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U.S. Nuclear Regulatory Commission
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**SUBJECT: RE-CONFIRMATION SURVEY OF THE SECTION 4 PONDS AREA
AT THE RIO ALGOM AMBROSIA LAKE FACILITY,
AMBROSIA LAKE, NEW MEXICO
DCN: 1797-SR-02-0 (DOCKET NO. 040-8905; RFTA NO. 15-004)**

Dear Dr. McLaughlin:

Enclosed is the subject report detailing the procedures and results of the re-confirmation surveys of the Section 4 Ponds area at the Rio Algom Ambrosia Lake Facility near Ambrosia Lake, New Mexico. A confirmatory survey of this area was initially performed in September of 2009; however, as a result of that initial survey and additional remediation performed by the licensee, re-confirmation of the radiological status was requested. Comments provided on the draft report have been incorporated into this final document.

If you have any questions, please direct them to me at 865.576.5073 or Erika Bailey at 865.576.6659.

Sincerely,

A handwritten signature in blue ink, appearing to read 'Timothy J. Vitkus', is written over a light blue horizontal line.

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TJV:fs

Enclosure

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File/1797



RE-CONFIRMATION SURVEY OF THE SECTION 4 PONDS AREA AT THE RIO ALGOM AMBROSIA LAKE FACILITY, AMBROSIA LAKE, NEW MEXICO

Timothy J. Vitkus

Prepared for the U.S. Nuclear Regulatory Commission

Issued November 2015

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Prepared for the
U.S. Nuclear Regulatory Commission

FINAL REPORT

NOVEMBER 2015

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RE-CONFIRMATION SURVEY OF THE SECTION 4 PONDS AREA
AT THE RIO ALGOM AMBROSIA LAKE FACILITY,
AMBROSIA LAKE, NEW MEXICO

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FINAL REPORT

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ACRONYMS

CFR	Code of Federal Regulations
cpm	counts per minute
CU	confirmatory unit
DCGL	derived concentration guideline level
DP	decommissioning plan
FSS	final status survey
GPS	global positioning system
HQ	headquarters
MDC	minimum detectable concentration
NaI	sodium iodide
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
pCi/g	picocuries per gram
RAM	Rio Algom Mining, LLC
ROC	radionuclide of concern
SOR	sum of ratios
TAP	total absorption peak
UMTRCA	Uranium Mill Tailings Radiation Control Act



**RE-CONFIRMATION SURVEY OF THE SECTION 4 PONDS AREA
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EXECUTIVE SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) requested that ORAU, working under the Oak Ridge Institute for Science and Education (ORISE) contract, perform an independent re-confirmation of the Rio Algom Mining, LLC (RAM) Ambrosia Lake site Section 4 Ponds area. The area contained former evaporation ponds for managing tailings waste material generated from the uranium ore processing formerly conducted at the site. ORAU performed the initial Section 4 confirmatory survey during 2009. The results of that survey identified residual contamination in excess of the Section 4 surface soil cleanup levels. Subsequently, RAM performed additional site surveys and remediation and NRC requested that ORAU conduct a second confirmatory survey, which is the subject of this report. The survey was performed August 17–20, 2015.

This second ORAU confirmatory survey consisted of gamma radiation surface scans of 36 random and 5 judgmental 35 meter \times 35 meter (1,225 m²) confirmatory units (CUs) within the 103 hectare (256 acre) Section 4 Ponds area. These surface scans identified multiple gamma radiation anomalies indicative of potentially elevated radionuclide concentrations. Once gamma scans were completed within each of the selected units, five-increment composite samples were collected and analyzed. The gamma spectroscopy analysis of samples determined that the 100 m² average Th-230 concentration in 19 of 41 samples exceeded the area-specific release limit of 17 pCi/g averaged over an area of 100 m². The Ra-226 cleanup limit was also exceeded in 1 of these 19 samples and also in 1 additional sample. The concentrations in 2 additional samples were such that the SOR exceeded 1. Therefore, 22 of the 41 CUs were identified as containing 100 m² areas in excess of the surface soil cleanup limits based on individual ROC concentrations or as a result of an SOR equal to or greater than 1. Furthermore, because more than 50% of the confirmatory survey units contained residual contamination in excess of the surface soil cleanup levels, there is a high probability that there are multiple, as yet unidentified areas that would also likely exceed the cleanup levels and/or the unity rule.



**RE-CONFIRMATION SURVEY OF THE SECTION 4 PONDS AREA
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1. INTRODUCTION AND SITE HISTORY

The Rio Algom Mining, LLC (RAM) Ambrosia Lake site began processing uranium-bearing ore in 1958. Operating under the U.S. Nuclear Regulatory Commission (NRC) Source Material License SUA-1473, the site processed approximately 33 million tons of ore through 1985 and continued to be an active uranium production facility through December 2002. Reclamation of the uranium mill tailings began in 1989 and included the excavation and disposal of unlined evaporation pond residues, contaminated soil cleanup, construction of surface water erosion protection features, and the demolition of the mill buildings (NRC 2006). Construction of the Section 4 evaporation ponds, which are separated from the plant main site by a state highway, commenced in 1976 and was completed in 1979. The ponds were lined and used to evaporate liquid waste generated from RAM's processing mill and remained active until April 2004.

On January 19, 2005, the RAM submitted a soil decommissioning plan (DP) for its Ambrosia Lake uranium mill tailings facility, specifically the evaporation ponds, to the NRC. The NRC requested, in several comment letters, that RAM provide additional information and a revised plan (NRC 2006). RAM issued a revised DP that addressed the methods and procedures that would be implemented to ensure soil remediation would meet the requirements of the Uranium Mill Tailings Radiation Control Act (UMTRCA) and NRC regulations contained within the Code of Federal Regulations (CFR) Title 10, Part 40, Appendix A. The DP presented the geographical site, pertinent background information, and the design for surface reclamation of the Section 4 and Pond 9 evaporation pond sediment material. These sediment materials are considered byproduct material as defined by the Atomic Energy Act of 1954. As per the CFR requirements, the DP addressed the disposal of the uranium mill tailings in a manner that protects human health and the environment (NRC 2006). Section 4 reclamation activities included excavating the pond and contaminated soil and relocating the material to the main tailings disposal area (KOMEX 2006). In addition to the Section 4 Ponds area, the site has been performing reclamation activities of unlined evaporation pond residues, contaminated soil clean-up, completion of the majority of the required reclamations for

Impoundments 1 and 2, construction of a rock apron on Impoundment 2, demolition of the conventional milling structures and most support facilities, and the construction of erosion protection features adjacent to the tailings disposal facility.

In 2009, NRC Headquarters (HQ) and Region IV requested that ORAU, via the Oak Ridge Institute for Science and Education (ORISE) contract, perform an initial confirmatory radiological survey of the Section 4 Ponds area after RAM had completed the remediation and final status surveys (FSS). ORAU's independent data did not support the licensee's results, relative to the site's NRC-approved clean-up criteria, finding instead that the estimated mean concentration of residual contamination exceeded the release limit (ORISE 2010). As a result, the licensee has performed additional remediation and re-performed the FSS; the NRC subsequently requested that ORAU perform follow-on confirmatory surveys at the RAM Ambrosia Lake facility in Ambrosia Lake, New Mexico.

2. SITE DESCRIPTION

RAM's Ambrosia Lake site is located in the Ambrosia Lake mining district in the southeastern part of McKinley County, New Mexico, approximately 25 miles north of Grants, New Mexico (Figure A-1). The Grants Uranium Belt, specifically the Ambrosia Lake mining district, had numerous mining companies which operated two uranium ore processing mills and over 20 underground uranium mines within the Ambrosia Lake valley. Forty years of mining and milling activities throughout the valley has led to extensive surface disturbance within the area. The Section 4 Ponds, consisting of Ponds 11 through 21, are located entirely within Section 4 along the southeastern portion of the site. Overall, the Section 4 Ponds area occupies 103 hectares (256 acres). Figures 2.1a and b show aerial views of RAM together with an expanded, recent view of the Section 4 Ponds area.

