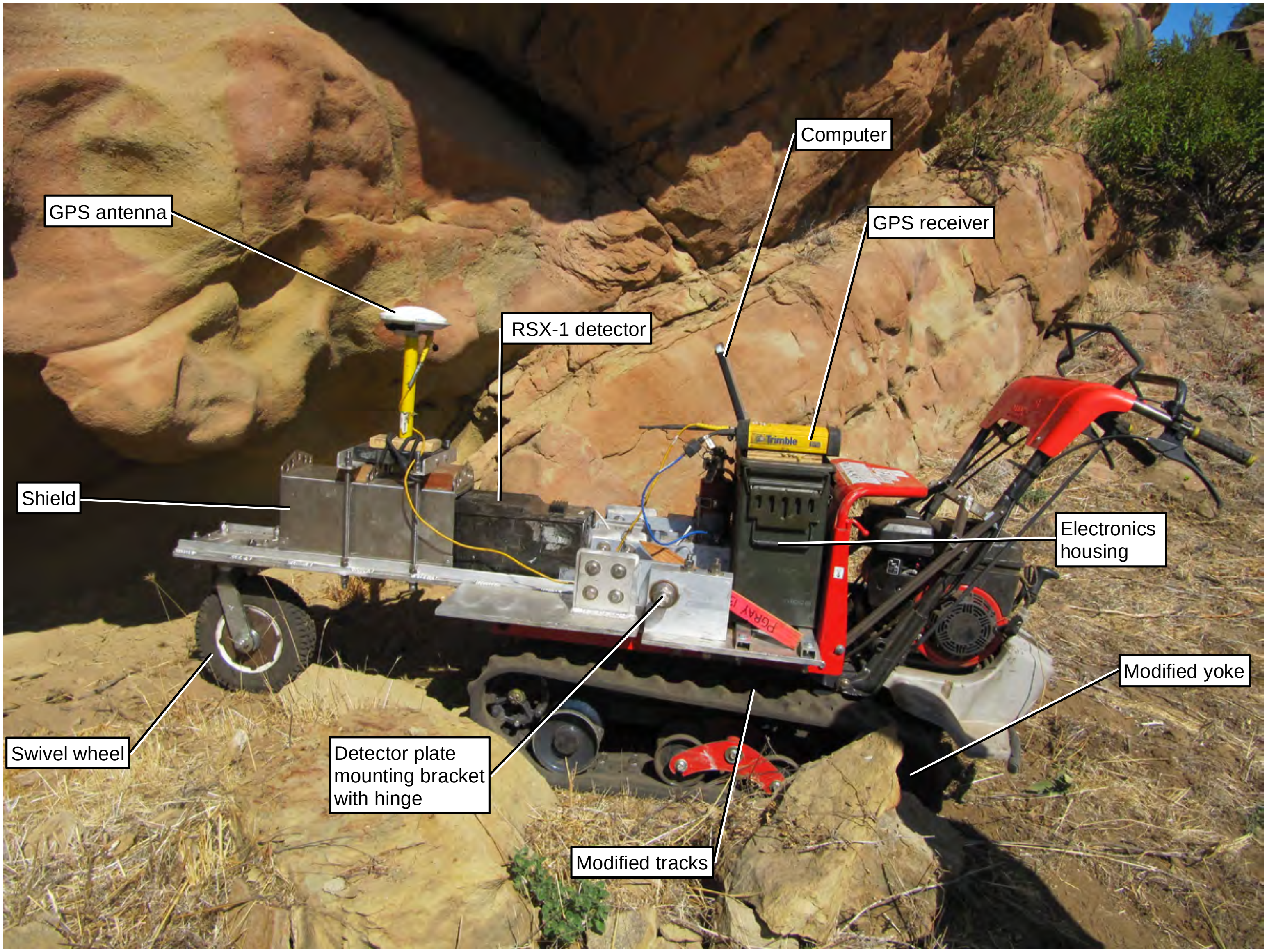
Wheel Mounted Gamma Scanner Transportation Mechanism



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-12)_STGSElectronicComponents.mxd
6/26/2012 plit
Source: HGL 2011

Figure 3.12

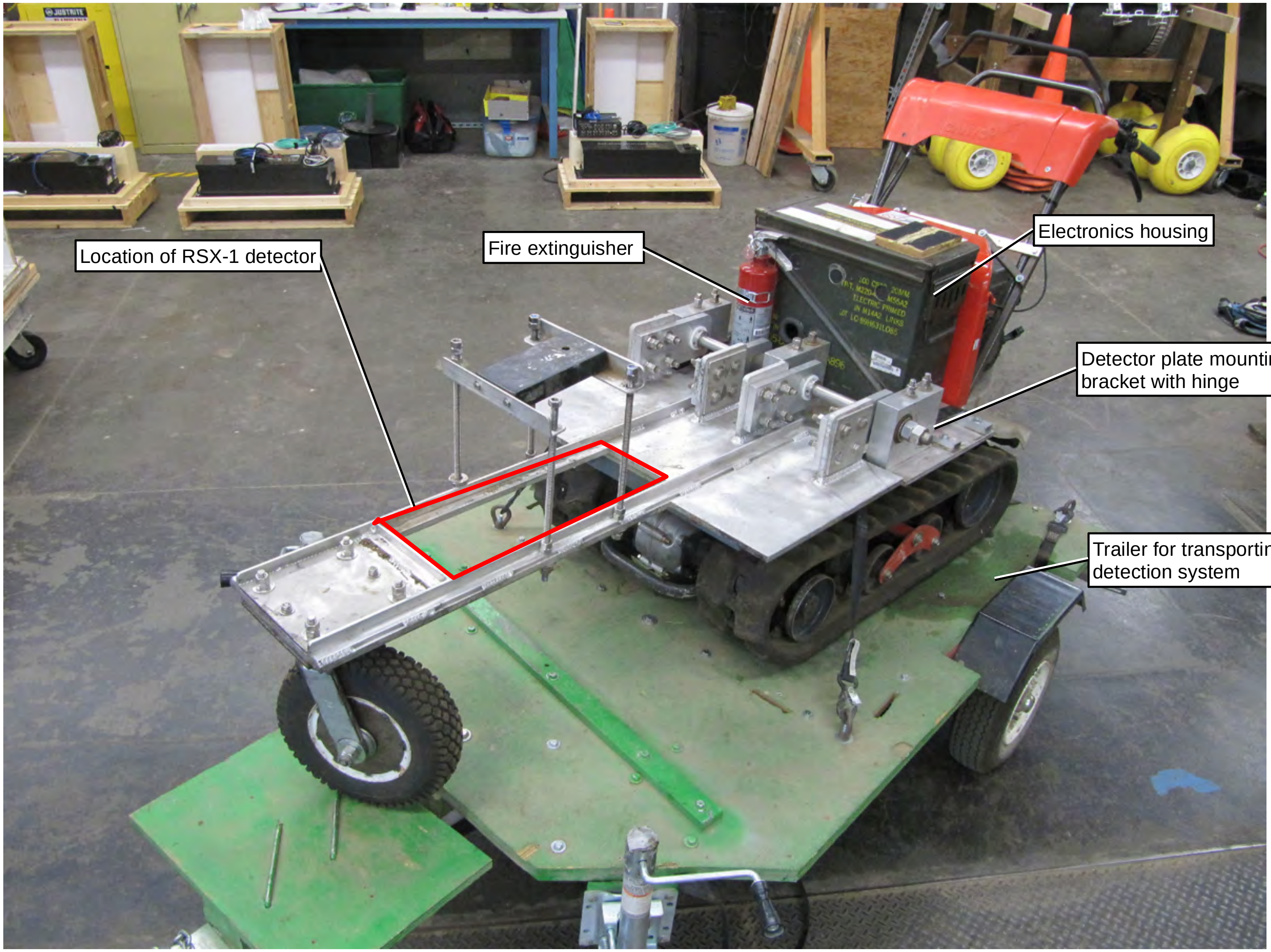
Wheel Mounted Gamma Scanner Electronic Components



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-13)_STGSDetectionSystem.mxd
6/26/2012 plit
Source: HGL 2011

Figure 3.13

Single Detector Track Mounted Gamma Scanner Detection System



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-14)_STGS_Detector Transportation.mxd
6/26/2012 plit
Source: HGL 2011

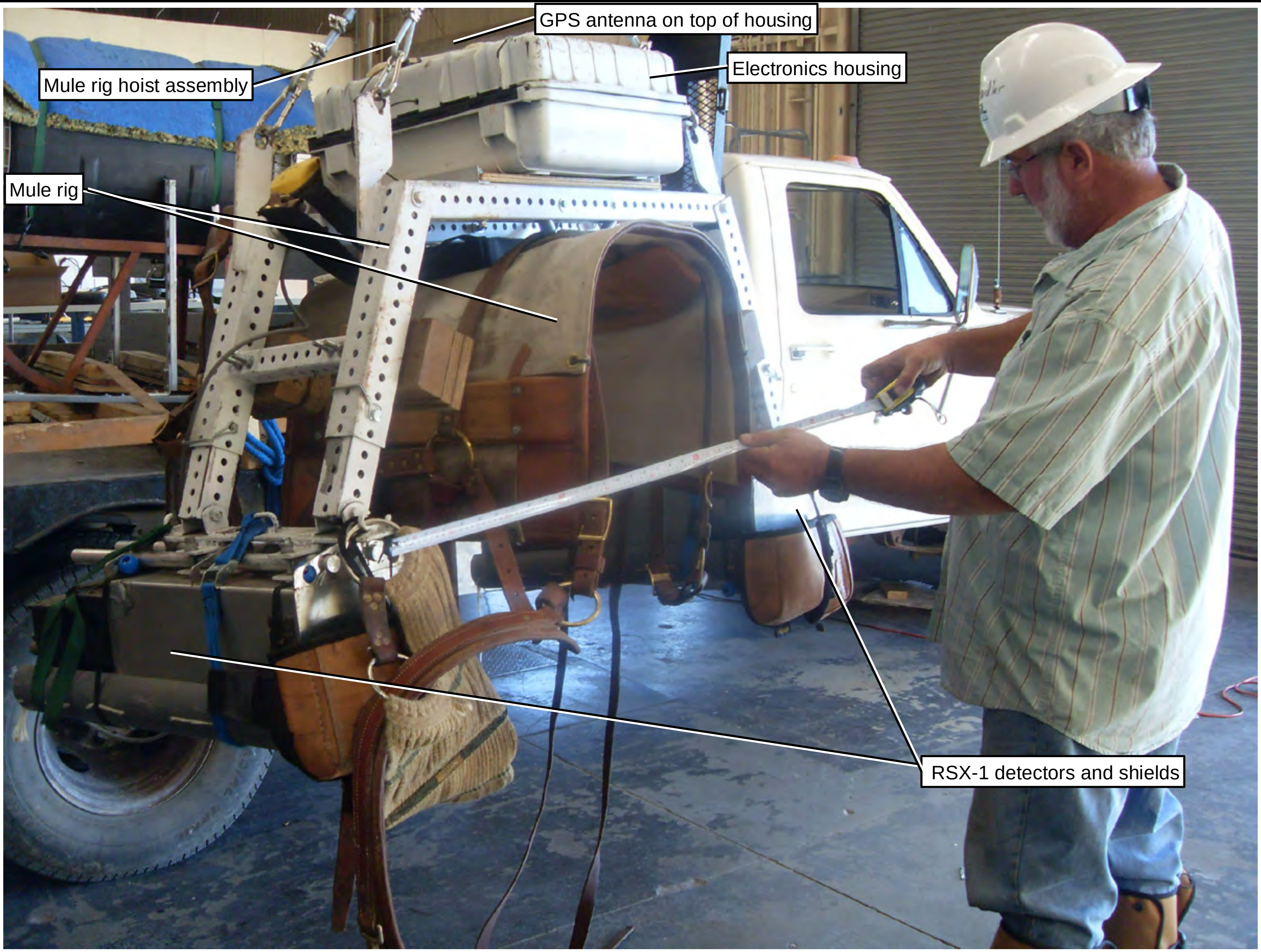
Figure 3.14

Single Detector Track Mounted Gamma Scanner Transportation Mechanism

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\
(3-15)_MMGSDetectionSystem.mxd
6/26/2012 plit
Source: HGL 2011

Figure 3.15

Mule Mounted Gamma Scanner Detection System



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-16)_AssembledMMGSRig.mxd
6/26/2012 plit
Source: HGL 2011

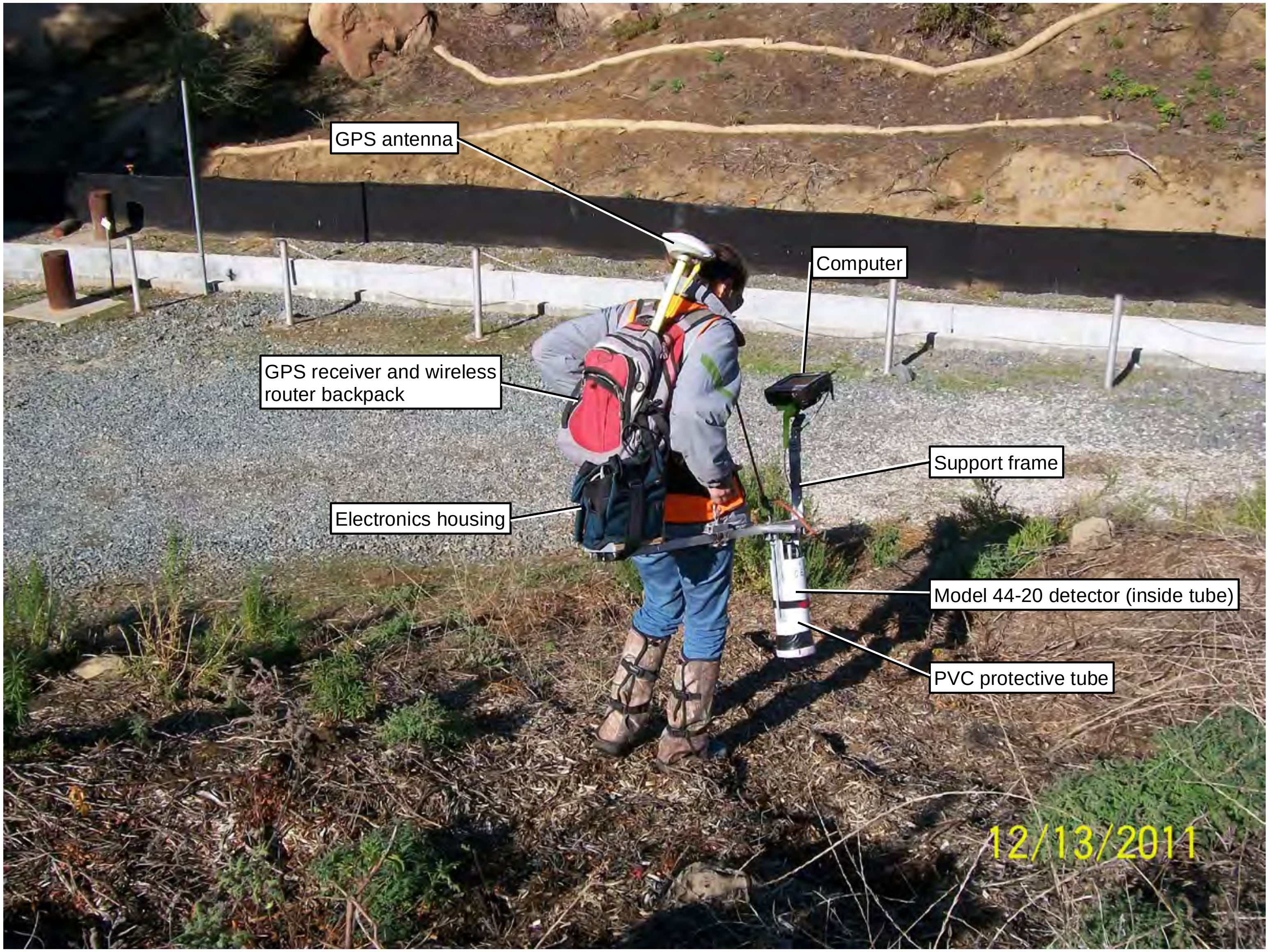
Figure 3.16

Mule Mounted Gamma Scanner Detector Mule Rig

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-17)_MMGS_ComponentsofElectronics.mxd
10/1/2012 pbillock
Source: HGL 2011

Figure 3.17

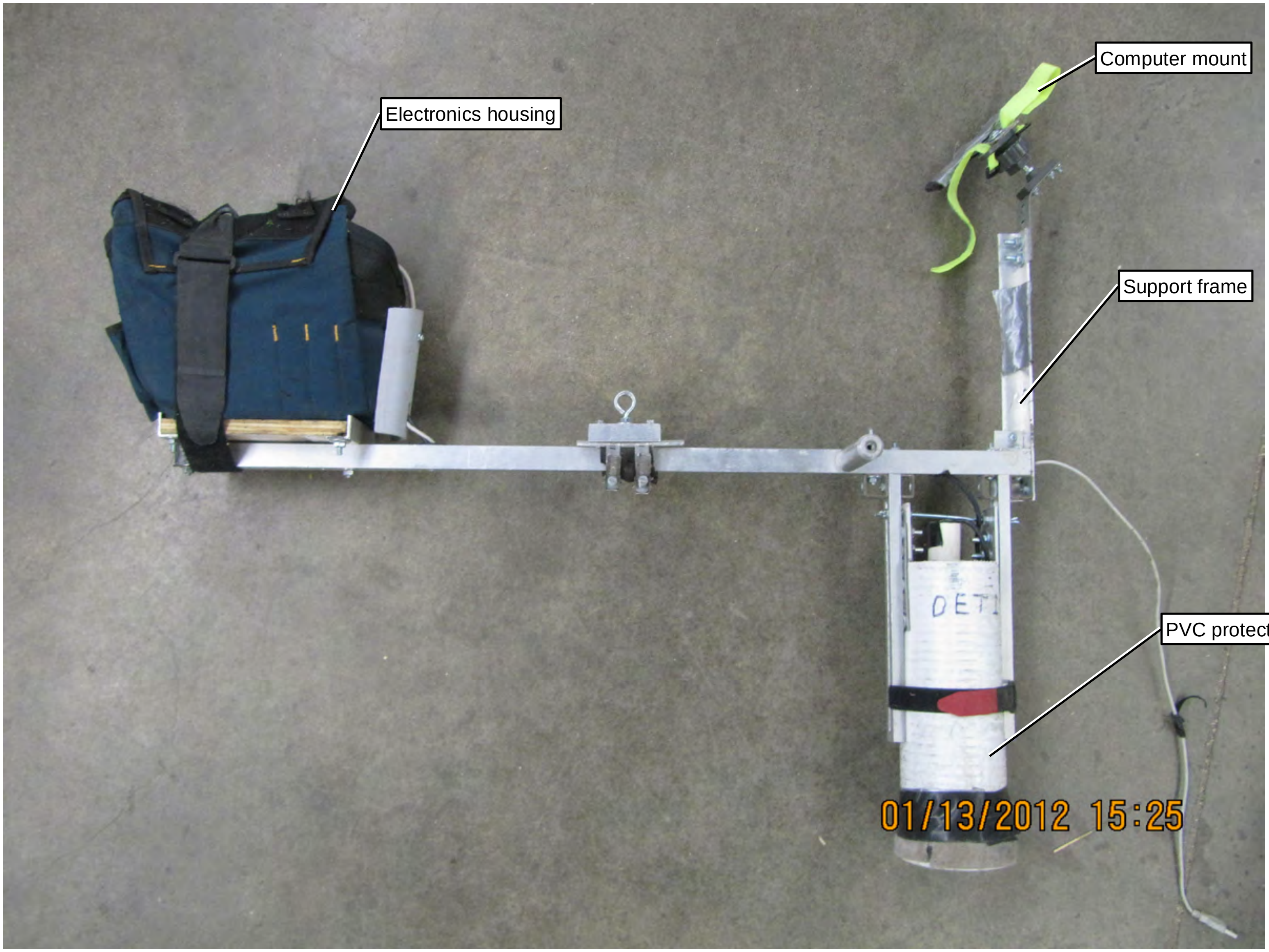
Mule Mounted Gamma Scanner Components of Electronics Housing