Residual contamination in excess of the release limits was identified during the 2009 confirmatory survey within former Ponds 13, 17, 20, and 21. The maximum residual contamination levels identified were within the bounds of the former Pond 13.

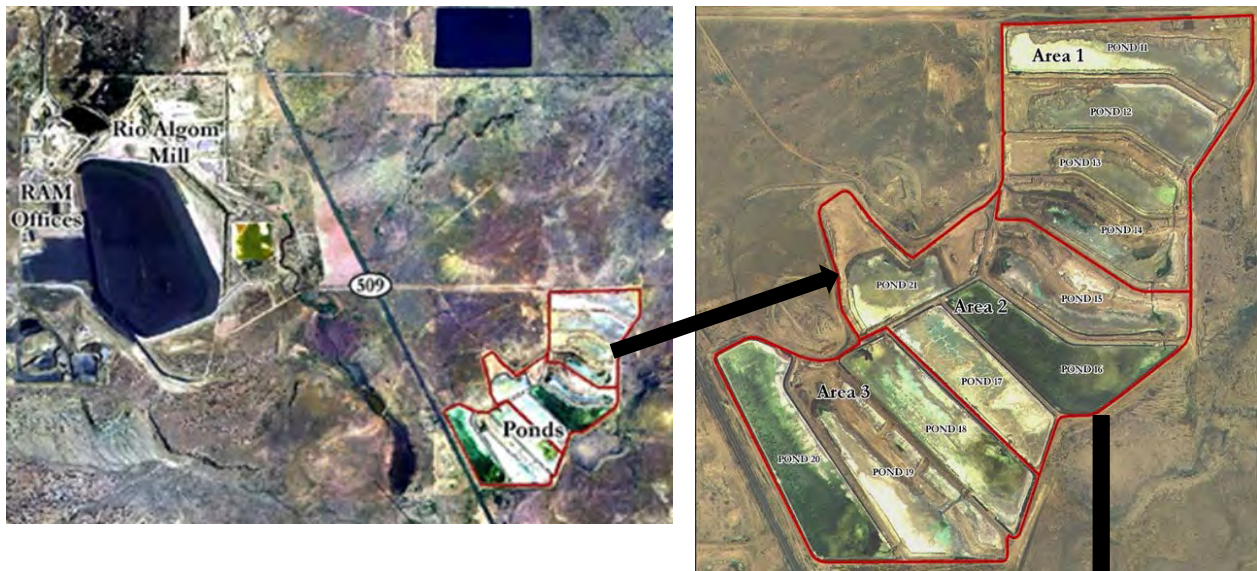


Figure 2.1a. Rio Algom Mining, LLC Mill Site and Section 4 Ponds, Ponds 11 - 21 (2005 Aerial View)



Figure 2.1b. Rio Algom Mine and Location of Section 4 Ponds Area (2012 Aerial View)

3. OBJECTIVES

There were three primary objectives of this follow-up confirmatory survey.

1. The first objective was to verify that the licensee had adequately assessed and remediated, when necessary, Section 4 areas of residual contamination identified during the initial 2009 confirmatory activities.
2. As the 2009 confirmation evaluated a random population of 100 m² areas—54 locations surveyed from which 18 were sampled—represented less than 1% of the Section 4 footprint, the second objective was to provide assurance that the licensee had also fully investigated Section 4 to identify and address any remaining locations where radionuclides of concern (ROCs) concentrations exceeded the release limits that were not subject to 2009 confirmatory surveys.
3. The third objective was to provide the NRC with independent radiological data to assess whether the licensee's documentation accurately and adequately describes the final radiological conditions of the RAM Ambrosia Lake, Section 4 Ponds area.

4. DOCUMENT REVIEW

ORAU reviewed RAM's most recent preliminary gamma radiation survey data and soil sample analytical results for compliance with the soil decommissioning plan commitments. The data provided for review consisted of gamma radiation scan maps, spreadsheets with recent soil sampling analytical results together with the required sum-of-fractions (also referred to sum-of-the-ratios or unity rule) calculations, and sample coordinates and identification numbers. The gamma radiation scan data were dichromatically binned as being either less than or equal (\leq) to or greater ($>$) than 21,000 counts per minute (cpm). The $>21,000$ cpm bin was used to highlight those locations that exceeded the site-specific gamma radiation count rate to Ra-226 concentration correlation. These RAM data and results were used as inputs for the confirmatory survey planning, as discussed in Section 5.



5. PROCEDURES

ORAU personnel mobilized to the RAM site during the period of August 17–20, 2015, to perform visual inspections and independent measurements and sampling of the Section 4 Ponds area. The confirmatory survey activities were conducted in accordance with a plan dated August 2015, that was submitted to and approved by the NRC, and the *ORAU Radiological and Environmental Survey Procedures Manual* and the *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORAU 2015a, 2015b, and 2015c).

RAM has delineated the areas into milling-affected areas, unaffected areas, and mining-affected areas. Areas not expected to contain radioactive contamination attributable to licensed activities and that have not been impacted by mining activities were classified as unaffected areas (natural background). Unaffected areas were generally located upwind and possessed natural background concentrations of ROCs and gamma radiation levels. Mining-affected areas are those areas near the site that were unaffected by *milling-related* activities but where soils have been affected by *mining-related* activities (non-11e.(2) material). Milling-affected areas, which include the 11 former evaporation ponds in Section 4 where this confirmatory survey was conducted, were known to, or may have been, impacted by the site's licensed milling operations.

To ensure systematic coverage and to reevaluate the radiological status of the entire Section 4 Ponds area, ORAU reassessed each of the three confirmatory survey sub-areas that were established for the 2009 effort. These sub-areas and the former ponds associated with each are:

1. Area 1: Ponds 11–14
2. Area 2: Ponds 15–17 and 21
3. Area 3: Ponds 18–20

ORAU implemented both a systematic and a judgmental confirmatory investigation as described below. The results of the confirmatory data assessments are discussed in the Findings and Results section of this report.

5.1 REFERENCE SYSTEM

Global positioning system (GPS) coordinates were used for referencing measurement and sampling locations. The specific reference system used was the New Mexico State Plane Coordinate System (NAD 27 horizontal), the same coordinate system that RAM has applied.

5.2 CONFIRMATORY UNIT AREA SELECTION

ORAU used the 2014 RAM Section 4 sampling results to estimate the ROCs mean and variability within Section 4. The RAM analytical data provided the Ra-226, Th-230, and the U-238 concentrations for 98 composite samples. Based on the provided data, the number of samples/areas that were required to estimate the upper 95% confidence interval of the mean for each sub-area was calculated to be 11, for a total of 33 locations. Visual Sample Plan v.7.4 was used to distribute the planned locations on a geo-referenced map in a random-start/systematic fashion. Based on the random-start location and available spacing, 36 locations were ultimately plotted across the entirety of the Section 4 Ponds area. In addition to these random locations, five of the random locations identified during the 2009 survey that exceeded the cleanup levels were selected for re-investigation. Once plotted on a geo-referenced map, ORAU bounded each location with a 35 meter \times 35 meter polygon (1,225 m²) to demarcate the planned confirmatory unit (CU) area for each location. The size of the CUs selected was based on maximizing the total area that could be investigated within the allotted confirmatory survey time. Figure A-2 shows the systematic confirmatory locations evaluated during this survey, as well as the previous soil sample locations (S002, S005, S008, S011, and S013) from the 2009 survey that exceeded the soil cleanup levels at that time and were therefore selected for reinvestigation. One of the planned CUs for this current investigation that is shown on Figure A-3 and others, CU S0029, was inaccessible for survey due to steep terrain and overgrowth. The CU S0029 location was judgmentally replaced with a location adjacent to, and identified while navigating to, CU S0032 during the survey implementation. Figure A-14 shows the CU S0029 replacement area that was surveyed.