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-18)_HHGS_I_DetectionSystem.mxd
6/26/2012 plit
Source: HGL 2011

Figure 3.18

Hand Held Gamma Scanner I Detection System



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-19)_HHGS_DetectorRig.mxd
6/26/2012 plit
Source: HGL 2011

Figure 3.19

Hand Held Gamma Scanner I Detector Rig

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-20)_HHGSElectronicContainer.mxd
6/26/2012 plit
Source: HGL 2011

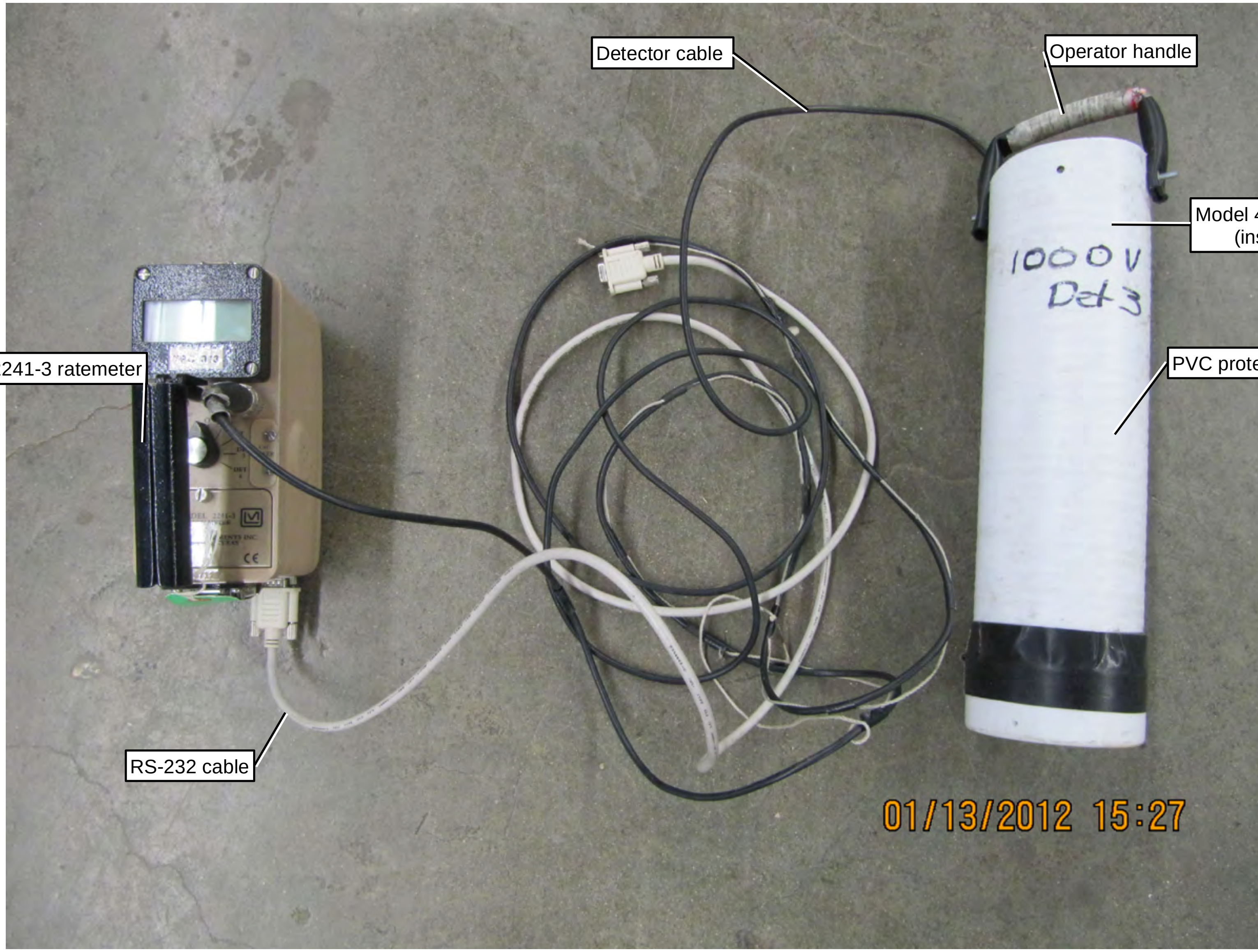
Figure 3.20

Hand Held Gamma Scanner I and II
Components of Electronics Housing and Backpack

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-21)_HHGSII_DetectorSystem.mxd
6/26/2012 plit
Source: HGL 2011

Figure 3.21

Hand Held Gamma Scanner II Detection System



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\
(3-22)_HHGS_DetectorRig.mxd
6/26/2012 plit
Source: HGL 2011

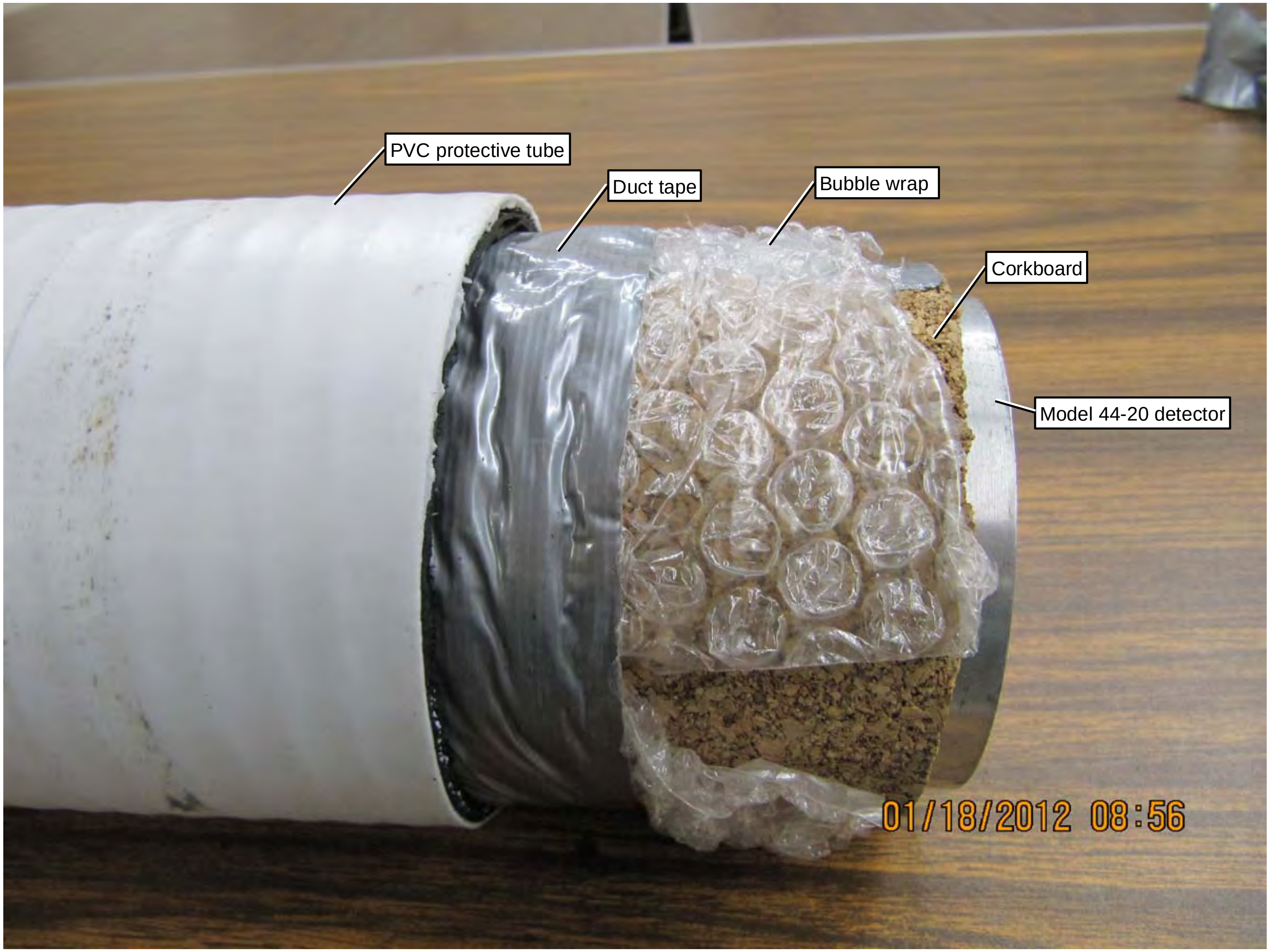
Figure 3.22

Hand Held Gamma Scanner II Detector Rig

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-23)_LudlumDetector.mxd
3/25/2012 pbillock
Source: HGL 2011

Figure 3.23

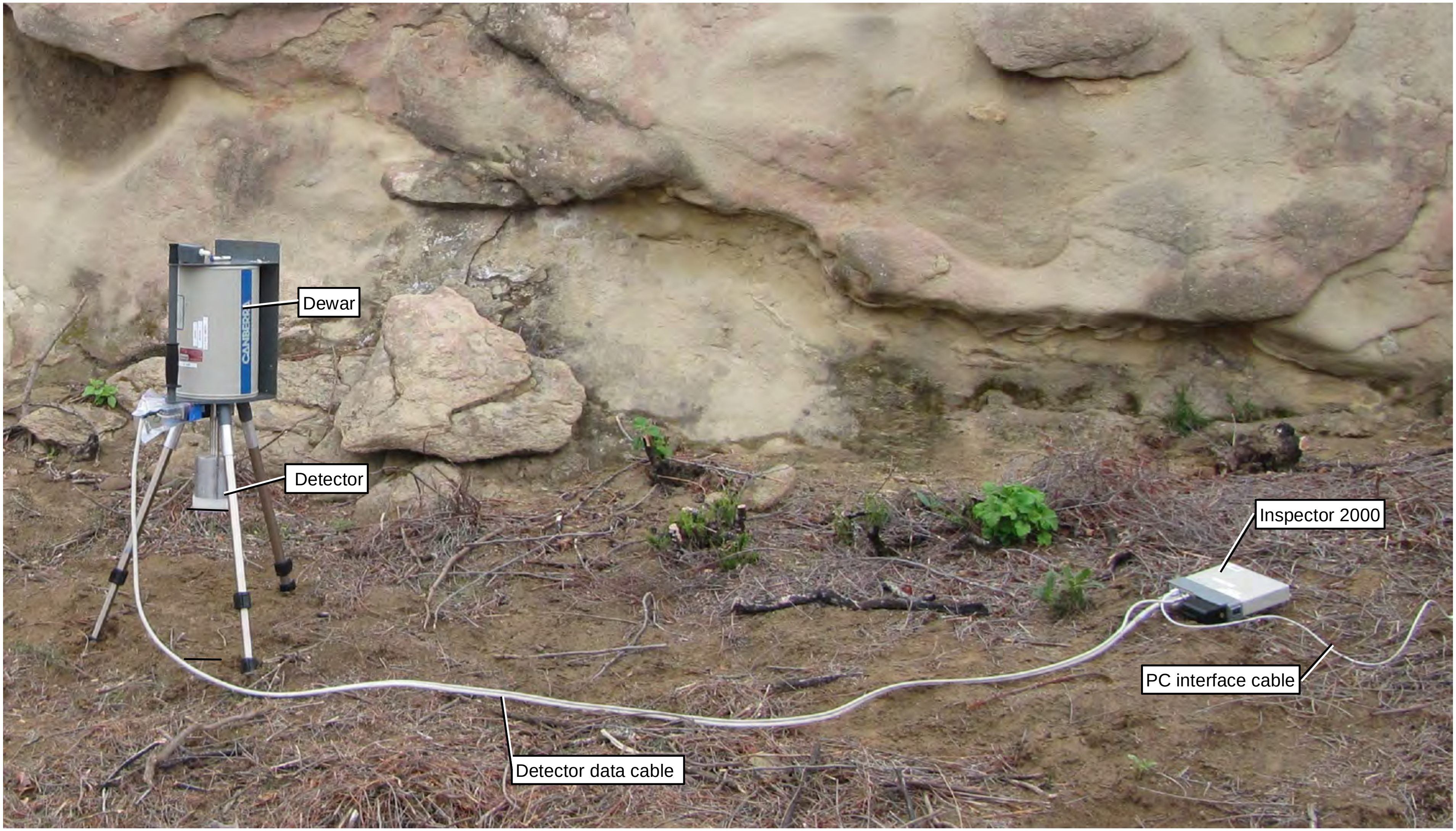
Ludlum Model 44-20 Detector



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\
(3-24)_HHGS_PVC_Container.mxd
3/25/2012 pbillock
Source: HGL 2011

Figure 3.24

Hand Held Gamma Scanner I and II
PVC Protective Tube



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-25)_InSitu_Detection_System.mxd
6/26/2012 plit
Source: HGL 2011

Figure 3.25

In Situ Gamma Spectrometer Detection System

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\
(3-26)_Troxler_MoistureGauge.mxd
3/25/2012 pbillock
Source: HGL 2011

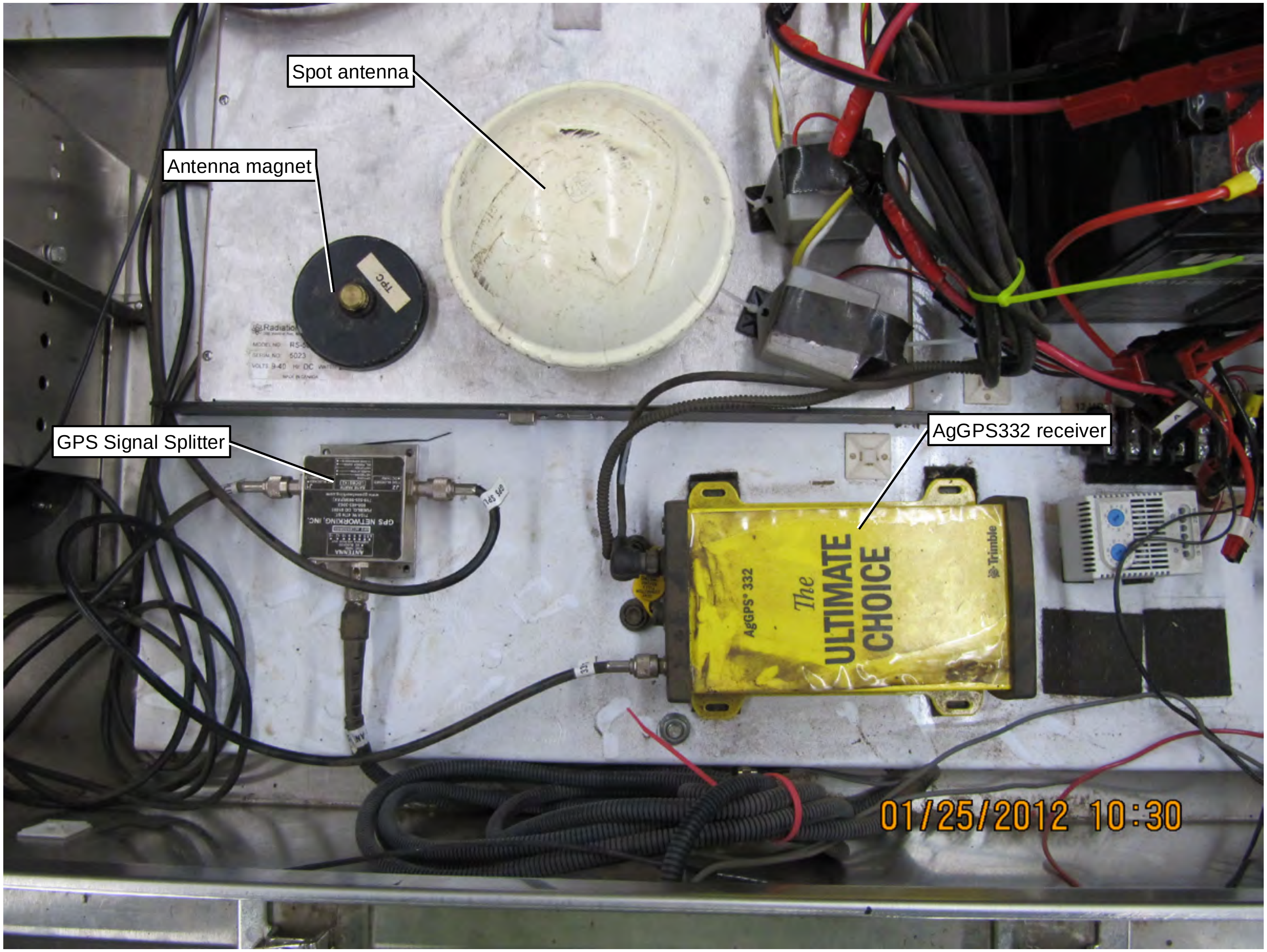
Figure 3.26

Troxler 3430 Nuclear Moisture Gauge

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-27)_TrimbleGEOXHSystem.mxd
6/26/2012 plit
Source: HGL 2011

Figure 3.27

Trimble® Explorer GeoXH 2008 GPS



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-28)_Trimble_AG332GPS.mxd
6/28/2012 plit
Source: HGL 2011

HGL HydroGeoLogic, Inc

Figure 3.28

Trimble® AgGPS 332

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-29)_TrinbleSPS_GPS.mxd
6/26/2012 plit
Source: HGL 2011

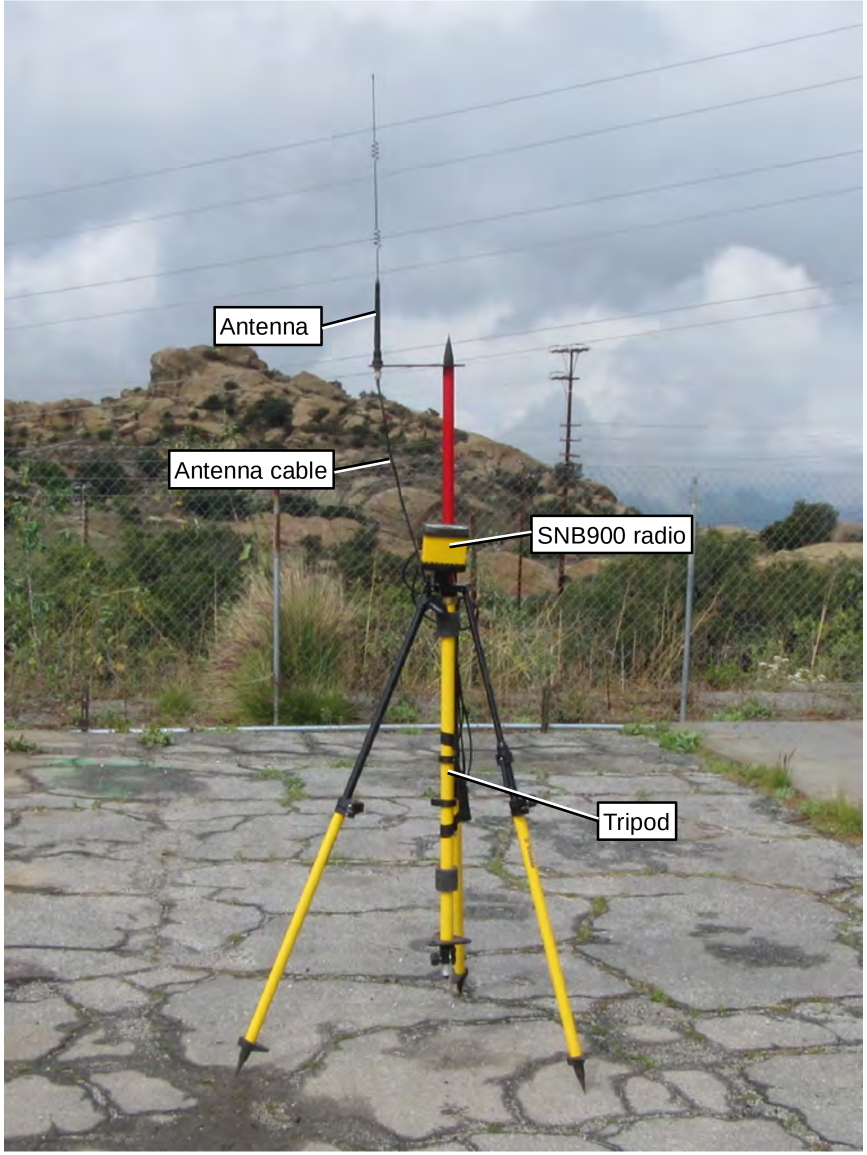
Figure 3.29

Trimble® SPS852 GPS

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-30)_Trimble_SPS_Base_GPSSystem.mxd
6/28/2012 plit
Source: HGL 2011

Figure 3.30

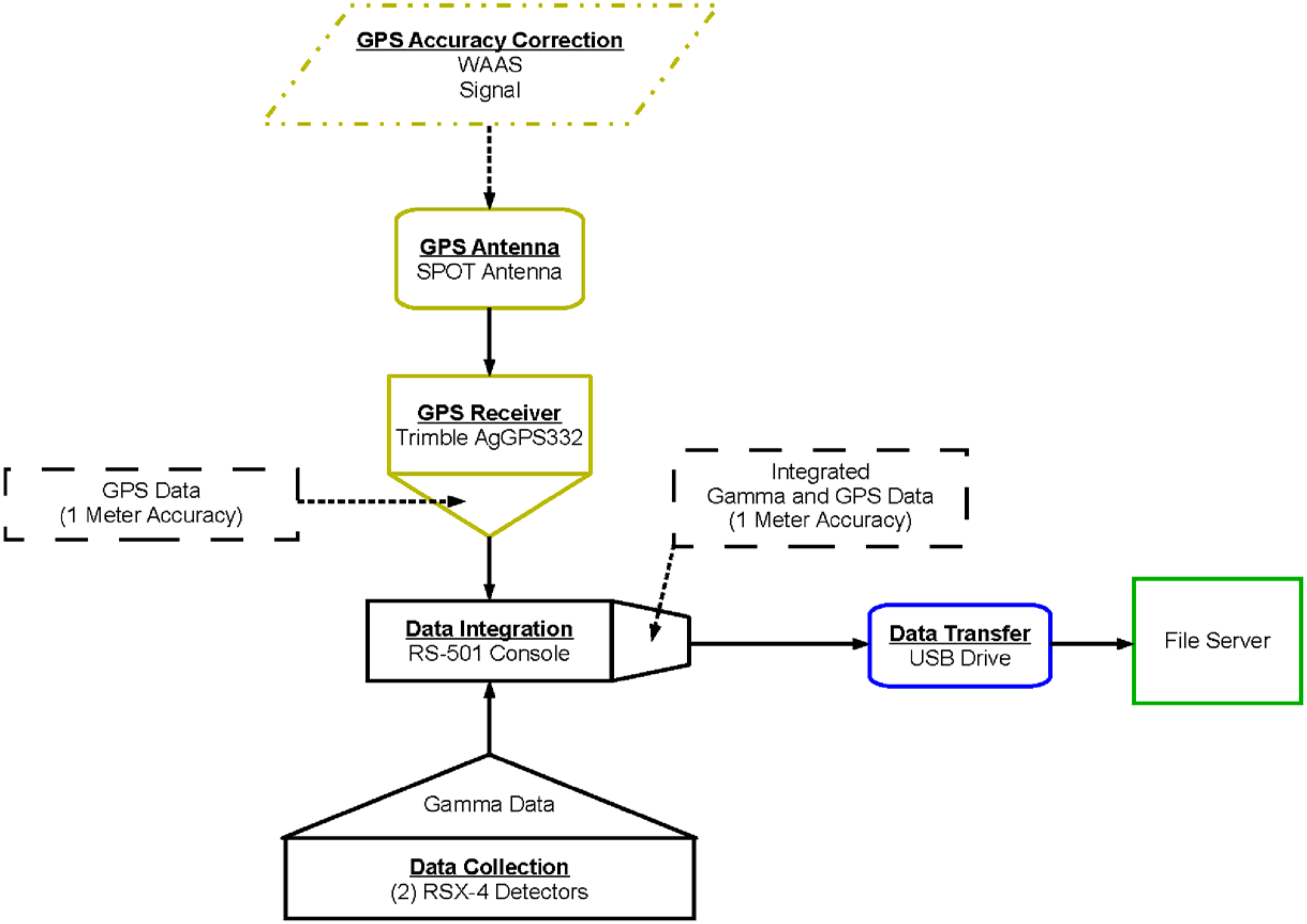
Trimble® SPS852 Base Station GPS



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-31)_SNB900_Radio_Repeater.mxd
6/26/2012 plit
Source: HGL 2011

Figure 3.31

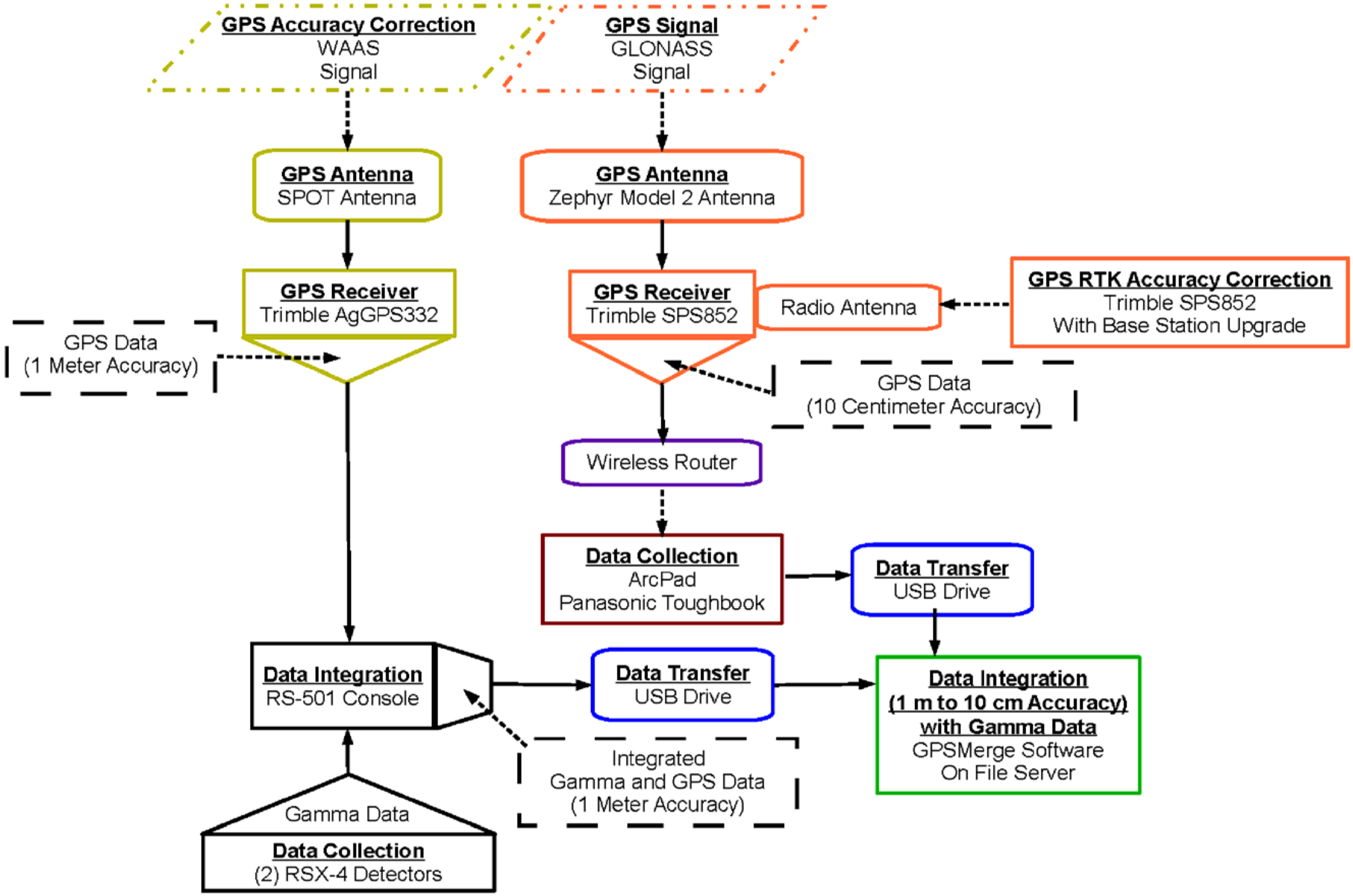
Trimble SNB900 GPS Radio Repeater



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-32)_Initial_ERGSII_DataCollectionSchematic.mxd
6/15/2012 pbillock
Source: HGL 2012

Figure 3.32

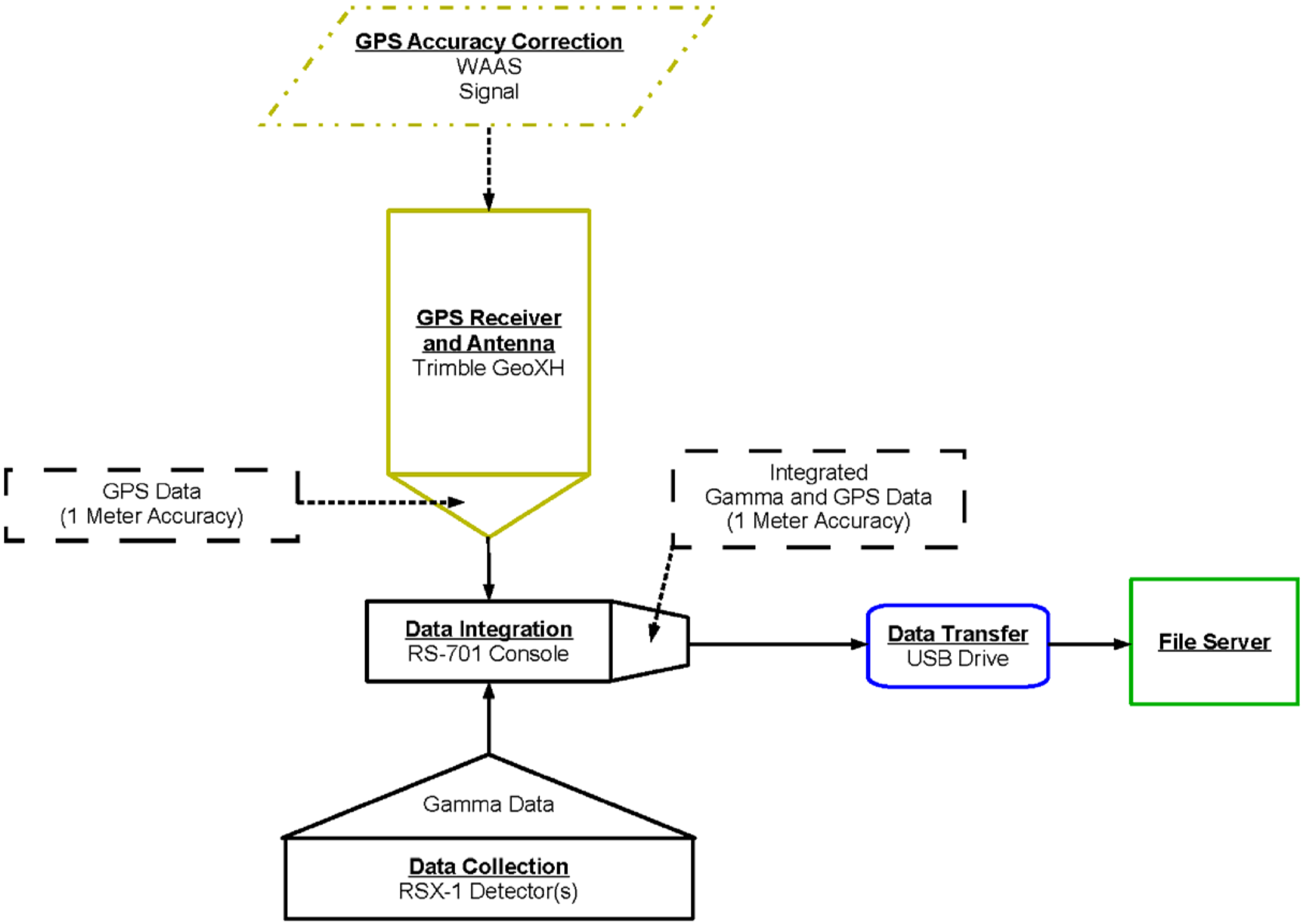
Initial ERGS II Data Collection Schematic



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-33)_Final_ERGSII_DataCollectionSchematic.mxd
6/15/2012 pbillock
Source: HGL 2012

Figure 3.33

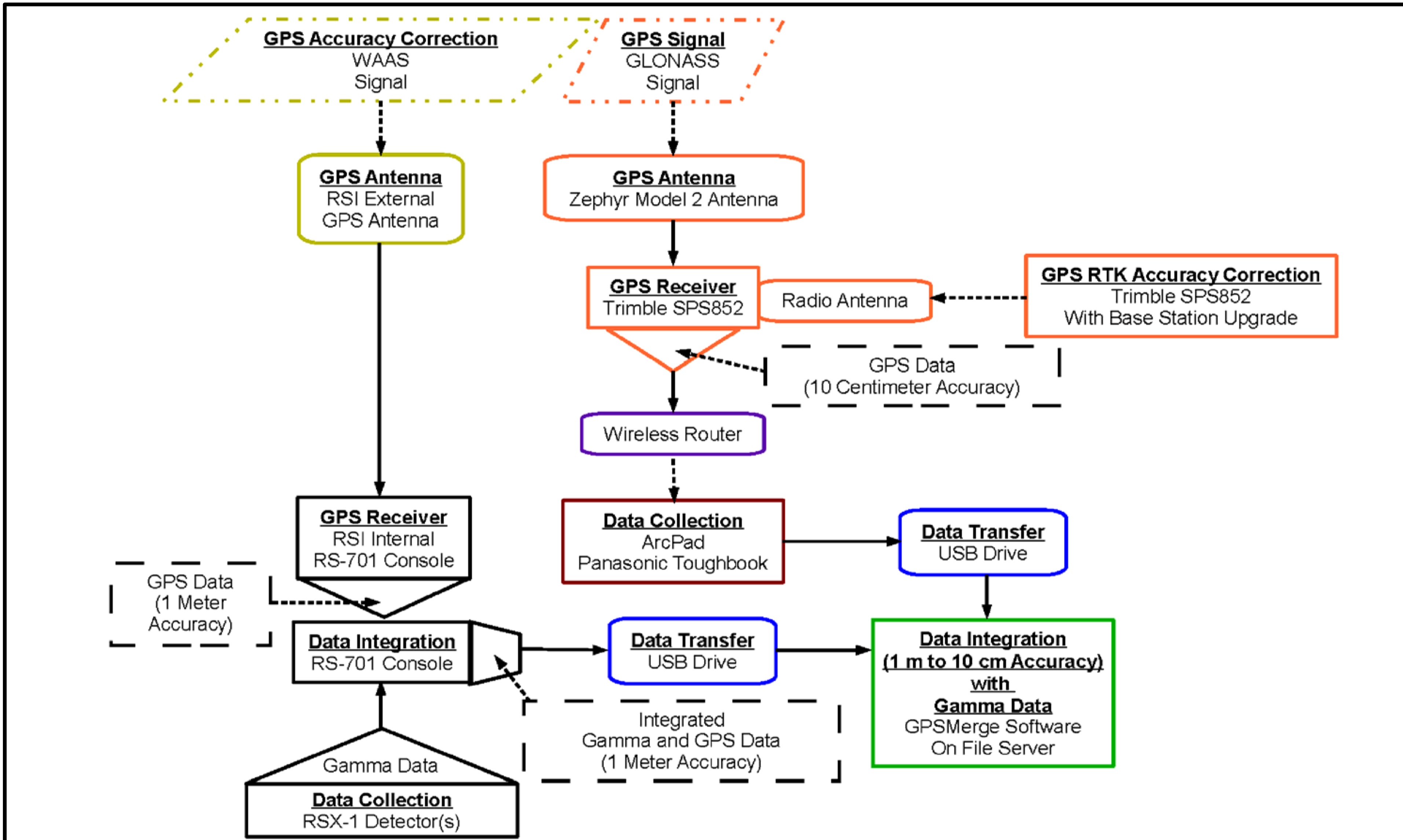
Final ERGS II Data Collection Schematic



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-34)_Initial_OtherRSI_DataCollectionSchematic.mxd
6/15/2012 pbillock
Source: HGL 2012

Figure 3.34

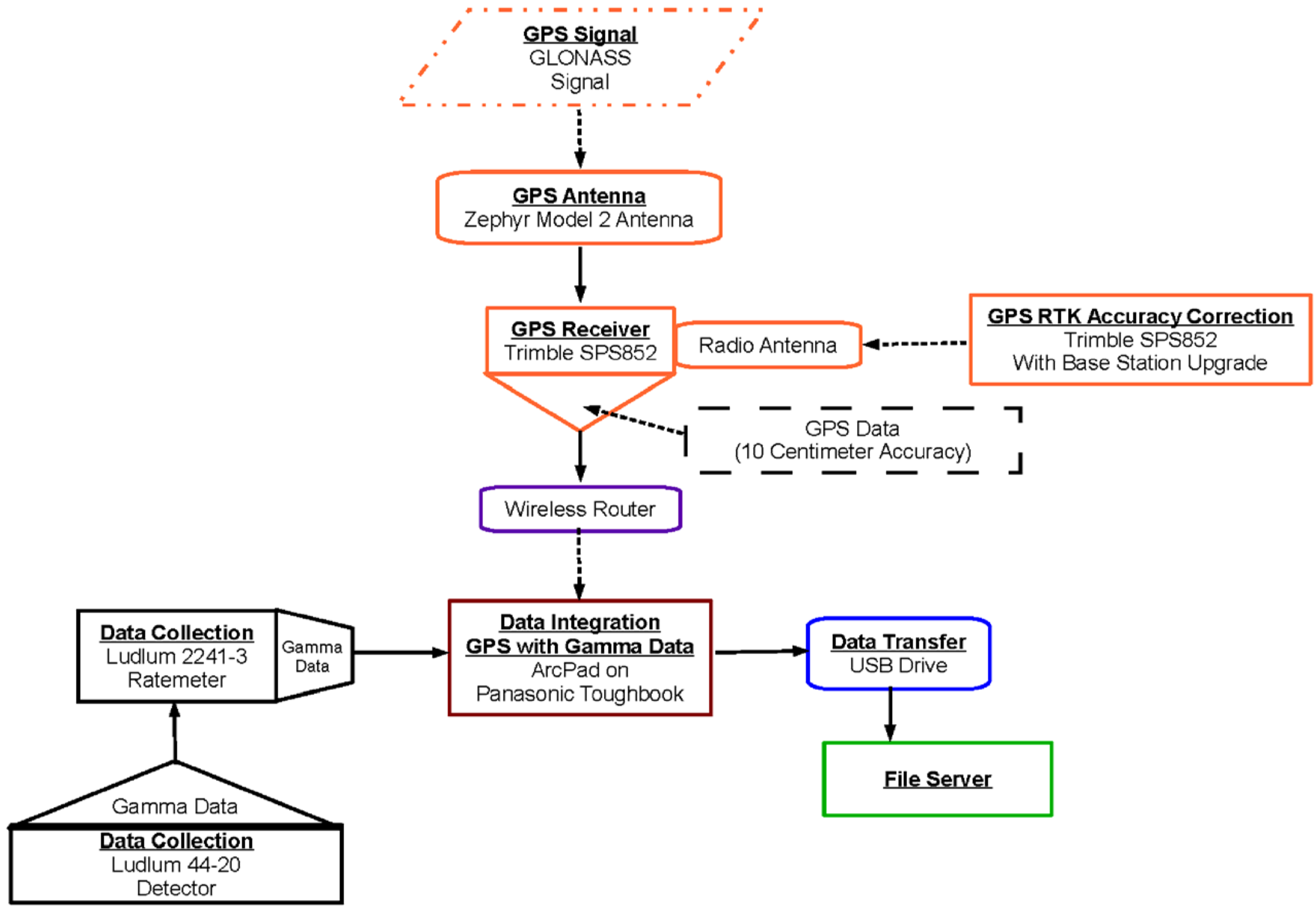
Initial WMGS/TMGS/STGS/MMGS Data Collection Schematic



Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-35)_Final_OtherRSI_DataCollectionSchematic.mxd
6/15/2012 pbillock
Source: HGL 2012

Figure 3.35

Final WMGS/TMGS/STGS/MMGS Data Collection Schematic



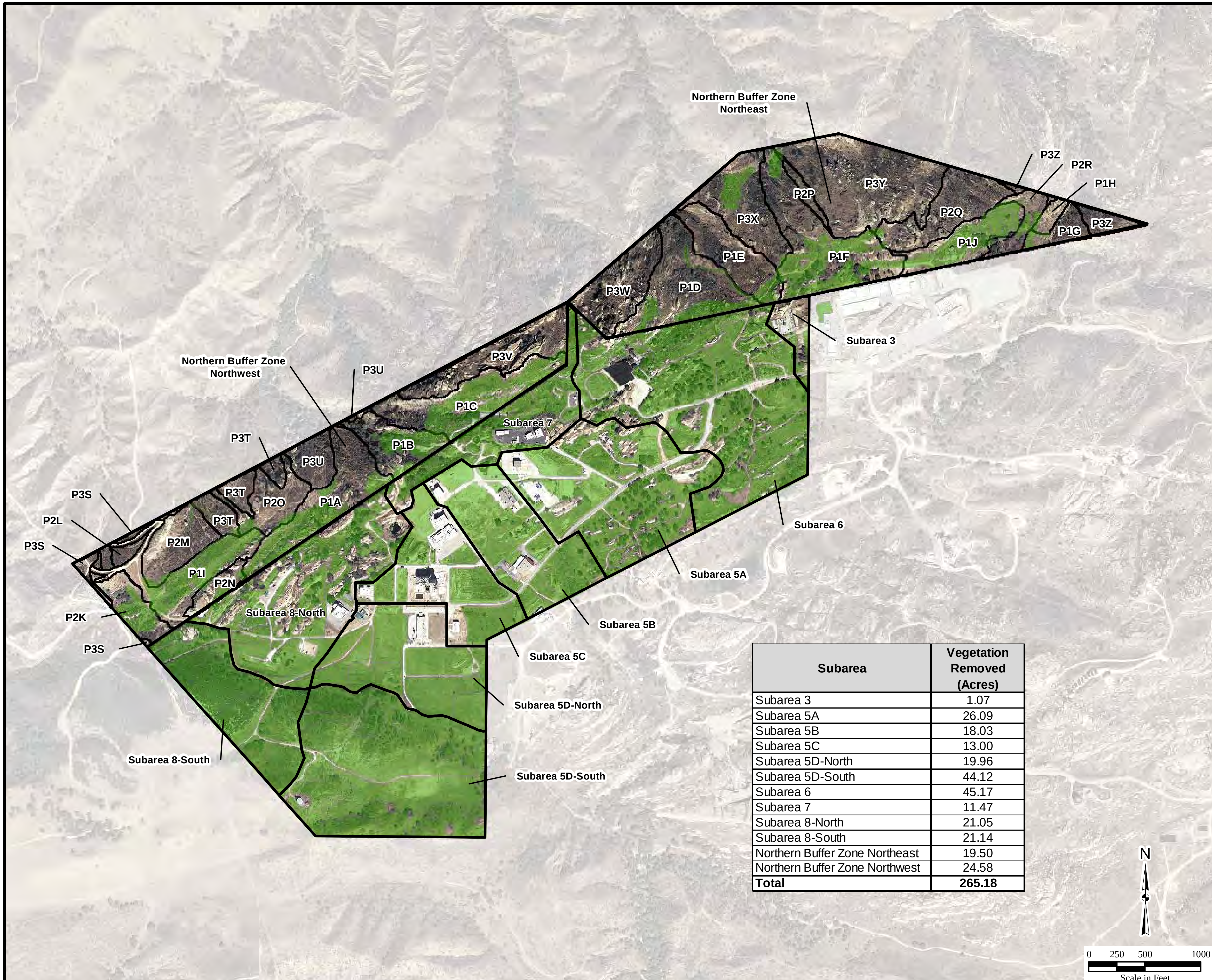
Y:\Santa_Susana\EP9038\GammaScanning\Report\Section_3\(3-36)_HHGSI_II_DataCollectionSchematic.mxd
6/15/2012 pbillock
Source: HGL 2012

Figure 3.36

HHGS I / HHGS II Data Collection Schematic

Figure 6.1
Vegetation Removed
Santa Susana Field Laboratory

U.S. EPA Region 9



Subarea	Vegetation Removed (Acres)
Subarea 3	1.07
Subarea 5A	26.09
Subarea 5B	18.03
Subarea 5C	13.00
Subarea 5D-North	19.96
Subarea 5D-South	44.12
Subarea 6	45.17
Subarea 7	11.47
Subarea 8-North	21.05
Subarea 8-South	21.14
Northern Buffer Zone Northeast	19.50
Northern Buffer Zone Northwest	24.58
Total	**265.18**

Legend

- Subarea and PriorityArea Boundaries
- Vegetation Removed

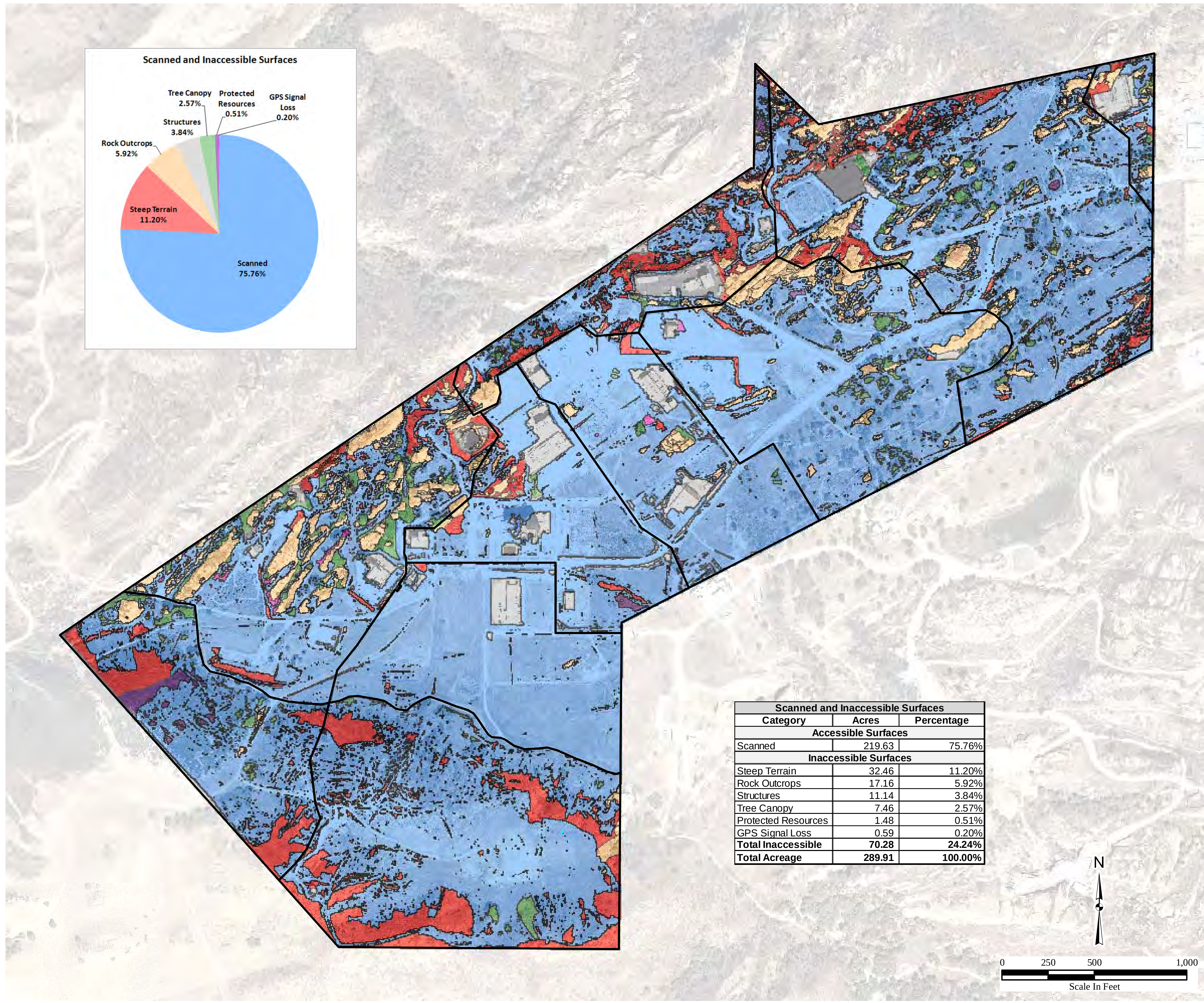
P3U
- Identification Letter
- Priority

* Includes initial clearing and subsequent reclearing

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section6\(6-1)_Vegetation_Removed.mxd
6/29/2012 pbillock
Source:HGL 2010, CIRGIS 2007

Figure 6.2
Scanned and Inaccessible Surfaces of Area IV
Santa Susana Field Laboratory

U.S. EPA Region 9



Scanned and Inaccessible Surfaces		
Category	**Acres**	**Percentage**
Accessible Surfaces		
Scanned	219.63	75.76%
Inaccessible Surfaces		
Steep Terrain	32.46	11.20%
Rock Outcrops	17.16	5.92%
Structures	11.14	3.84%
Tree Canopy	7.46	2.57%
Protected Resources	1.48	0.51%
GPS Signal Loss	0.59	0.20%
Total Inaccessible	**70.28**	**24.24%**
Total Acreage	**289.91**	**100.00%**

Legend

- Subarea Boundary
- Scanned

Inaccessible Surfaces

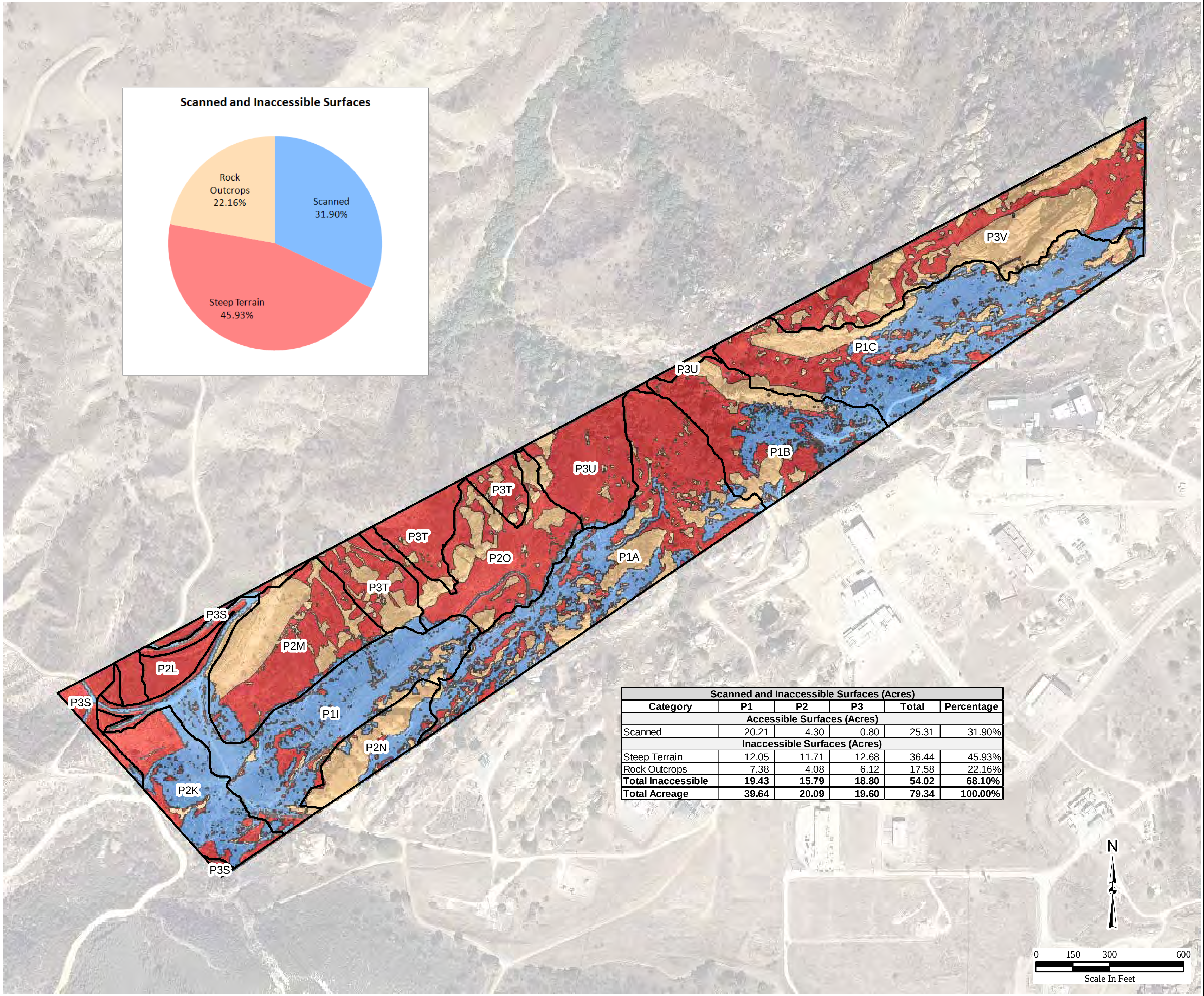
- Steep Terrain
- Rock Outcrops
- Structures
- Tree Canopy
- Protected Resources
- GPS Signal Loss

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section6\
(6-2)_AreaIV_Inaccessible_Catagories.mxd
6/29/2012 pbillock
Source: CIRGIS 2007; Boeing 2009; HGL 2011

HGL HydroGeoLogic, Inc

Figure 6.3
Scanned and Inaccessible Surfaces of the Nothern Buffer Zone Northwest Santa Susana Field Laboratory

U.S. EPA Region 9



Scanned and Inaccessible Surfaces (Acres)					
Category	**P1**	**P2**	**P3**	**Total**	**Percentage**
Accessible Surfaces (Acres)					
Scanned	20.21	4.30	0.80	25.31	31.90%
Inaccessible Surfaces (Acres)					
Steep Terrain	12.05	11.71	12.68	36.44	45.93%
Rock Outcrops	7.38	4.08	6.12	17.58	22.16%
Total Inaccessible	**19.43**	**15.79**	**18.80**	**54.02**	**68.10%**
Total Acreage	**39.64**	**20.09**	**19.60**	**79.34**	**100.00%**

Legend

Priority Areas
Scanned

Inaccessible Surfaces

Steep Terrain
Rock Outcrops

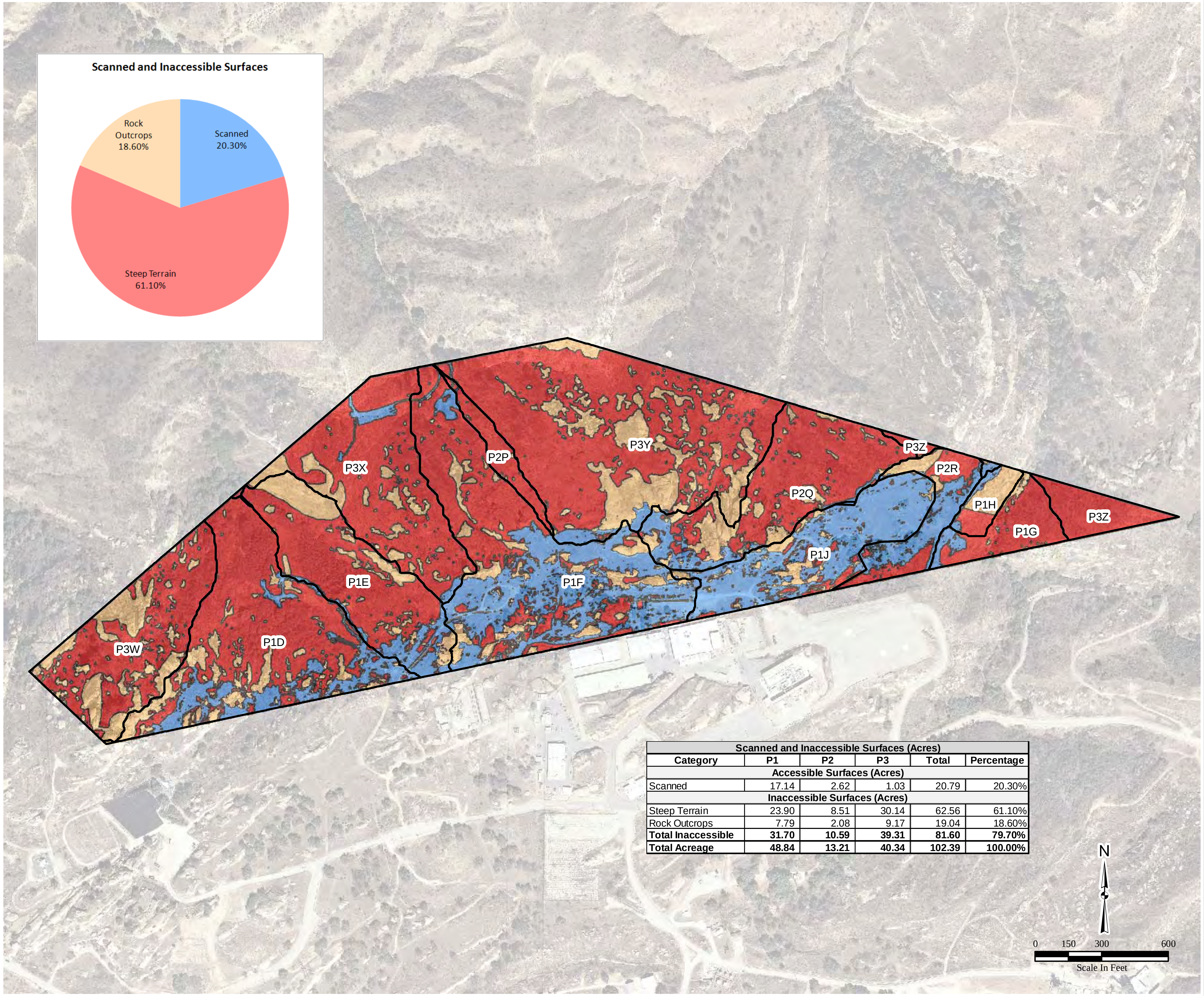
P3U
Identification Letter
Priority

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section6\
(6-3)NBZ_West_Inaccessible_Catagories.mxd
6/29/2012 pbillock
Source: CIRGIS 2007; Boeing 2009; HGL 2011

HGL HydroGeoLogic, Inc

Figure 6.4
Scanned and Inaccessible Surfaces of the Nothern Buffer Zone Northeast Santa Susana Field Laboratory