5.3 GAMMA RADIATION SURFACE SCANS

Medium- to high-density gamma radiation surface scans were conducted over the soil surface within, and in several cases extending past, most selected 1,200 m² areas. Those CUs with heavy brush overgrowth or extensive standing water could only be scanned at a lower density. Additional low-density gamma radiation surface scans of the Section 4 surface soils were performed as ORAU personnel navigated to each coordinate. For qualitative comparison purposes, background gamma count rate surface scan data were also collected from an area outside of the Section 4 impacted zone. The background location selected was in the least prominent wind direction based on local meteorology and outside of mine water impacted areas. The area where direct gamma radiation counts were considered most representative of the site background was selected based on professional judgment and local, historical wind patterns.

Surface scans were performed using sodium iodide (NaI) scintillation detectors coupled to ratemeter-scalers with audible indicators. Detectors were also coupled to GPS systems that enabled real-time gamma count rate and position data capture. Locations of elevated radiation, suggesting the presence of residual contamination, were marked and identified for direct gamma radiation measurements and sampling.

Gamma radiation scan paths for 35 of the 41 scanned CUs are provided as available in Figures A-3 through A-43. A data cable malfunction prevented the capture of complete data in the remaining six CUs, specifically CUs S0005, S0032, S0042, S0043, S0047, and S0056. Figures A-44 through A-46 show overviews of the gamma scans for Areas 1–3. These figures are provided to present those data that were logged while navigating to the next CU.

5.4 GAMMA DIRECT MEASUREMENTS

Within each 1,200 m² CU, the 100 m² area exhibiting the highest observed gamma radiation levels or visual differences (as observed and documented during the 2009 confirmatory survey) were selected for static gamma direct measurements and subsequent sampling. These gamma measurements were performed at the center of each 10 m × 10 m area.

5.5 SOIL SAMPLING

A composite soil sample was collected from each 100 m² area. The composite sample was formed by collecting equal volume, 0–15 centimeter deep aliquots, at the center and at four points equidistant from the center and corners of each 100 m² area. As the site's cleanup levels include contributions from background concentrations of the ROCs, background soils samples were not collected.

Table B-1 provides the sample number and coordinates for the central point of each area sampled. Figures A-3 through A-43 show the sampling location and whether the sample was collected systematically from the center of the CU or from a judgmental (biased) location based on the gamma surface scan results.

6. SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data were returned to the Radiological and Environmental Analytical Laboratory in Oak Ridge, Tennessee for analysis and interpretation. Sample analyses were performed in accordance with the *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2015d). Soil samples were analyzed by solid-state gamma spectroscopy for Ra-226, Th-230, U-235, and U-238. The spectra were also reviewed for other identifiable photopeaks. In particular, for those ROCs characterized by multiple direct or progeny photopeaks (e.g., Ra-226 by the 185 keV peak and its progeny Pb-214 351 keV peak) the photopeaks were compared for concentration consistency to identify those photopeaks that may have had interference by the presence of one or more of the other ROCs. Analytical results were reported as gross concentrations in units of picocuries per gram (pCi/g).

Gamma spectroscopy sample count times were a minimum of four hours to ensure analytical minimum detectable concentrations (MDC) were a fraction of the cleanup levels for all ROCs. Samples were also recounted after 28 days to allow for in-growth and re-equilibrium between radon and the short-lived progeny that are used to quantify Ra-226. Appendix D provides the representative MDCs achieved as well as additional information on survey and analytical procedures.

7. APPLICABLE SITE GUIDELINES

The soil data generated were compared with the NRC-approved soil cleanup levels established for the RAM Ambrosia Lake Section 4 Ponds area and with the RAM FSS data. The applicable site-specific cleanup levels for the ROCs are provided in Table 7.1.

Table 7.1. Rio Algom Mining Surface Soil Cleanup Levels	
Radionuclide	Soil Guidelines (pCi/g) ^{a,b}
Total uranium	38
Th-230	17 ^c
Ra-226	7

^aCleanup levels from Section 8: *Final Status Survey Plan within the Soil Decommissioning Plan* (KOMEX 2006). These values include background.

^bGuidelines are based on the average concentrations per 100 m² area

^cSection 8.1.1.3 initial Th-230 cleanup level was 14 pCi/g. As this level did not include background, the Th-230 cleanup level was revised to 17 pCi/g (RAM 2008).

To demonstrate compliance, each radionuclide concentration should be less than its respective cleanup level as well as application of the unity rule. The unity rule, also referred to as the sum-of-the-ratios (SOR), requires that the sum of the concentration (C) of each contaminant divided by the respective derived concentration guideline level (DCGL)—cleanup level may be substituted for DCGL in the case of RAM—be less than 1 in accordance with the following equation.

$$SOR = \sum_{j=0}^n \frac{C_j}{DCGL_j}$$

8. FINDINGS AND RESULTS

The results for each of the verification activities are discussed below.

8.1 DOCUMENT REVIEW

The ORAU reviews of project documentation determined that RAM had identified 2 out of 98 composite samples from their 2014 FSS sampling campaign where a result exceeded the SOR limit

of 1. ORAU has not received any formal documentation regarding action that RAM may have taken to address the 2 samples that exceeded the SOR of 1.

The Section 4 Ponds area RAM gamma radiation scan data that consisted of plotted gamma radiation levels in counts per minute (cpm) were dichromatically binned to highlight areas greater than 21,000 cpm. RAM had established this gamma count rate as the correlation threshold to identify contaminated soils that would exceed the Ra-226 cleanup limit. However, based on both the 2009 and this confirmatory survey, Th-230 is the predominant ROC based on relative concentration ratios. Additionally, Th-230 is also the more difficult of the site ROCs to detect because of the low abundance, low-energy gamma emissions characteristic of Th-230. Based on these two factors, reliance upon a Ra-226 concentration to gamma radiation count rate correlation to guide remediation and sampling was not considered adequate to demonstrate cleanup level compliance for the current state of the Section 4 Ponds area.

8.2 GAMMA RADIATION SURFACE SCANS

Figures A-3 through A-43 show the gamma radiation surface scan results in cpm for all CUs where the electronic data were successfully logged. The gamma count rate data are plotted as a function of the average, observed local background and binned based on the standard deviation below or above the mean and normalized between CUs via z-scoring. The Section 4 Ponds area 99th percentile ambient background gamma radiation population ranged from <8,200 to 18,400 cpm and averaged approximately 13,000 cpm. The off-site background area data ranged from 6,200 to 15,500 cpm and averaged 11,000 cpm. Areas of the site exhibiting gamma radiation levels generally in excess of 18,000 cpm were considered anomalous and subjected to bias (judgmental) sampling. However, there were CUs where the ambient background was generally lower than this threshold and suspect anomalies were judgmentally sampled. The maximum count rates of >75,000 cpm were observed in CU S0058 in the northeast corner of sub-area 1 (Figure A-43). For those CUs where data were not logged or not completely logged, the presence or absence of elevated direct gamma radiation levels within these CUs may be established based on the type of sample indicated in the figure legend, “Systematic” indicates that the gamma radiation levels were comparable to the ambient background count rate and “Bias” indicates that elevated direct gamma radiation levels were identified within the CU. Section 8.3 discusses the direct gamma measurements collected. Furthermore, as previously

discussed and illustrated on Figures A-44 through A-46, surveyors noted multiple other elevated gamma radiation anomalies while traversing the surfaces between CUs that were not investigated. The data points between CUs with gamma count rates above approximately 18,000 cpm—the background mean plus 3 sigma upper tail—are indicative of potential residual contamination and have been highlighted with red shading on Figures A-44 through A-46.

8.3 GAMMA DIRECT MEASUREMENTS

Table B-1 provides the static gamma one-minute count results for the static measurements made at contact with the soil at the center of each sampled 100 m² area. These counts reflect the results observed during the surface scans and ranged from 10,711 to 88,057 cpm. For those CUs where gamma scan data were not captured—S0005, S0032, S0042, S0043, S0047, and S0056—the maximum observed gamma radiation levels from Table B-1 are provided in Table 8.1.