U.S. EPA Region 9



Scanned and Inaccessible Surfaces (Acres)					
Category	**P1**	**P2**	**P3**	**Total**	**Percentage**
Accessible Surfaces (Acres)					
Scanned	17.14	2.62	1.03	20.79	20.30%
Inaccessible Surfaces (Acres)					
Steep Terrain	23.90	8.51	30.14	62.56	61.10%
Rock Outcrops	7.79	2.08	9.17	19.04	18.60%
Total Inaccessible	**31.70**	**10.59**	**39.31**	**81.60**	**79.70%**
Total Acreage	**48.84**	**13.21**	**40.34**	**102.39**	**100.00%**

Legend

- Priority Areas
- Scanned

Inaccessible Surfaces

- Steep Terrain
- Rock Outcrops

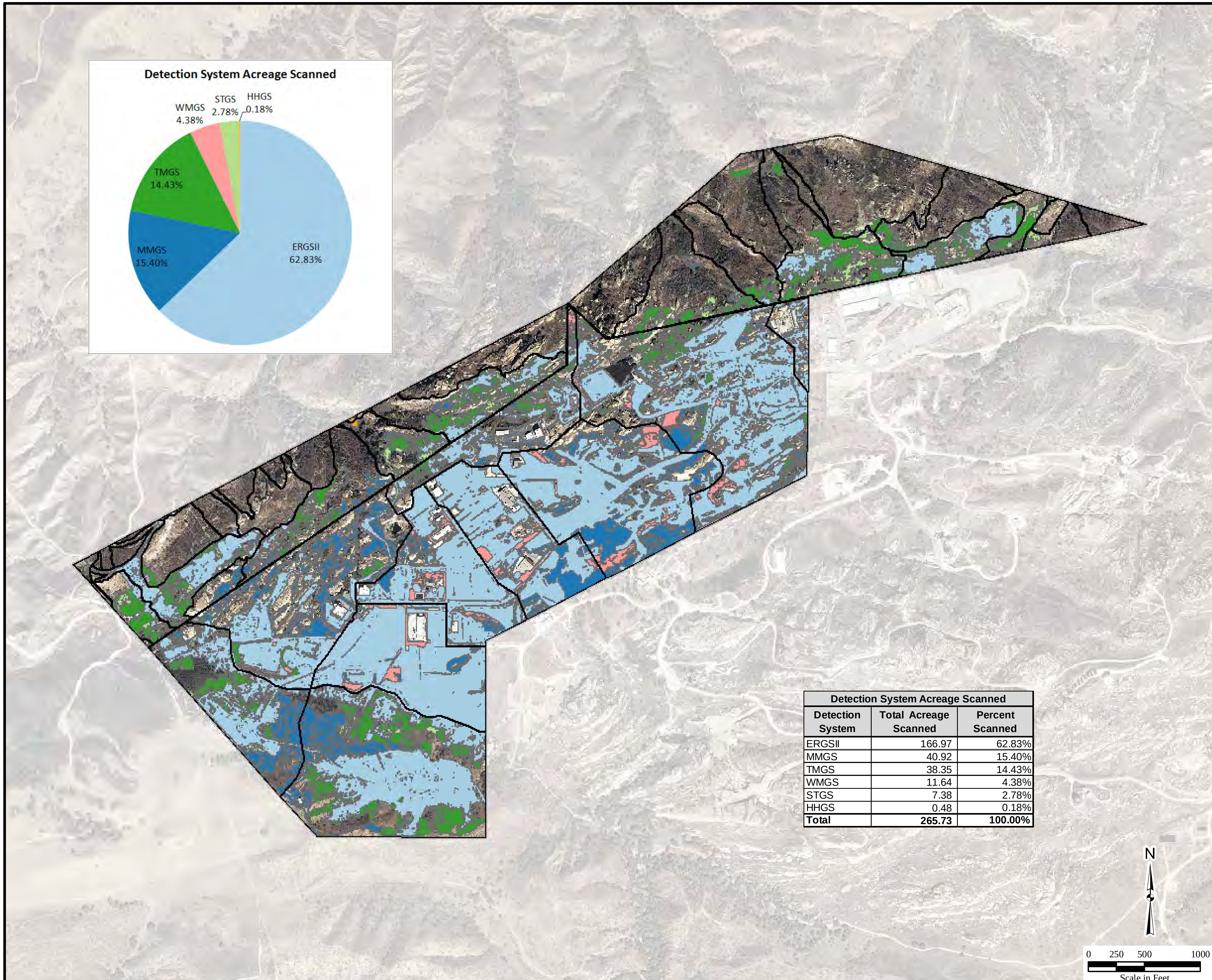
P3U
- Identification Letter
- Priority

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section6\
(6-4)NBZ_East_Inaccessible_Catagories.mxd
6/29/2012 pbillock
Source: CIRGIS 2007; Boeing 2009; HGL 2011

HGL HydroGeoLogic, Inc

Figure 6.5
Acreage Scanned by Each Detection System
Santa Susana Field Laboratory

U.S. EPA Region 9



Detection System Acreage Scanned		
Detection System	Total Acreage Scanned	Percent Scanned
ERGSII	166.97	62.83%
MMGS	40.92	15.40%
TMGS	38.35	14.43%
WMGS	11.64	4.38%
STGS	7.38	2.78%
HHGS	0.48	0.18%
Total	**265.73**	**100.00%**

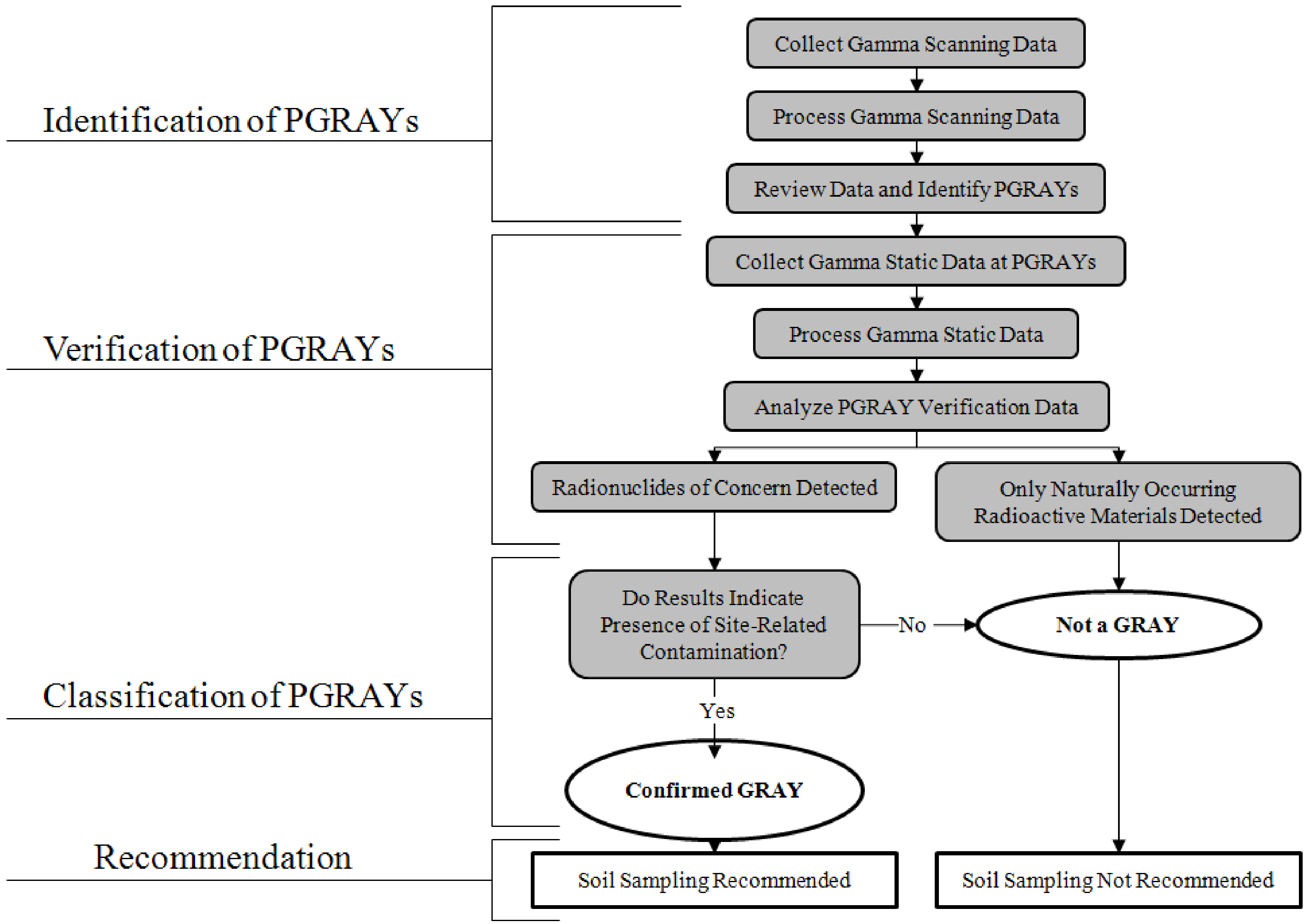
Legend

- Subarea and PriorityArea Boundaries
- ERGSII
- MMGS
- TMGS
- WMGS
- STGS
- HHGS

Notes:
ERGSII - Enhanced Radiation Ground Scanner II
MMGS - Mule Mounted Gamma Scanner
TMGS - Dual Detector Track Mounted Gamma Scanner
WMGS - Wheel Mounted Gamma Scanner
STGS - Single Detector Track Mounted Gamma Scanner
HHGS - Hand Held Gamma Scanner

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section6\(6-5)_Area_Scanned_withDetectionSystem.mxd
6/29/2012 pbillock
Source:HGL 2010, CIRGIS 2007

HGL HydroGeoLogic, Inc



\\Gst-srv-01\Gmap\Santa_Susana\EP9038\GammaScanning
\Report\Section 7\
(7-1)_PGRAY_Identification_Workflow.mxd
3/29/2012 plit
Source: HGL 2011

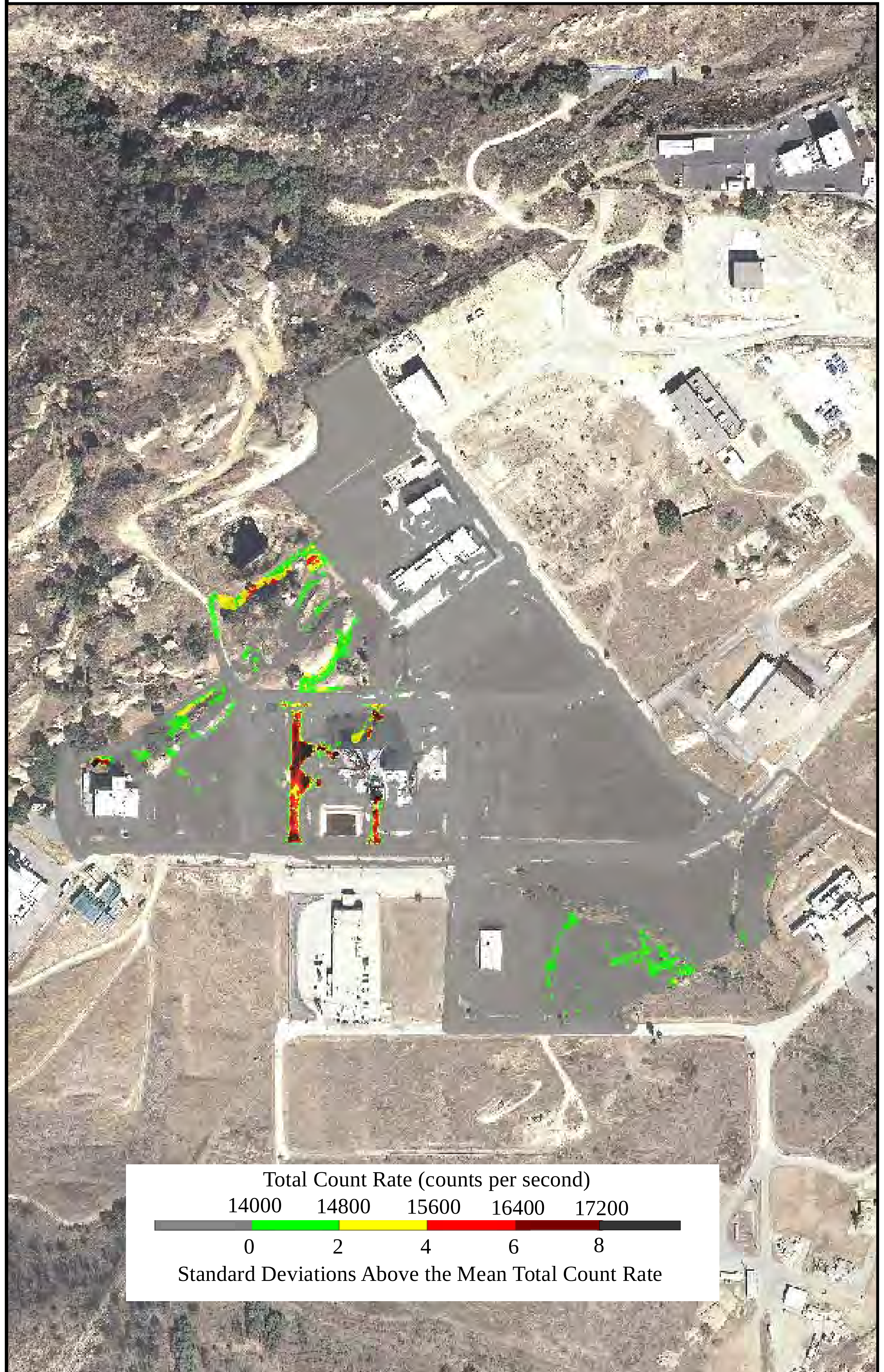
Figure 7.1

Potential Gamma Radiation Anomaly Evaluation Process

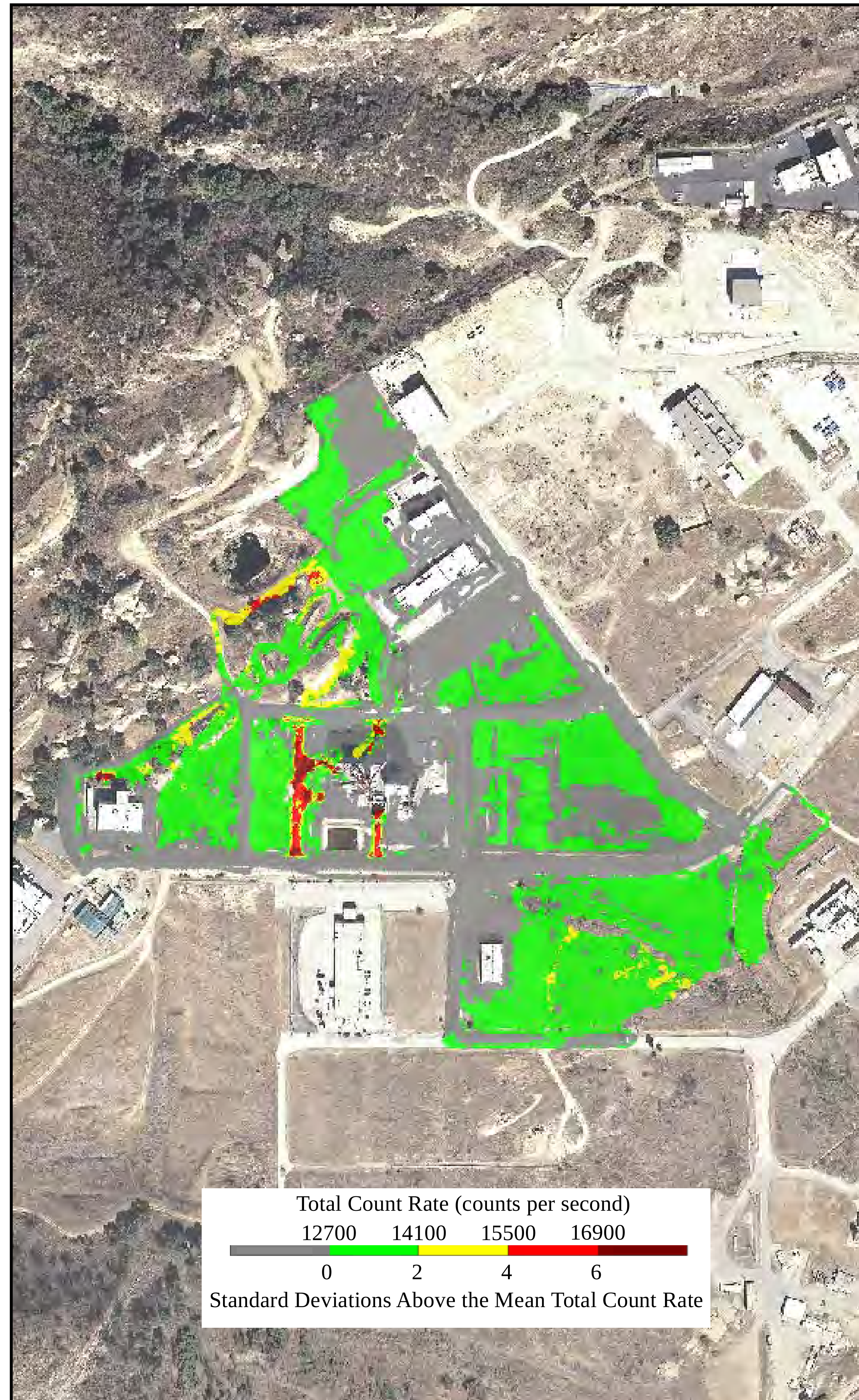
Figure 9.1
Comparison of Subarea 5C Scanning Results with Lang Ranch and Subarea 5C Backgrounds
Santa Susana Field Laboratory

U.S. EPA Region 9

Lang Ranch RBRA Background Applied

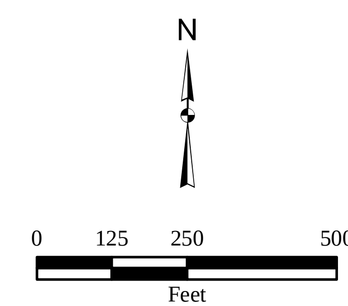


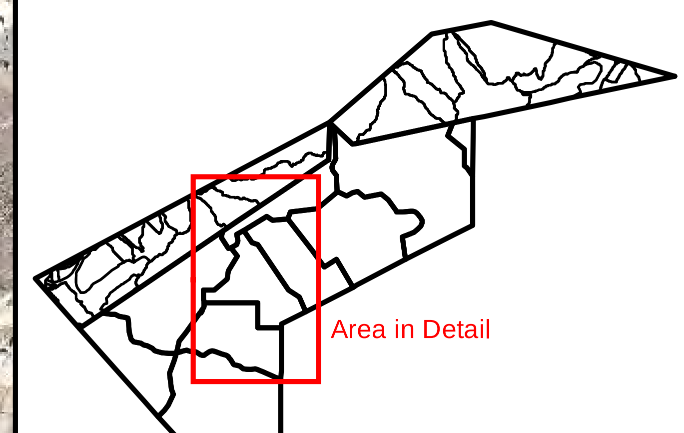
Subarea 5C Background Applied



Legend

Notes:
RBRA: radiological background reference area





Y:\Santa_Susana\EP9038\GammaScanning\Report\Section 9\20120710
(9-1)_Gamma_Langranch_Background_20120720.mxd
7/27/2012 plit
Source:HGL 2010, CIRGIS 2007