Table 8.1. Maximum Observed Gamma Radiation Levels					
Confirmatory Unit ID					
S0005B	S00032B	S0042S	S0043S	S0047S	S0056B
Gamma Direct Measurement (cpm)					
21,283	27,887	12,789	14,800	14,459	14,958

S = systematic sample

B = bias sample

8.4 RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES

Individual composite sample results for Ra-226, Th-230, U-235, U-238, and total-uranium are provided in Appendix B. Table 8.2 provides the summarized data for Ra-226, Th-230, and the total uranium concentrations by sub-area.

Table 8.2. Summary of Radionuclide Concentrations in Composite Samples

Survey Areas by Ponds	Radionuclide Concentrations (pCi/g)			
	Ra-226	Th-230	Total Uranium	SOR
Area 1: Ponds 11–14	0.71 to 23.4	1.9 to 1,250	2.0 to 19.6	0.27 to 77.4
<i>Mean Concentration</i>	3.5	151	8.0	9.6
Area 2: Ponds 15–17, 21	0.78 to 3.14	-0.1 to 174	2.3 to 34.6	0.23 to 11.6
<i>Mean Concentration</i>	1.4	22.2	7.2	1.7
Area 3: Ponds 18–20	0.848 to 8.24	0.1 to 301	1.9 to 19.3	0.38 to 18.7
<i>Mean Concentration</i>	3.0	100.4	9.1	6.6

9. COMPARISON OF RESULTS WITH GUIDELINES

In total, 20 composite samples contained concentrations above one or more of the ROC cleanup limits. The 17 pCi/g Th-230 cleanup level was exceeded in 19 of the 41 composite samples collected. The Ra-226 cleanup limit was also exceeded in 1 of these 19 samples—sample number 1797S0058. The Ra-226 cleanup limit was exceeded in 1 additional sample. The concentrations in 2 additional samples were such that the SOR exceeded 1. Therefore, 22 of the 41 CUs were identified as containing 100 m² areas in excess of the surface soil cleanup limits based on individual ROC concentrations or as a result of an SOR equal to or greater than 1. Three of the SOR exceedances were from composite samples collected at the systematic center of CUs, with the remainder collected from locations with detectable elevated direct gamma radiation levels. Figure A-47 provides a posting plot of the SOR results.

On-site discussions with the licensee and the NRC Region IV representative indicated that the north-eastern area of Section 4 could have been impacted by mine wastes. Therefore, individual radionuclide concentrations were also examined to confirm that uranium processing tailings were the source of the observed elevated activity concentrations, or potentially the result of mine waste (unprocessed uranium) migration into the Section 4 Ponds area in the vicinity of sample location 1797S0058. Contamination consistent with mine wastes would be expected to exhibit similar activity concentrations of U-238, Th-230, and Ra-226 when secular equilibrium exists, where the Th-230 and Ra-226 activity ratios to U-238 are essentially 1:1. The ratios in confirmatory sample 1797S0058

were 140:1 and 2.6:1 for Th-230 to U-238 and Ra-226 to U-238, respectively. These ratios are indicative of tailings.

10. SUMMARY

At the request of the NRC, ORAU conducted confirmatory surveys of the Section 4 Ponds area at the Rio Algom Mining, LLC Ambrosia Lake site during the period of August 17–20, 2015. The survey activities included visual inspections, gamma radiation surface scans, the collection of composite soil samples, and the laboratory analysis of the samples. Confirmatory activities also included the review and assessment of the licensee’s project documentation for the additional final status surveys performed in 2014. Those additional activities were the result of ORAU’s 2009 confirmatory survey findings and results.

This confirmatory survey determined that of the 41 confirmatory units investigated, more than half (22) contained areas of residual contamination that exceed the established limits. Based on the systematic confirmatory investigation of a sample population and the spatial distributions of confirmatory samples where individual or collective radionuclide concentrations exceeded cleanup criteria, there is a high probability that numerous other as-yet unidentified locations in excess of the cleanup limits exist over all portions of the Section 4 Ponds area. A potential root cause as to why the licensee did not identify the residual contamination may be a result of the reliance upon the Ra-226 gamma radiation to cleanup limit correlation, when Th-230 is the now the primary ROC. ORAU’s independent conclusion is that the Section 4 Ponds area does not meet the decommissioning plan requirements for release from radiological controls.



11. REFERENCES

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RAM 2008. Letter from T. Fletcher (RAM) to T. McLaughlin (NRC). RE: *License SUA-1473, Docket No. 40-8905, Clarification Soils Decommissioning Plan*. Rio Algom Mining LLC. Grants, New Mexico. October 15.

APPENDIX A FIGURES



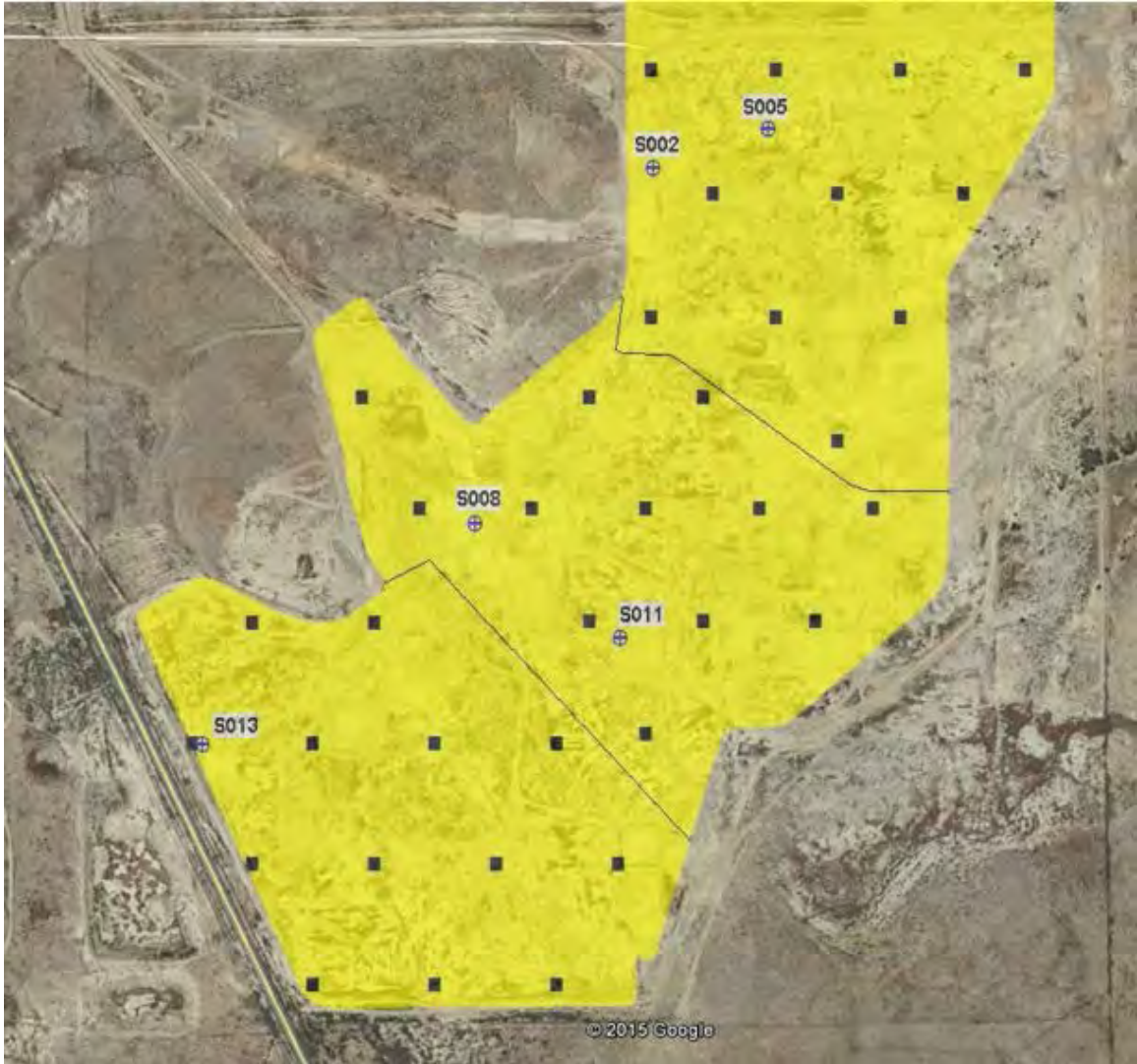


Figure A-2. Section 4 Ponds Area, Planned Systematic and Judgmental Investigation Locations

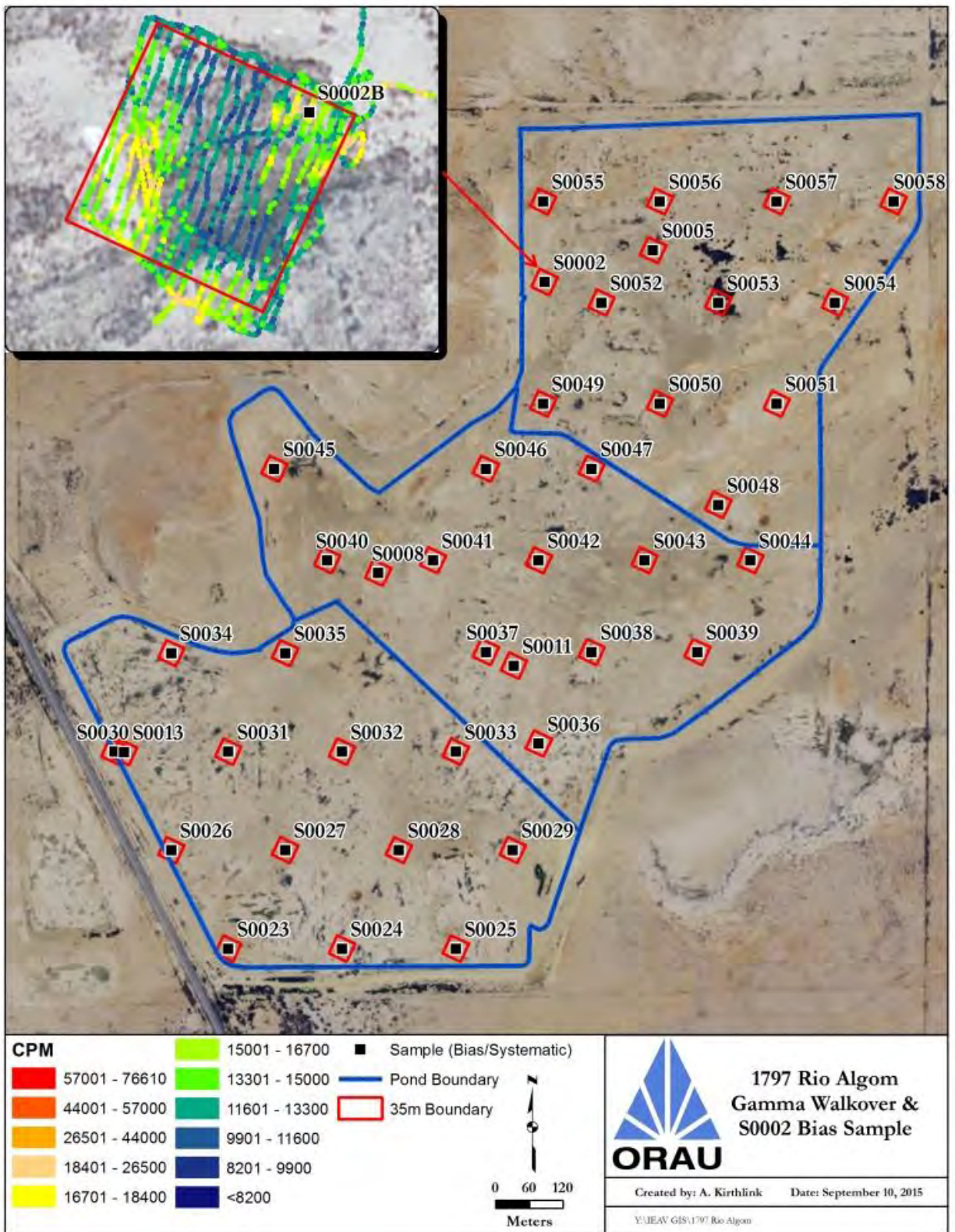


Figure A-3. CU S0002: Gamma Radiation Scans and Sample Location

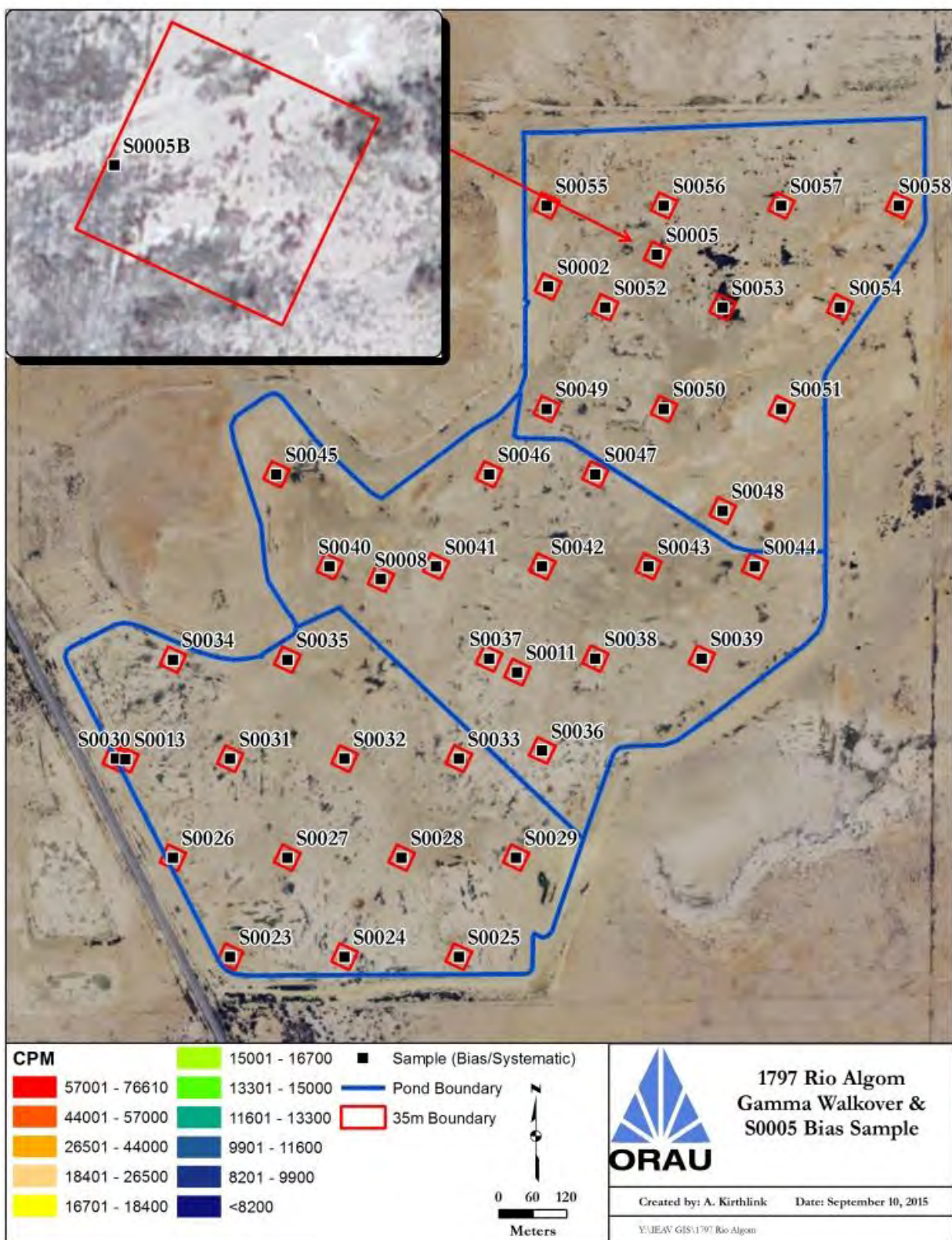


Figure A-4. CU S0005: Sample Location