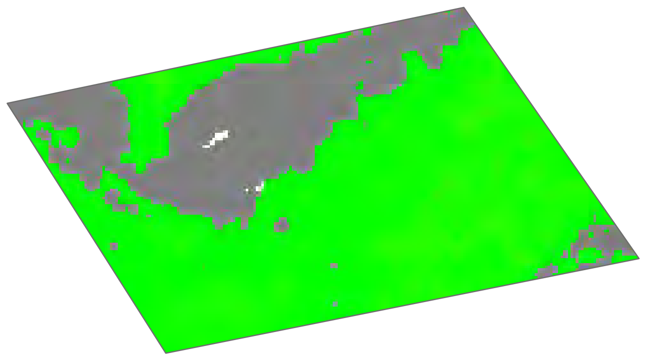
HGL HydroGeoLogic, Inc

Figure 9.2
ERGS II Quality Control
Adjustment of Normalization Areas
SS-1 and SS-6
Santa Susana Field Laboratory

U.S. EPA Region 9

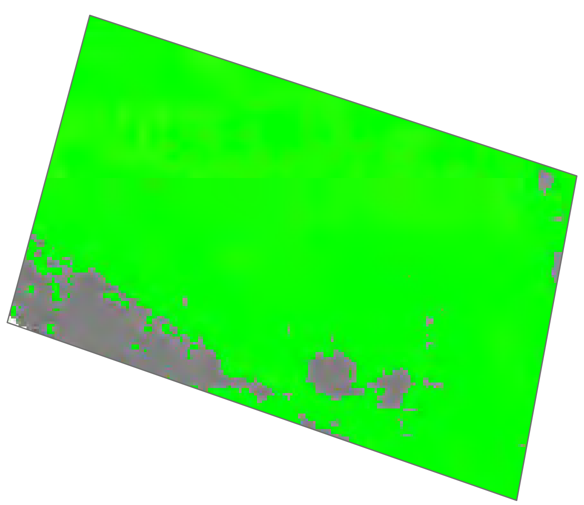
Initial Scanning Results

Normalization Area SS-6



Total Count Rate (counts per second)
12700 14100 15500 16900
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

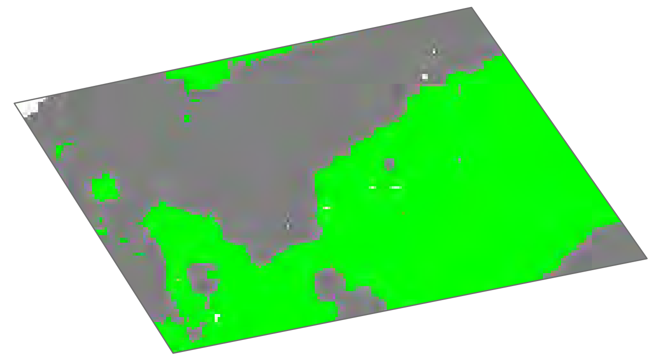
Normalization Area SS-1



Total Count Rate (counts per second)
12700 14100 15500 16900
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

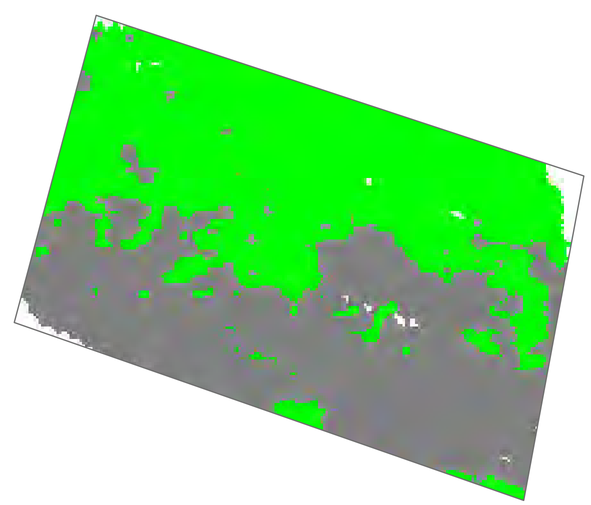
Quality Control Scanning Results

Normalization Area SS-6



Total Count Rate (counts per second)
12700 14100 15500 16900
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

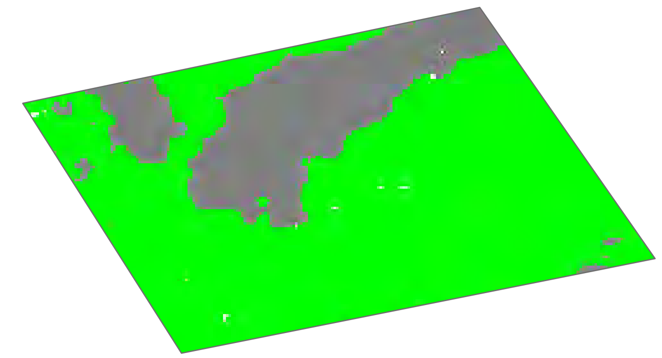
Normalization Area SS-1



Total Count Rate (counts per second)
12700 14100 15500 16900
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

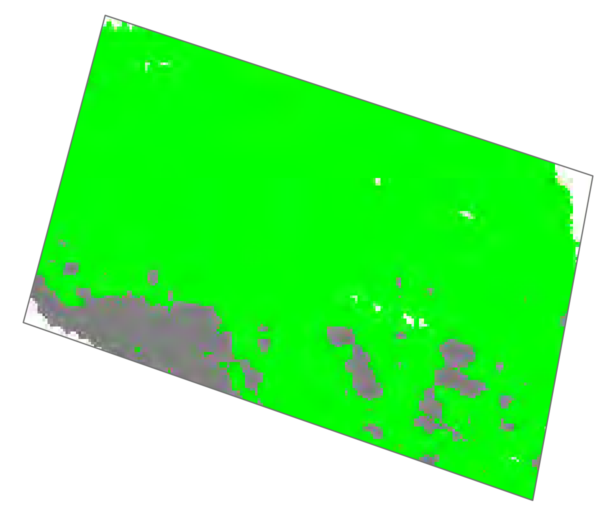
Adjusted Quality Control Scanning Results

Normalization Area SS-6



Total Count Rate (counts per second)
12300 13650 15000 16350
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

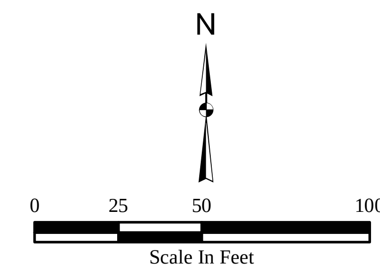
Normalization Area SS-1

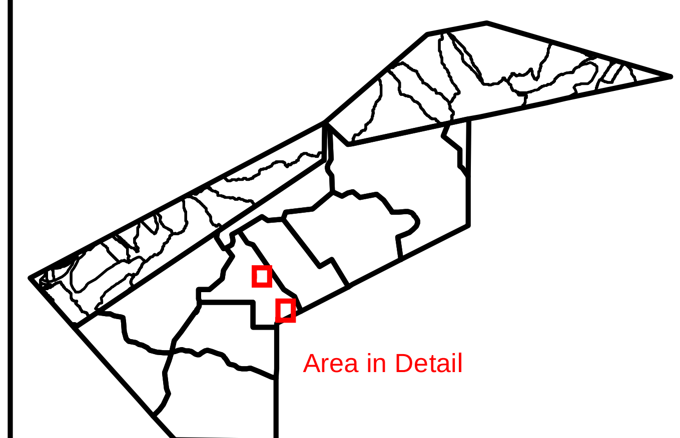


Total Count Rate (counts per second)
12300 13650 15000 16350
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

Legend

Notes:
ERGSII - Enhanced Radiation Ground Scanner II
SS - Survey Section





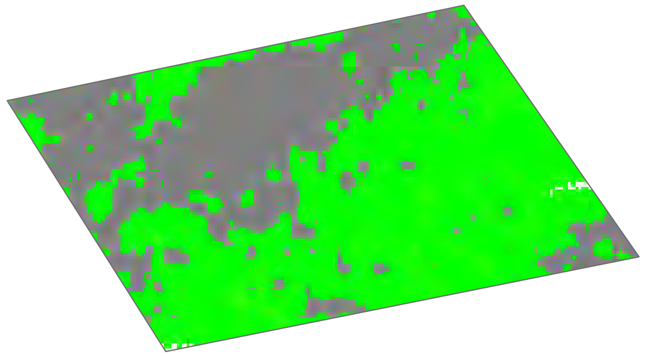
Y:\Santa_Susana\EP9038\GammaScanning\Report\Section 9\20120710
(9-2)_Gamma_ERGSII_QCscan_normalization_evaluation_20120721.mxd
7/21/2012 plit
Source:HGL 2010, CIRGIS 2007

Figure 9.3
WMGS Quality Control
Adjustment of Normalization Areas
SS-1 and SS-6
Santa Susana Field Laboratory

U.S. EPA Region 9

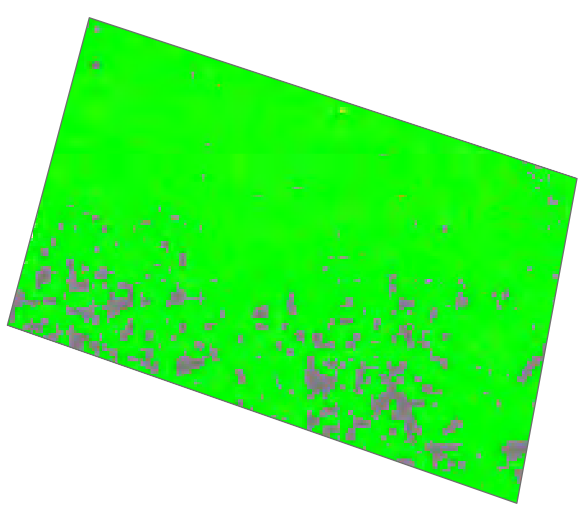
Initial Scanning Results

Normalization Area SS-6



Total Count Rate (counts per second)
12700 14100 15500 16900
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

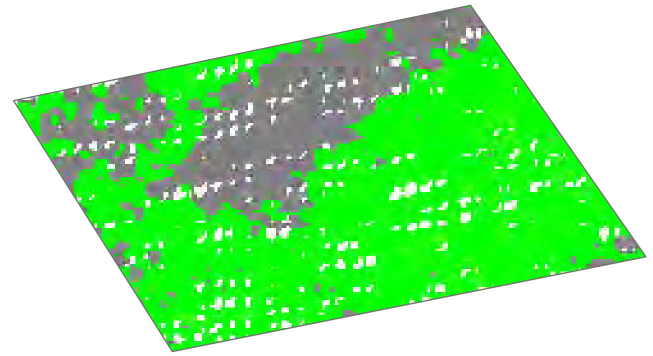
Normalization Area SS-1



Total Count Rate (counts per second)
12700 14100 15500 16900
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

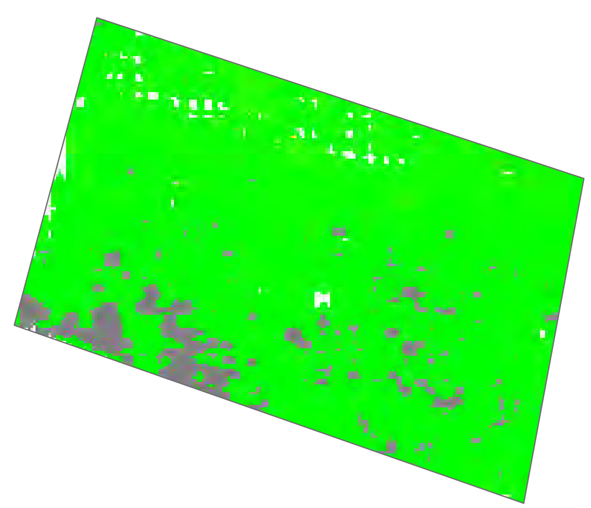
Quality Control Scanning Results

Normalization Area SS-6



Total Count Rate (counts per second)
12700 14100 15500 16900
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

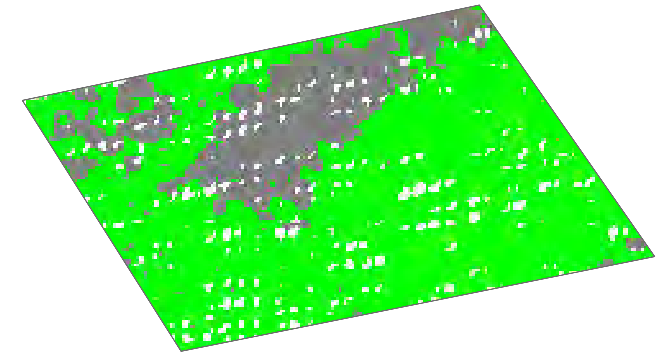
Normalization Area SS-1



Total Count Rate (counts per second)
12700 14100 15500 16900
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

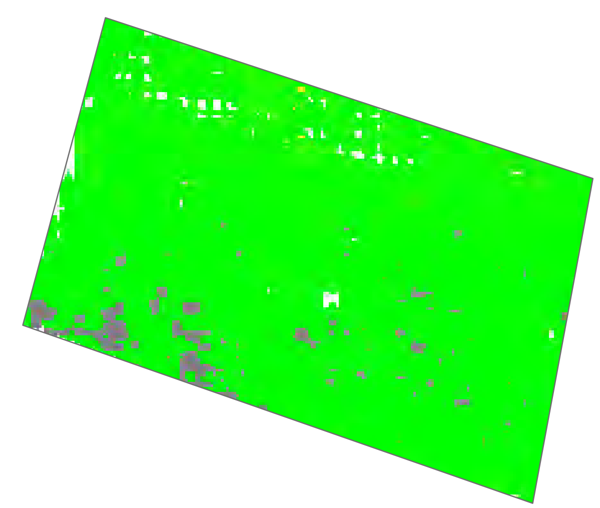
Adjusted Quality Control Scanning Results

Normalization Area SS-6



Total Count Rate (counts per second)
12600 14000 15400 16800
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

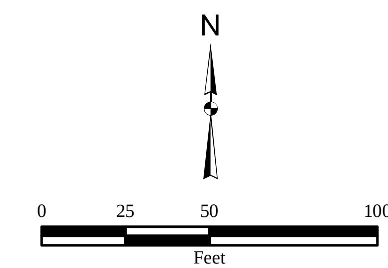
Normalization Area SS-1

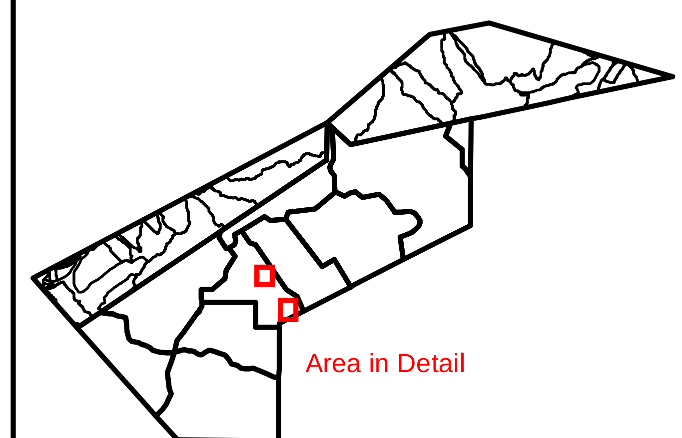


Total Count Rate (counts per second)
12600 14000 15400 16800
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

Legend

Notes:
WMGS - Wheel Mounted Gamma Scanner
SS - Survey Section



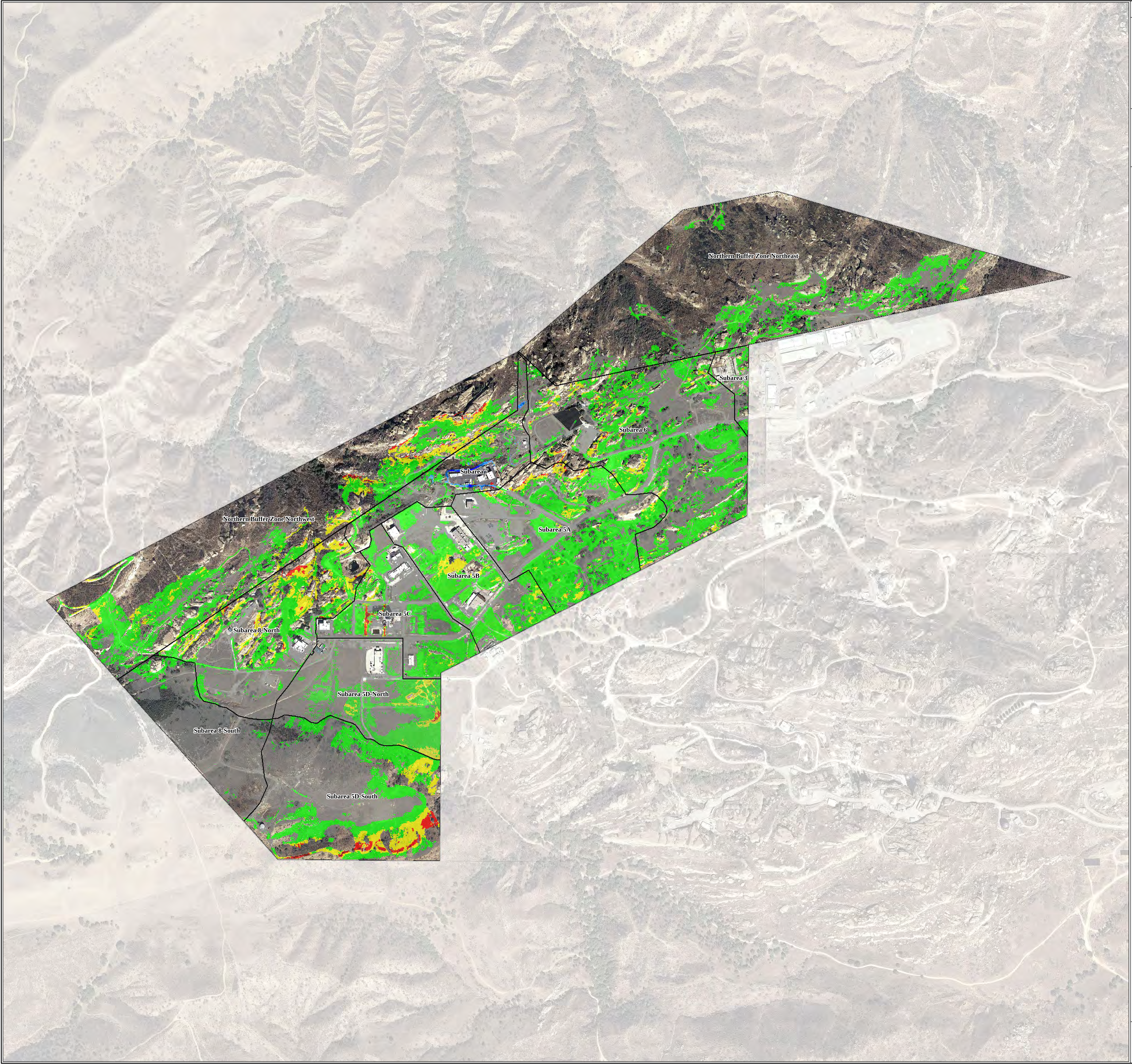


Y:\Santa_Susana\EP9038\GammaScanning\Report\Section 9\20120710\(9-3)_Gamma_WMGS_QCscan_normalization_evaluation_20120721.mxd
7/21/2012 plit
Source:HGL 2010, CIRGIS 2007

HGL
HydroGeoLogic, Inc

Figure 9.4
Area IV and Northern Buffer Zone Gamma Results
Santa Susana Field Laboratory

U.S. EPA Region 9



Legend

Subarea Boundaries

N

0 250 500 1000
Feet

Lower Cs-137 Ratio Higher

0 2 4 6
Standard Deviations Above the Mean Total Count Rate

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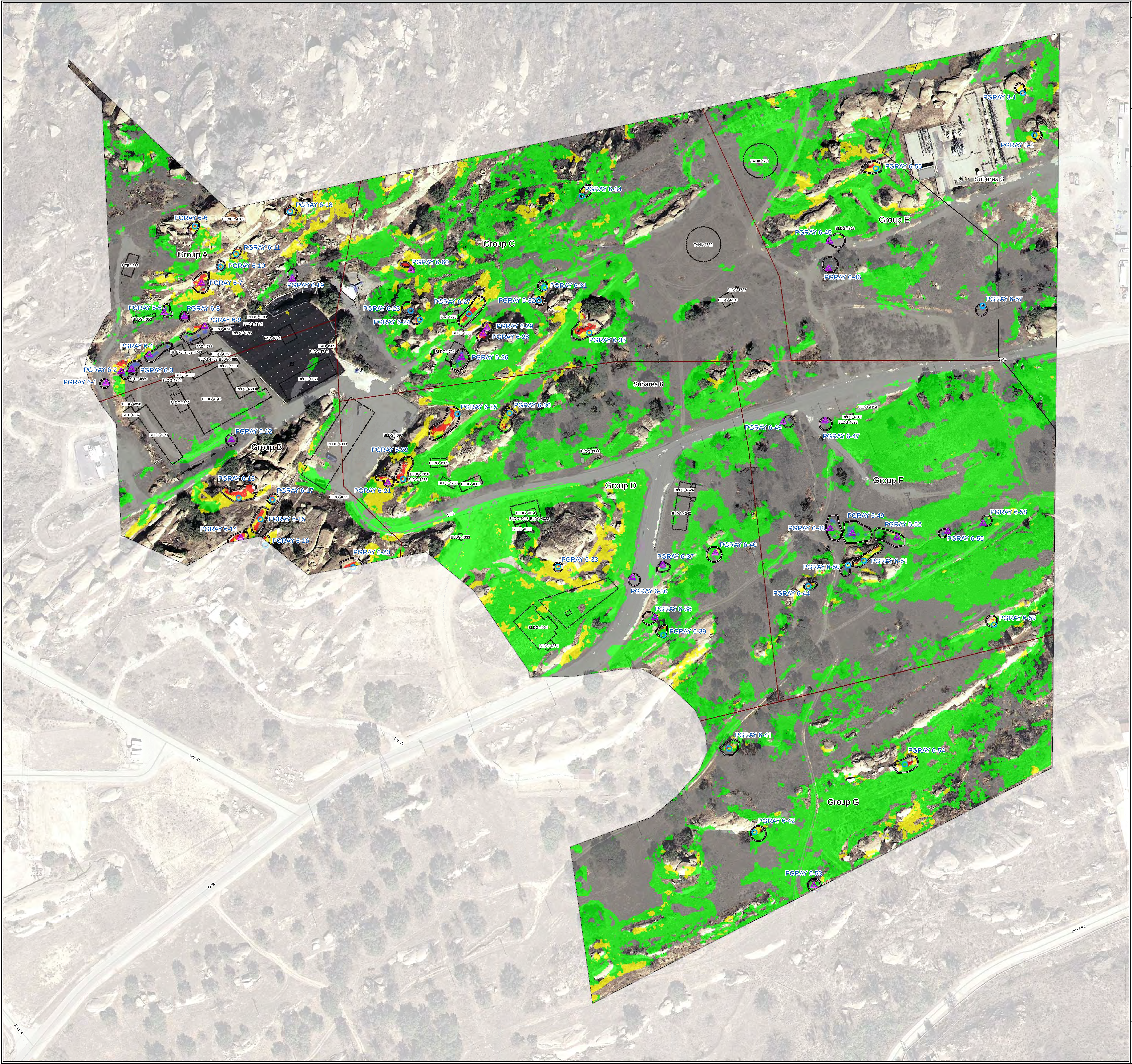
(9-4)_Gamma_Stoplight_ALL_Subarea_NBZ_20120712.mxd
7/26/2012 plit

HGL HydroGeoLogic, Inc

Figure 9.5
Subarea 3 and Subarea 6 Gamma Results Santa Susana Field Laboratory

U.S. EPA Region 9



Legend

- Static Count Location "Not a GRAY"
- Static Count Location "Confirmed GRAY"
- PGRAY Boundary
- Subarea Boundary
- Group Boundary

Buildings

- Demolished
- Existing

Roads

- Primary
- Secondary
- Tertiary

Notes:
GRAY-Gamma Radiation Anomaly
PGRAY-Potential Gamma Radiation Anomaly

PGRAY	Result	Group
3-1	Not a GRAY	Not Applicable
3-2	Not a GRAY	Not Applicable
6-1	Confirmed GRAY	Group A
6-2	Confirmed GRAY	Group A
6-3	Confirmed GRAY	Group A
6-4	Confirmed GRAY	Group A
6-5	Confirmed GRAY	Group A
6-6	Not a GRAY	Group A
6-7	Confirmed GRAY	Group A
6-8	Confirmed GRAY	Group A
6-9	Confirmed GRAY	Group A
6-10	Not a GRAY	Group A
6-11	Not a GRAY	Group A
6-12	Confirmed GRAY	Group B
6-13	Not a GRAY	Group B
6-14	Confirmed GRAY	Group B
6-15	Not a GRAY	Group B
6-16	Not a GRAY	Group B
6-17	Not a GRAY	Group B
6-18	Not a GRAY	Group A
6-19	Confirmed GRAY	Group A
6-20	Not a GRAY	Group B
6-21	Confirmed GRAY	Group D
6-22	Not a GRAY	Group D
6-23	Not a GRAY	Group C
6-24	Not a GRAY	Group C
6-25	Not a GRAY	Group D
6-26	Confirmed GRAY	Group C
6-27	Not a GRAY	Group C
6-28	Confirmed GRAY	Group C
6-29	Confirmed GRAY	Group C
6-30	Not a GRAY	Group D
6-31	Not a GRAY	Group C
6-32	Not a GRAY	Group C
6-33	Not a GRAY	Group D
6-34	Not a GRAY	Group C
6-35	Not a GRAY	Group C
6-36	Confirmed GRAY	Group D
6-37	Confirmed GRAY	Group D
6-38	Confirmed GRAY	Group D
6-39	Not a GRAY	Group D
6-40	Confirmed GRAY	Group D
6-41	Not a GRAY	Group G
6-42	Not a GRAY	Group G
6-43	Confirmed GRAY	Group F
6-44	Not a GRAY	Group F
6-45	Confirmed GRAY	Group E
6-46	Confirmed GRAY	Group E
6-47	Confirmed GRAY	Group F
6-48	Confirmed GRAY	Group F
6-49	Confirmed GRAY	Group F
6-50	Not a GRAY	Group F
6-51	Not a GRAY	Group F
6-52	Confirmed GRAY	Group F
6-53	Confirmed GRAY	Group G
6-54	Not a GRAY	Group G
6-55	Not a GRAY	Group E
6-56	Confirmed GRAY	Group F
6-57	Not a GRAY	Group E
6-58	Confirmed GRAY	Group F
6-59	Not a GRAY	Group F
6-60	Confirmed GRAY	Group C

N

0 50 100 200
Feet

Lower — Cs-137 Ratio — Higher

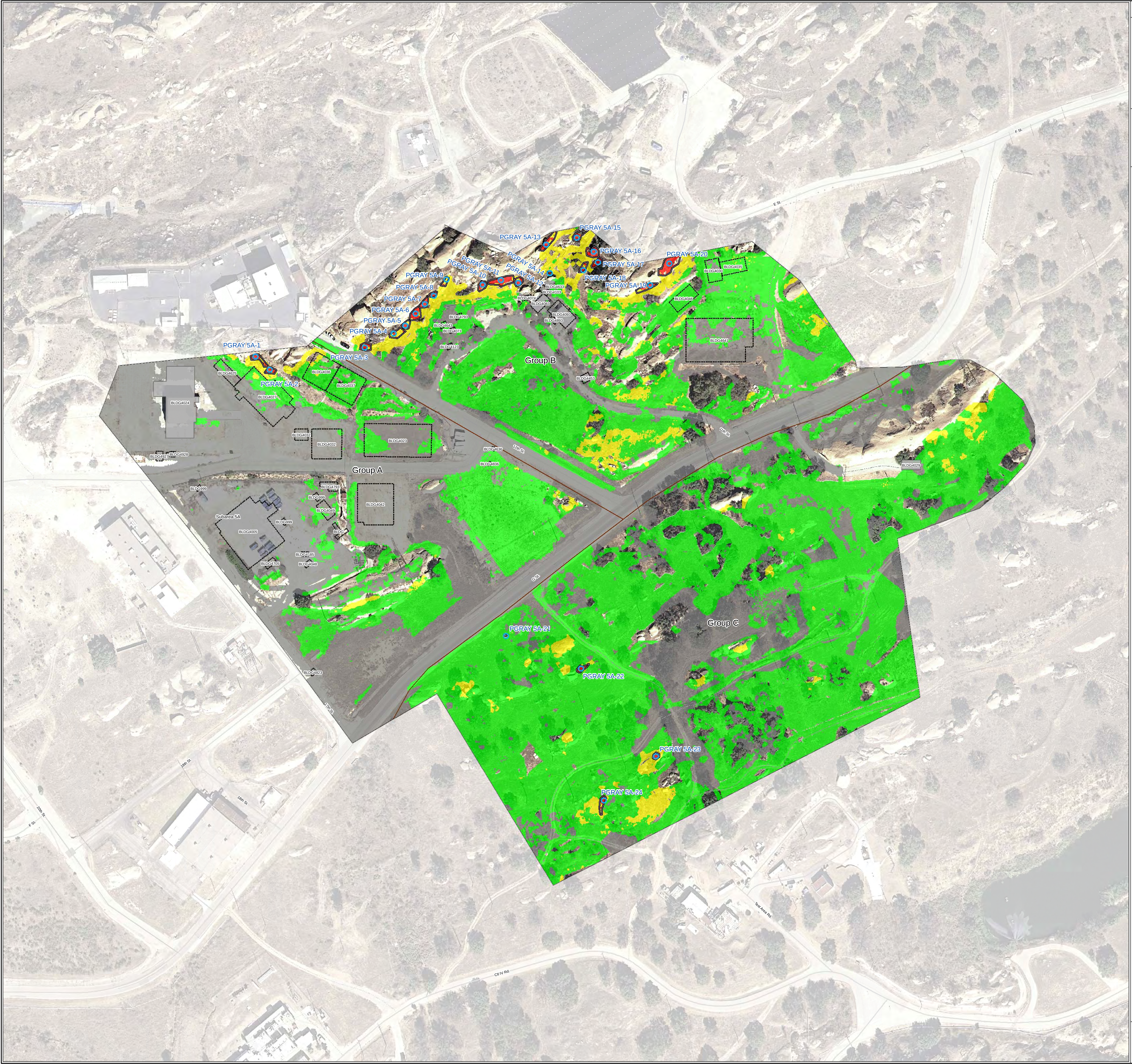
Total Count Rate (counts per second)
13000 14800 16600 18400
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section 9\20120710\(9-5)_Gamma_Radiation_Subarea3&6_20120710.mxd
7/26/2012 plit

HGL HydroGeoLogic, Inc

Figure 9.6
Subarea 5A Gamma Results
Santa Susana Field Laboratory

U.S. EPA Region 9



Legend

- Static Count Location (Not a GRAY)
- PGRAY Boundary
- Subarea Boundary
- Group Boundary

Buildings

- Demolished
- Existing

Roads

- Primary
- Secondary
- Tertiary

Notes:
GRAY-Gamma Radiation Anomaly
PGRAY-Potential Gamma Radiation Anomaly

PGRAY	Result	Group
5A-1	Not a GRAY	Group A
5A-2	Not a GRAY	Group A
5A-3	Not a GRAY	Group B
5A-4	Not a GRAY	Group B
5A-5	Not a GRAY	Group B
5A-6	Not a GRAY	Group B
5A-7	Not a GRAY	Group B
5A-8	Not a GRAY	Group B
5A-9	Not a GRAY	Group B
5A-10	Not a GRAY	Group B
5A-11	Not a GRAY	Group B
5A-12	Not a GRAY	Group B
5A-13	Not a GRAY	Group B
5A-14	Not a GRAY	Group B
5A-15	Not a GRAY	Group B
5A-16	Not a GRAY	Group B
5A-17	Not a GRAY	Group B
5A-18	Not a GRAY	Group B
5A-19	Not a GRAY	Group B
5A-20	Not a GRAY	Group B
5A-21	Not a GRAY	Group C
5A-22	Not a GRAY	Group C
5A-23	Not a GRAY	Group C
5A-24	Not a GRAY	Group C

N

0 50 100 200
Feet

Total Counts
(Counts per Second)
13300 15100 16900 18700

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section 9\20120710\(9-6)_Gamma_Radiation_Subarea5A_20120712.mxd
7/26/2012 plit

HGL HydroGeoLogic, Inc

Figure 9.7
Subarea 5B Gamma Results
Santa Susana Field Laboratory

U.S. EPA Region 9

Legend

- Static Count Location "Not a GRAY"
- PGRAY Boundary
- Subarea Boundary

Buildings

- Demolished
- Existing

Roads

- Primary
- Secondary
- Tertiary

Notes:
GRAY-Gamma Radiation Anomaly
PGRAY-Potential Gamma Radiation Anomaly

PGRAY	Result	Group
5B-1	Not a GRAY	Not Applicable
5B-2	Not a GRAY	Not Applicable
5B-3	Not a GRAY	Not Applicable
5B-4	Not a GRAY	Not Applicable
5B-5	Not a GRAY	Not Applicable
5B-6	Not a GRAY	Not Applicable

N

0 50 100 200
Feet

Total Count Rate (counts per second)
12700 14100 15500 16900
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section 9\20120710\
(9-7)_Gamma_Radiation_Subarea5B_20120711.mxd
7/26/2012 plit

HGL HydroGeoLogic, Inc

Figure 9.8
Subarea 5C Gamma Results
Santa Susana Field Laboratory

U.S. EPA Region 9

Legend

- Static Count Location "Not a GRAY"
- PGRAY Boundary
- Subarea Boundary

Buildings

- Demolished
- Existing

Roads

- Primary
- Secondary
- Tertiary

Notes:
GRAY-Gamma Radiation Anomaly
PGRAY-Potential Gamma Radiation Anomaly

PGRAY	Result	Group
5C-1	Not a GRAY	Not Applicable
5C-2	Not a GRAY	Not Applicable
5C-3	Not a GRAY	Not Applicable
5C-4	Not a GRAY	Not Applicable
5C-5	Not a GRAY	Not Applicable
5C-6	Not a GRAY	Not Applicable

N

0 50 100 200
Feet

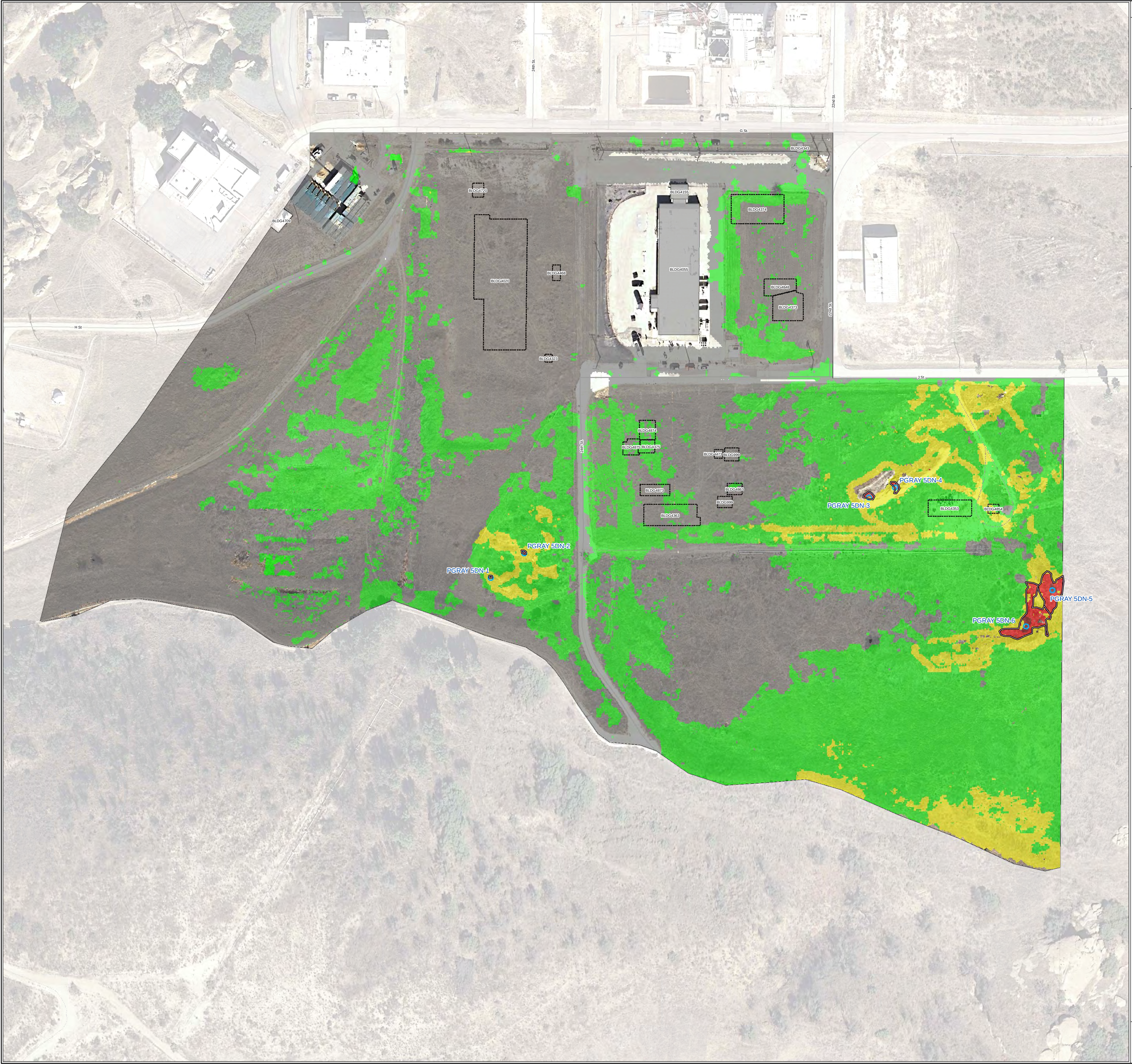
Total Count Rate (counts per second)
12700 14100 15500 16900
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section 9\20120710\
(9-8)_Gamma_Radiation_Subarea5C_20120326.mxd
7/26/2012 plit

HGL HydroGeoLogic, Inc

Figure 9.9
Subarea 5D–North Gamma Results
Santa Susana Field Laboratory

U.S. EPA Region 9



Legend

- Static Count Location "Not a GRAY"
- PGRAY Boundary
- Subarea Boundary

Buildings

- Demolished
- Existing

Roads

- Primary
- Secondary
- Tertiary

Notes:
GRAY-Gamma Radiation Anomaly
PGRAY-Potential Gamma Radiation Anomaly

PGRAY	Result	Group
5DN-1	Not a GRAY	Not Applicable
5DN-2	Not a GRAY	Not Applicable
5DN-3	Not a GRAY	Not Applicable
5DN-4	Not a GRAY	Not Applicable
5DN-5	Not a GRAY	Not Applicable
5DN-6	Not a GRAY	Not Applicable