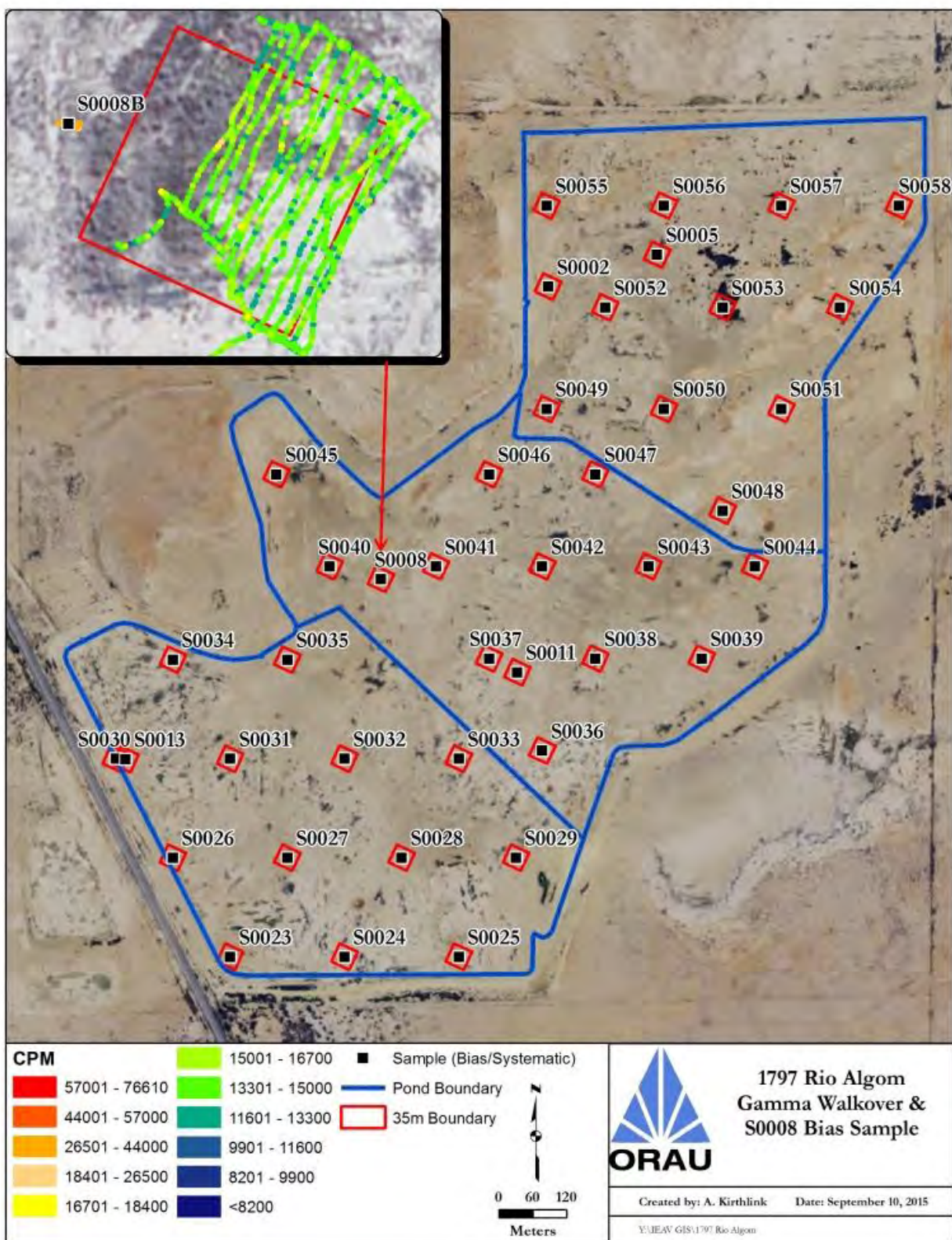


Figure A-5. CU S0008: Gamma Radiation Scans and Sample Location

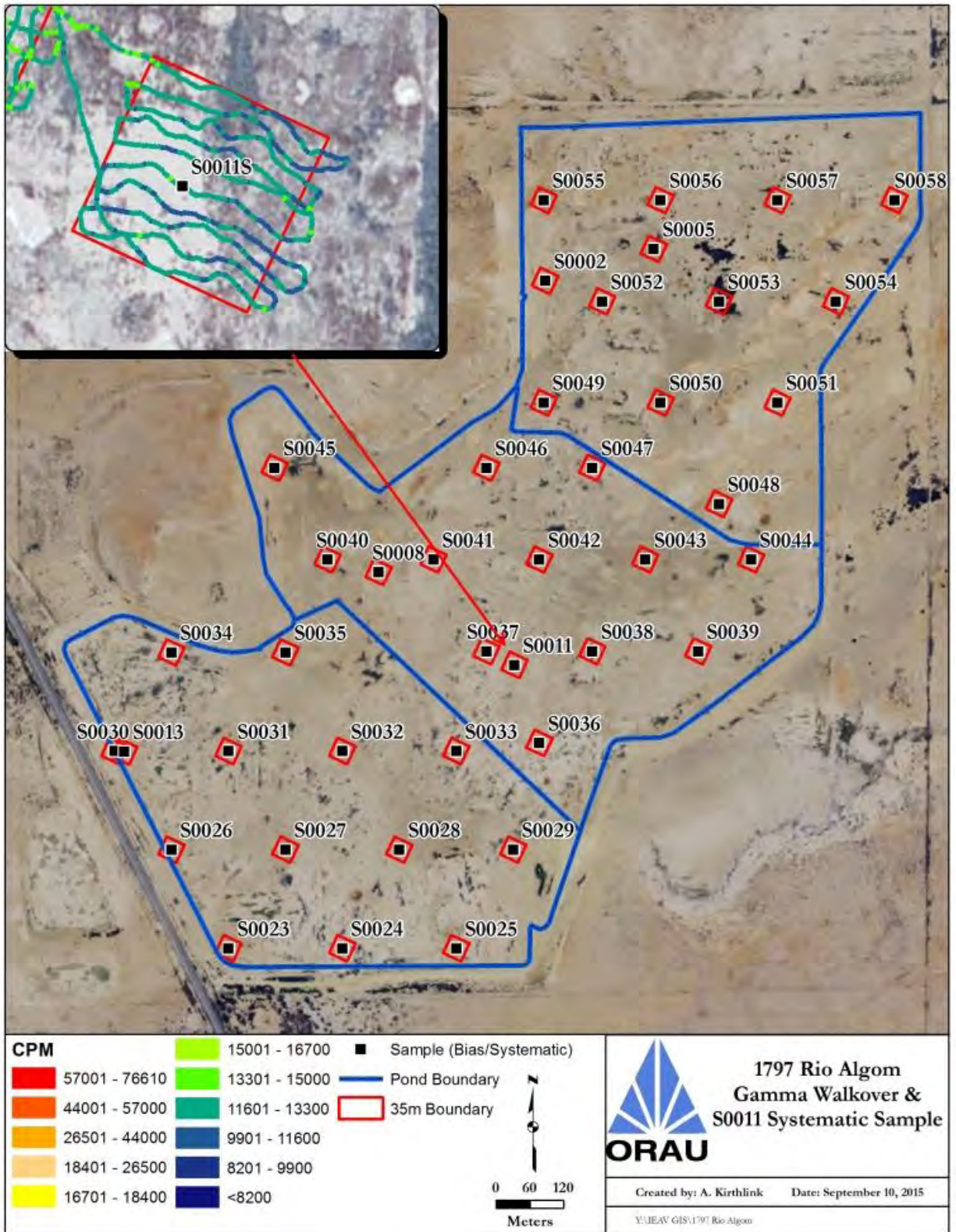


Figure A-6. CU S0011: Gamma Radiation Scans and Sample Location

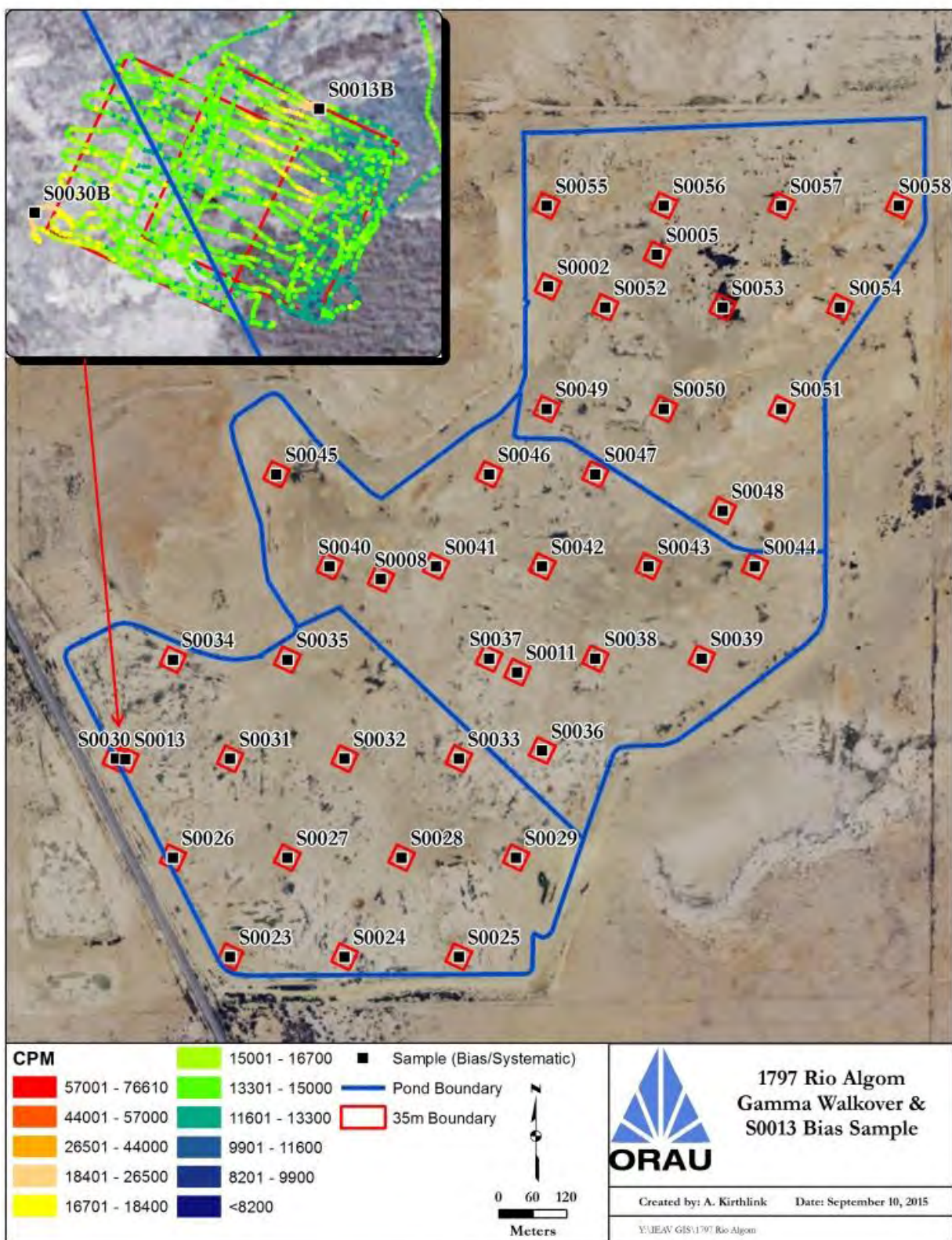


Figure A-7. CU S0013: Gamma Radiation Scans and Sample Location

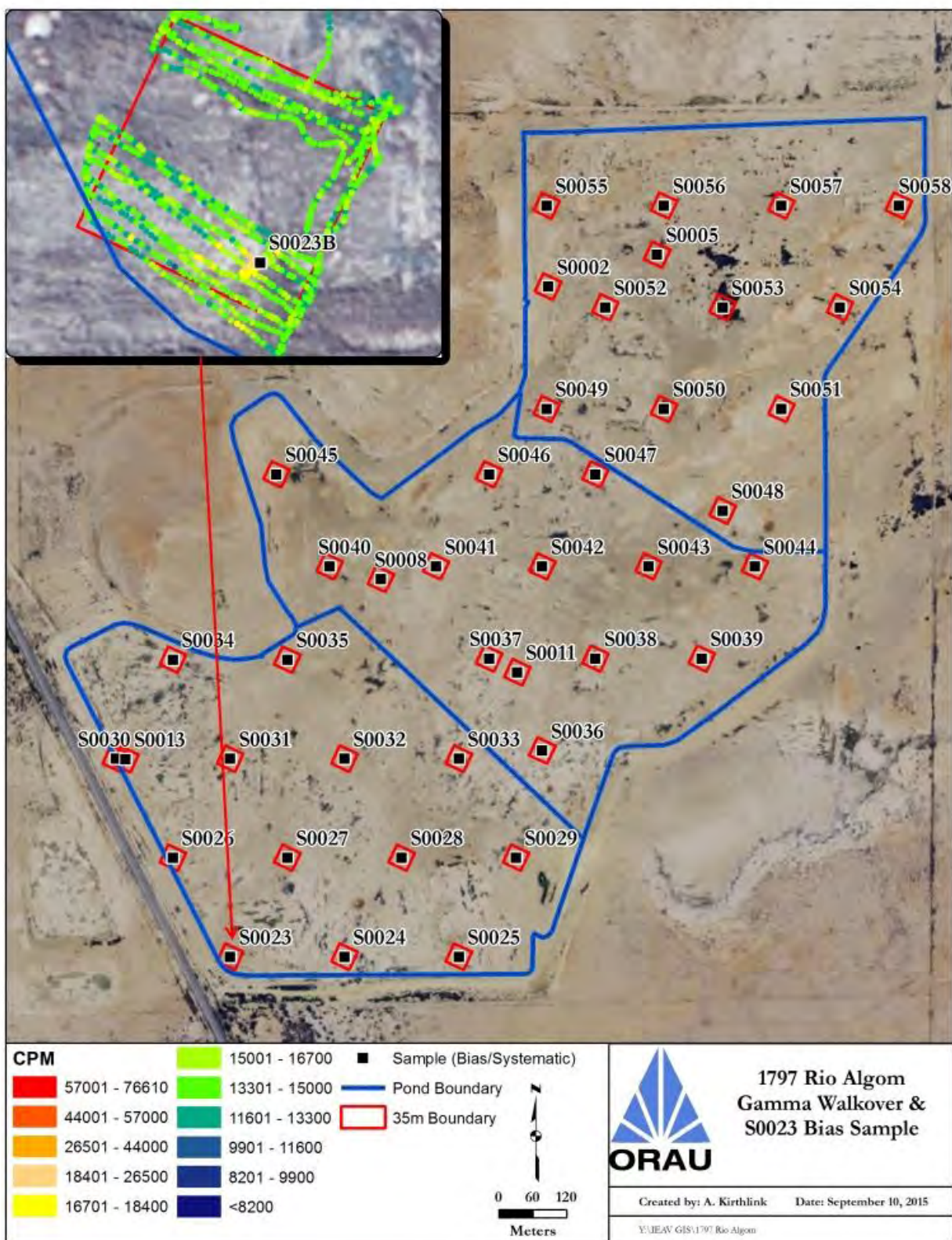


Figure A-8. CU S0023: Gamma Radiation Scans and Sample Location