N

0 50 100 200
Feet

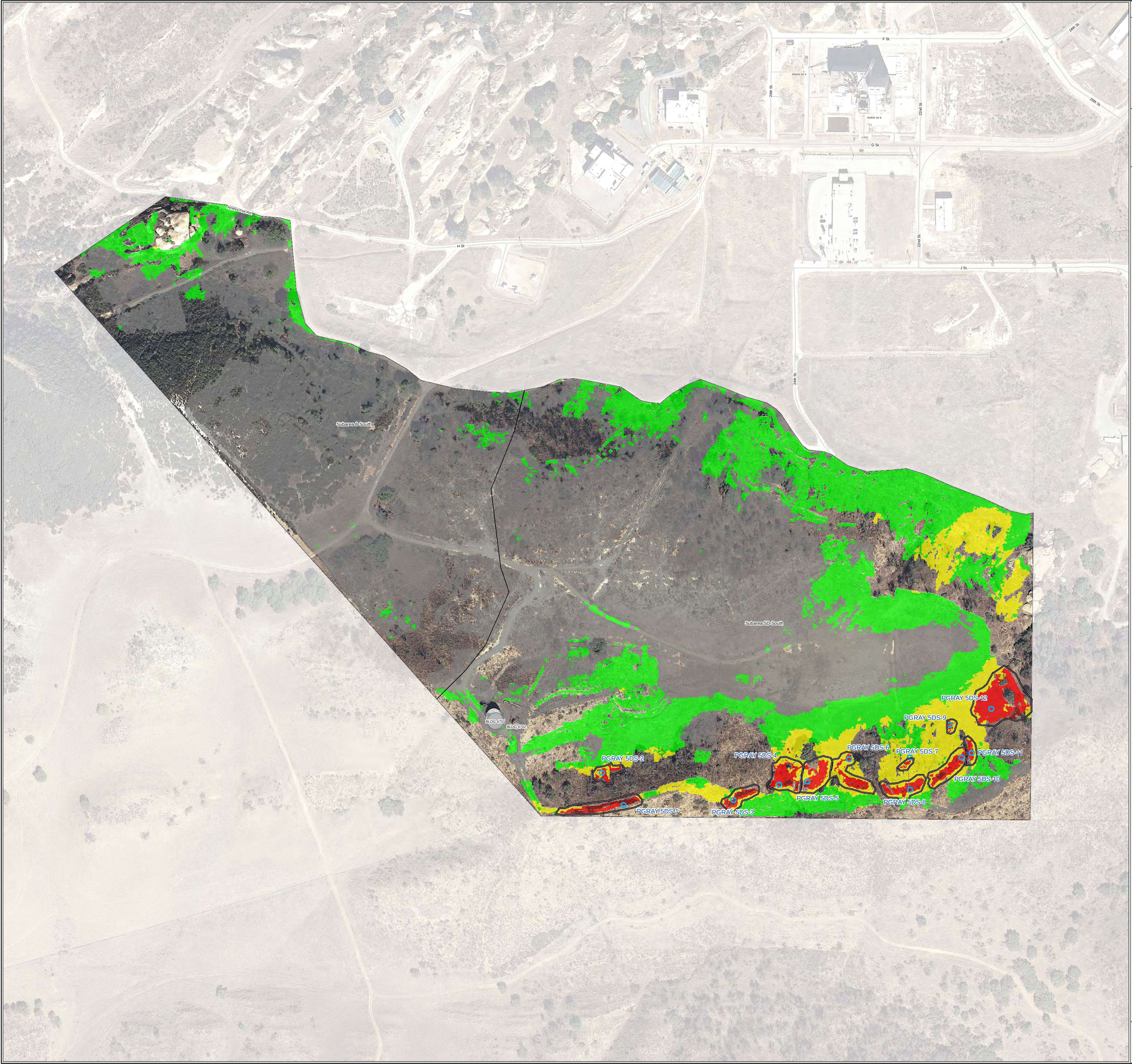
Total Count Rate (counts per second)
12400 13600 14800 16000
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section 9\20120710\(9-9)_Gamma_Radiation_Subarea5DNorth_20120711.mxd
7/27/2012 plit

HGL HydroGeoLogic, Inc

Figure 9.10
Subarea 5D–South and Subarea 8–South Gamma Results
Santa Susana Field Laboratory

U.S. EPA Region 9



Legend

- Static Count Location "Not a GRAY"
- PGRAY Boundary
- Subarea Boundary

Buildings

- Demolished
- Existing

Roads

- Primary
- Secondary
- Tertiary

Notes:
GRAY-Gamma Radiation Anomaly
PGRAY-Potential Gamma Radiation Anomaly

PGRAY	Result	Group
5DS-1	Not a GRAY	Not Applicable
5DS-2	Not a GRAY	Not Applicable
5DS-3	Not a GRAY	Not Applicable
5DS-4	Not a GRAY	Not Applicable
5DS-5	Not a GRAY	Not Applicable
5DS-6	Not a GRAY	Not Applicable
5DS-7	Not a GRAY	Not Applicable
5DS-8	Not a GRAY	Not Applicable
5DS-9	Not a GRAY	Not Applicable
5DS-10	Not a GRAY	Not Applicable
5DS-11	Not a GRAY	Not Applicable
5DS-12	Not a GRAY	Not Applicable

N

0 50 100 200
Feet

Total Count Rate (counts per second)
12000 15000 18000 21000
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section 9\20120710\(9-10)_Gamma_Radiation_Subarea_5ds_8s_20120725.mxd
7/27/2012 plit

HGL HydroGeoLogic, Inc

Figure 9.11
Subarea 7 Gamma Results
Santa Susana Field Laboratory

U.S. EPA Region 9

Legend

Static Count Location (Not a GRAY)

Static Count Location (Confirmed GRAY)

PGRAY Boundary

Subarea Boundary

Group Boundary

Buildings

Demolished

Existing

Roads

Primary

Secondary

Tertiary

Notes:
GRAY-Gamma Radiation Anomaly
PGRAY-Potential Gamma Radiation Anomaly

PGRAY	Result	Group
7-1	Not a GRAY	Group A
7-2	Confirmed GRAY	Group B
7-3	Confirmed GRAY	Group B
7-4	Confirmed GRAY	Group B
7-5	Confirmed GRAY	Group B
7-6	Confirmed GRAY	Group B
7-7	Confirmed GRAY	Group C
7-8	Confirmed GRAY	Group C
7-9	Confirmed GRAY	Group C
7-10	Confirmed GRAY	Group C
7-11	Confirmed GRAY	Group C
7-12	Confirmed GRAY	Group C
7-13	Confirmed GRAY	Group C
7-14	Confirmed GRAY	Group C
7-15	Confirmed GRAY	Group C
7-16	Confirmed GRAY	Group C
7-17	Confirmed GRAY	Group C
7-18	Confirmed GRAY	Group C
7-19	Confirmed GRAY	Group C
7-20	Confirmed GRAY	Group C
7-21	Confirmed GRAY	Group C
7-22	Confirmed GRAY	Group C
7-23	Confirmed GRAY	Group D
7-24	Confirmed GRAY	Group D
7-25	Confirmed GRAY	Group D
7-26	Confirmed GRAY	Group D
7-27	Confirmed GRAY	Group D
7-28	Not a GRAY	Group D
7-29	Confirmed GRAY	Group D
7-30	Confirmed GRAY	Group D
7-31	Confirmed GRAY	Group D
7-32	Confirmed GRAY	Group D
7-33	Confirmed GRAY	Group D
7-34	Confirmed GRAY	Group D
7-35	Confirmed GRAY	Group D
7-36	Confirmed GRAY	Group D
7-37	Confirmed GRAY	Group E
7-38	Confirmed GRAY	Group D
7-39	Confirmed GRAY	Group D
7-40	Not a GRAY	Group E
7-41	Confirmed GRAY	Group E
7-42	Not a GRAY	Group B

N

0 50 100 200
Feet

Lower — Cs-137 Ratio — Higher

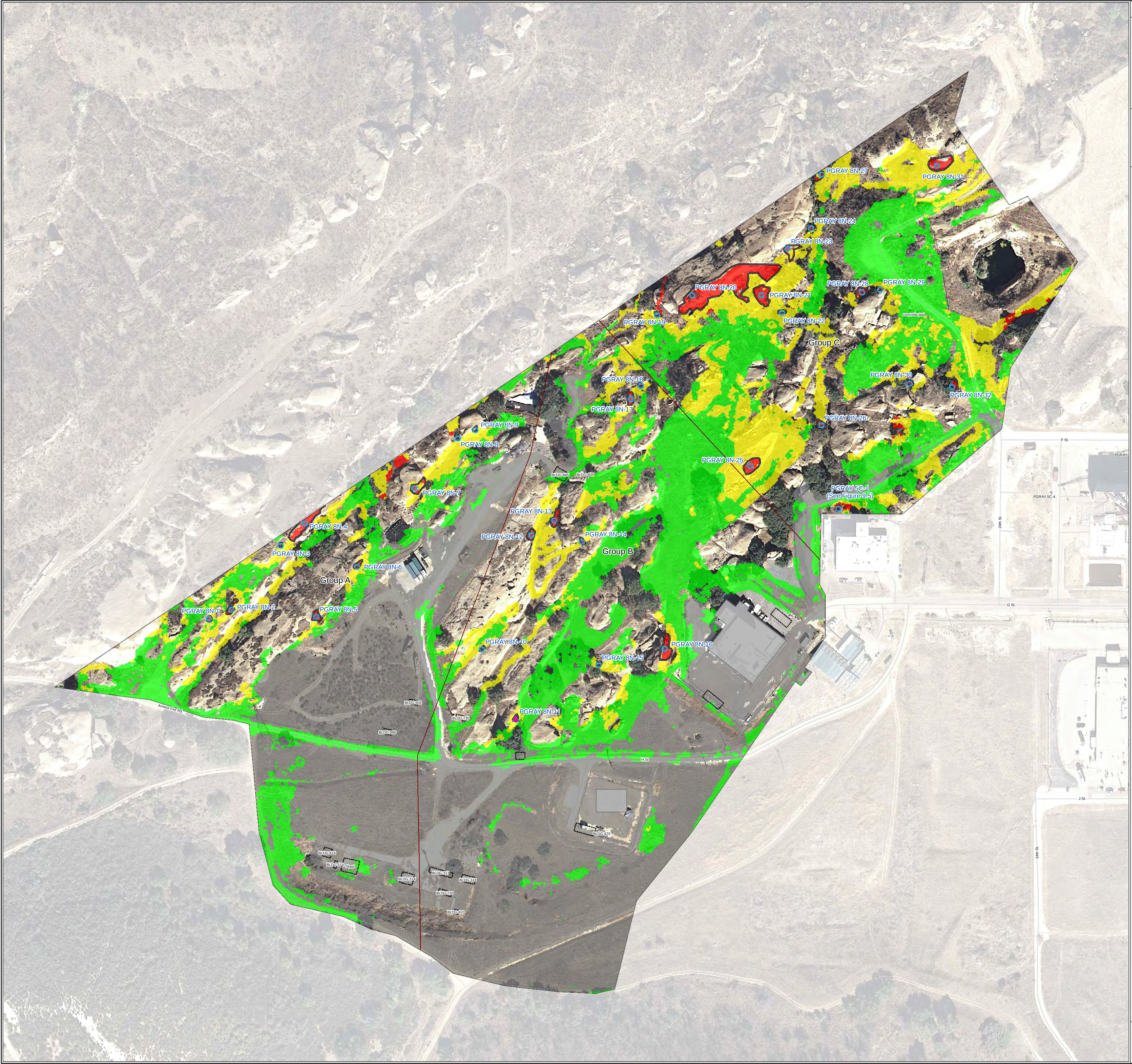
Total Count Rate (counts per second)
13600 15200 16800 18400
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

Y:\Santa_Susana\EP9038\GammaScanning\Report\Section 9\20120710\(9-11)_Gamma_Radiation_Subarea7_20120711.mxd
7/26/2012 plit

HGL HydroGeoLogic, Inc

Figure 9.12
Subarea 8–North Gamma Results
Santa Susana Field Laboratory

U.S. EPA Region 9



Legend

- Static Count Location "Not a GRAY"
- Static Count Location "Confirmed GRAY"
- PGRAY Boundary
- Subarea Boundary
- Group Boundary

Buildings

- Demolished
- Existing

Roads

- Primary
- Secondary
- Tertiary

Notes:
GRAY-Gamma Radiation Anomaly
PGRAY-Potential Gamma Radiation Anomaly

PGRAY	Result	Group
8N-1	Not a GRAY	Group A
8N-2	Not a GRAY	Group A
8N-3	Not a GRAY	Group A
8N-4	Not a GRAY	Group A
8N-5	Not a GRAY	Group A
8N-6	Not a GRAY	Group A
8N-7	Not a GRAY	Group A
8N-8	Not a GRAY	Group A
8N-9	Not a GRAY	Group A
8N-10	Not a GRAY	Group B
8N-11	Confirmed GRAY	Group B
8N-12	Not a GRAY	Group B
8N-13	Not a GRAY	Group B
8N-14	Not a GRAY	Group B
8N-15	Not a GRAY	Group B
8N-16	Not a GRAY	Group B
8N-17	Not a GRAY	Group B
8N-18	Not a GRAY	Group B
8N-19	Not a GRAY	Group C
8N-20	Not a GRAY	Group C
8N-21	Not a GRAY	Group C
8N-22	Not a GRAY	Group C
8N-23	Not a GRAY	Group C
8N-24	Not a GRAY	Group C
8N-25	Not a GRAY	Group C
8N-26	Not a GRAY	Group C
8N-27	Not a GRAY	Group C
8N-28	Not a GRAY	Group C
8N-29	Not a GRAY	Group C
8N-30	Not a GRAY	Group C
8N-31	Not a GRAY	Group C
8N-32	Not a GRAY	Group C

N

0 50 100 200
Feet

Total Count Rate (counts per second)
12000 13800 15600 17400
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

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7/26/2012 plit

HGL HydroGeoLogic, Inc.

Figure 9.13
Northern Buffer Zone Northeast Gamma Results
Santa Susana Field Laboratory

U.S. EPA Region 9

Legend

Static Count Location (Inconclusive or Not a GRAY)

PGRAY Boundary

Subarea Boundary

Buildings

Demolished

Existing

Roads

Primary

Secondary

Tertiary

Notes:
GRAY-Gamma Radiation Anomaly
PGRAY-Potential Gamma Radiation Anomaly

PGRAY	Result	Group
P1D-1	Not a GRAY	Not Applicable

N

0 125 250 500
Feet

Total Count Rate (counts per second)
14000 17000 20000 23000
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

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7/26/2012 plit

HGL HydroGeoLogic, Inc

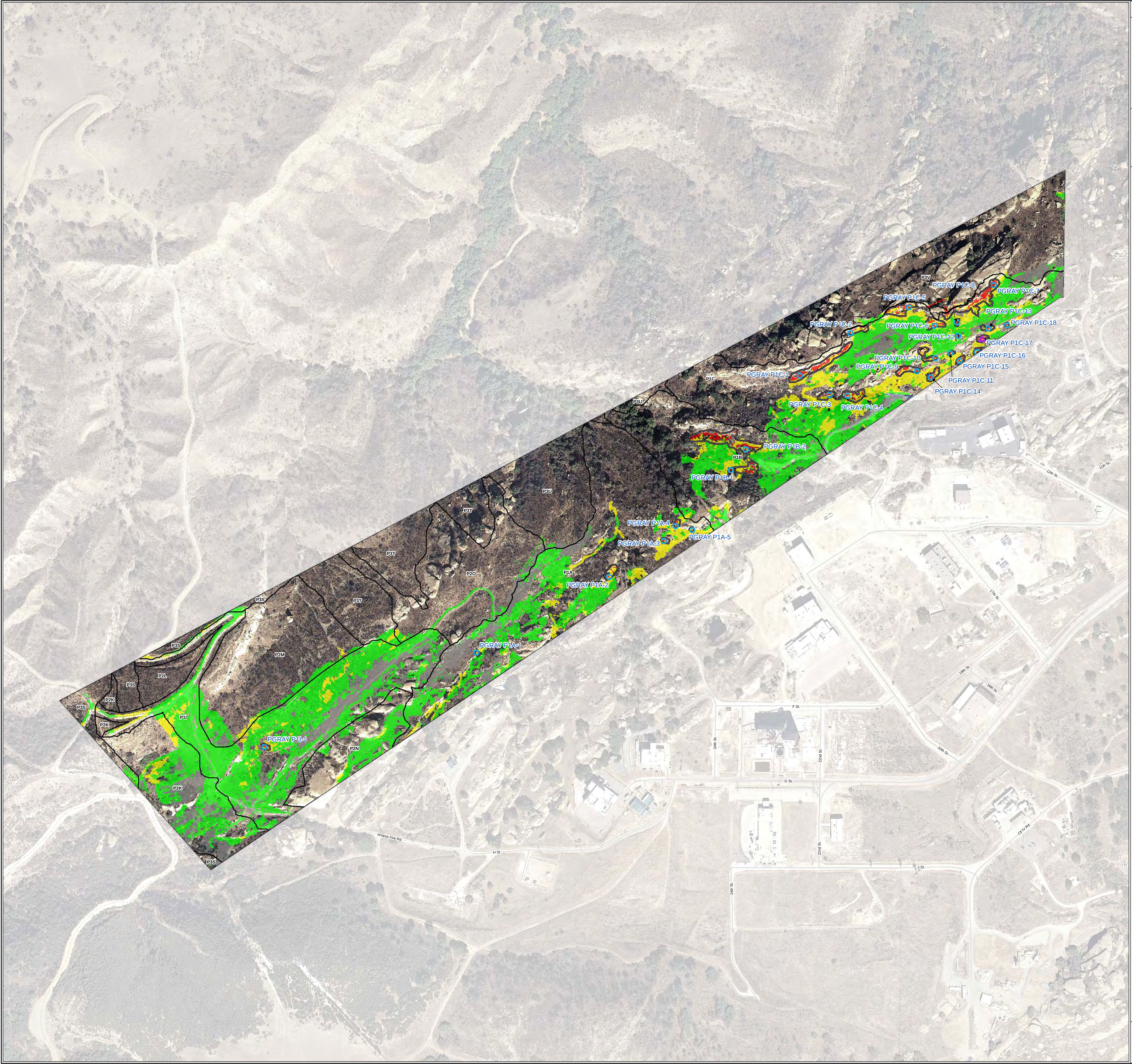

Figure 9.14
Northern Buffer Zone Northwest Gamma Results
Santa Susana Field Laboratory

U.S. EPA Region 9

Legend

- Static Count Location (Inconclusive or Not a GRAY)
- Static Count Location (Confirmed GRAY)
- PGRAY Boundary
- Subarea Boundary

Buildings

- Demolished
- Existing

Roads

- Primary
- Secondary
- Tertiary

Notes:
GRAY-Gamma Radiation Anomaly
PGRAY-Potential Gamma Radiation Anomaly

PGRAY	Result	Group
P1A-1	Not a GRAY	Not Applicable
P1A-2	Not a GRAY	Not Applicable
P1A-3	Not a GRAY	Not Applicable
P1A-4	Not a GRAY	Not Applicable
P1A-5	Not a GRAY	Not Applicable
P1B-1	Not a GRAY	Not Applicable
P1B-2	Not a GRAY	Not Applicable
P1C-1	Not a GRAY	Not Applicable
P1C-2	Not a GRAY	Not Applicable
P1C-3	Not a GRAY	Not Applicable
P1C-4	Not a GRAY	Not Applicable
P1C-5	Not a GRAY	Not Applicable
P1C-6	Not a GRAY	Not Applicable
P1C-7	Not a GRAY	Not Applicable
P1C-8	Not a GRAY	Not Applicable
P1C-9	Not a GRAY	Not Applicable
P1C-10	Not a GRAY	Not Applicable
P1C-11	Not a GRAY	Not Applicable
P1C-12	Not a GRAY	Not Applicable
P1C-13	Not a GRAY	Not Applicable
P1C-14	Not a GRAY	Not Applicable
P1C-15	Not a GRAY	Not Applicable
P1C-16	Not a GRAY	Not Applicable
P1C-17	Confirmed GRAY	Not Applicable
P1C-18	Not a GRAY	Not Applicable
P1I-1	Not a GRAY	Not Applicable

Total Count Rate (counts per second)
13000 15000 17000 19000
0 2 4 6
Standard Deviations Above the Mean Total Count Rate

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(9-14)_Gamma_Radiation_NBZW_20120711.mxd
7/27/2012 plit