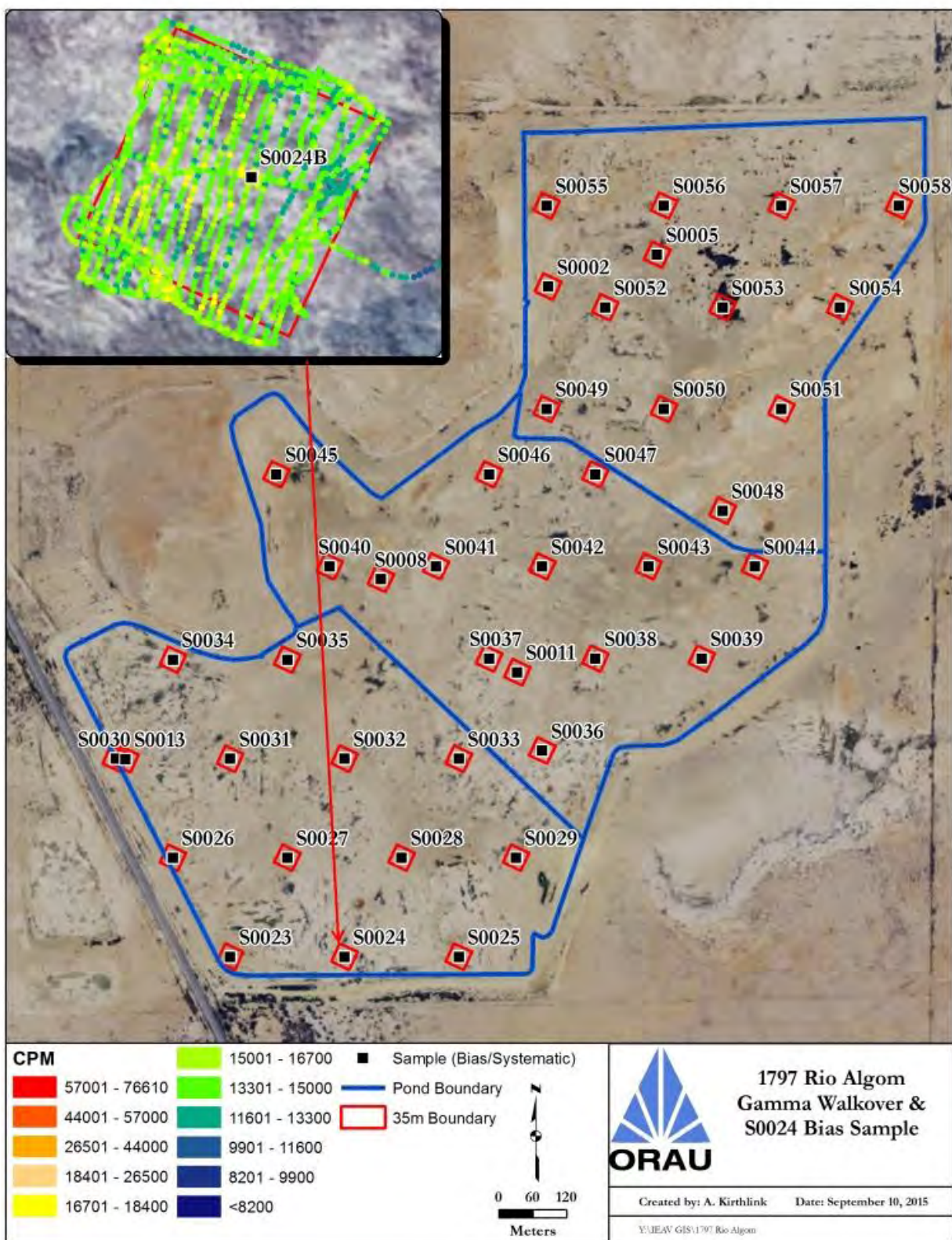


Figure A-9. CU S0024: Gamma Radiation Scans and Sample Location

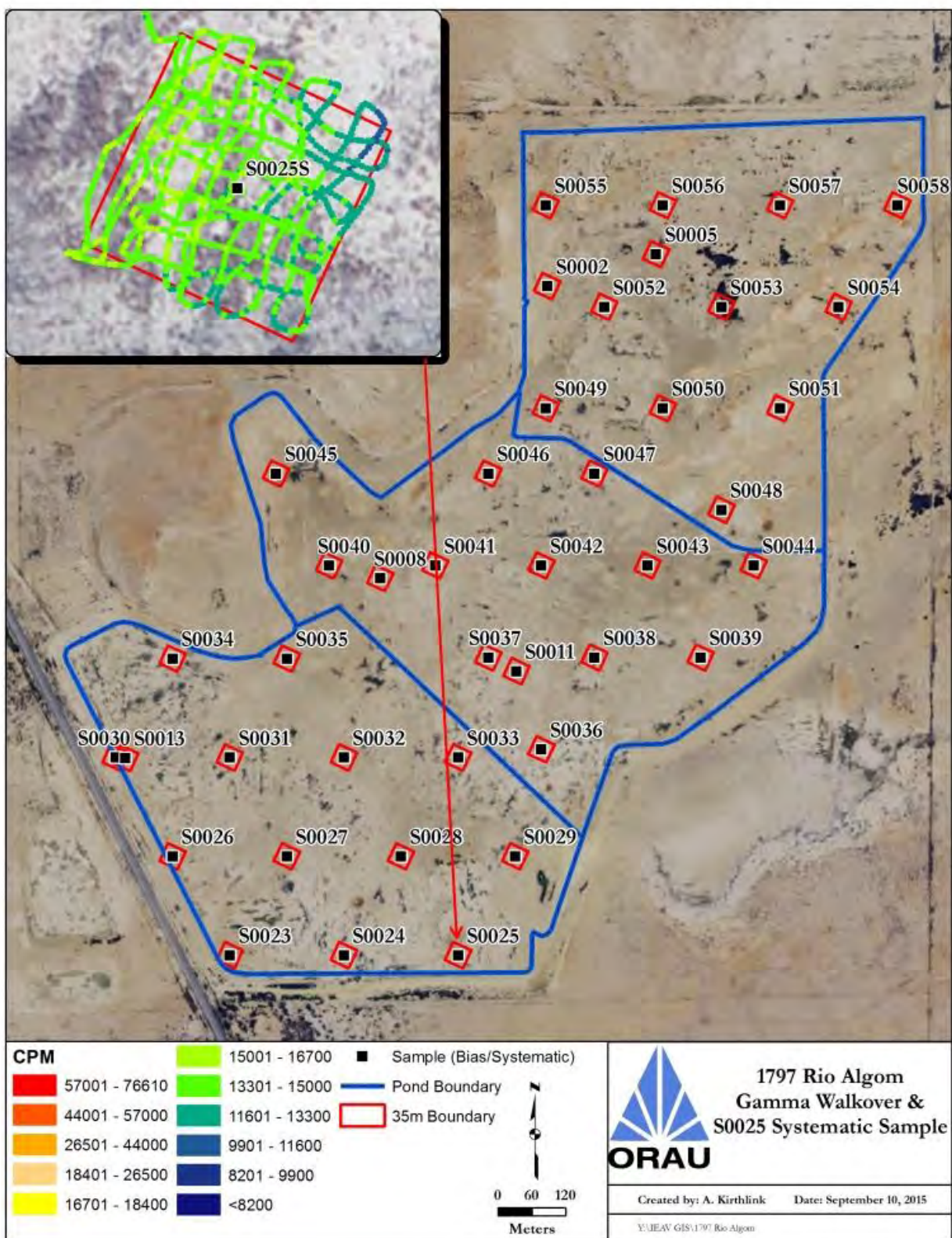


Figure A-10. CU S0025: Gamma Radiation Scans and Sample Location

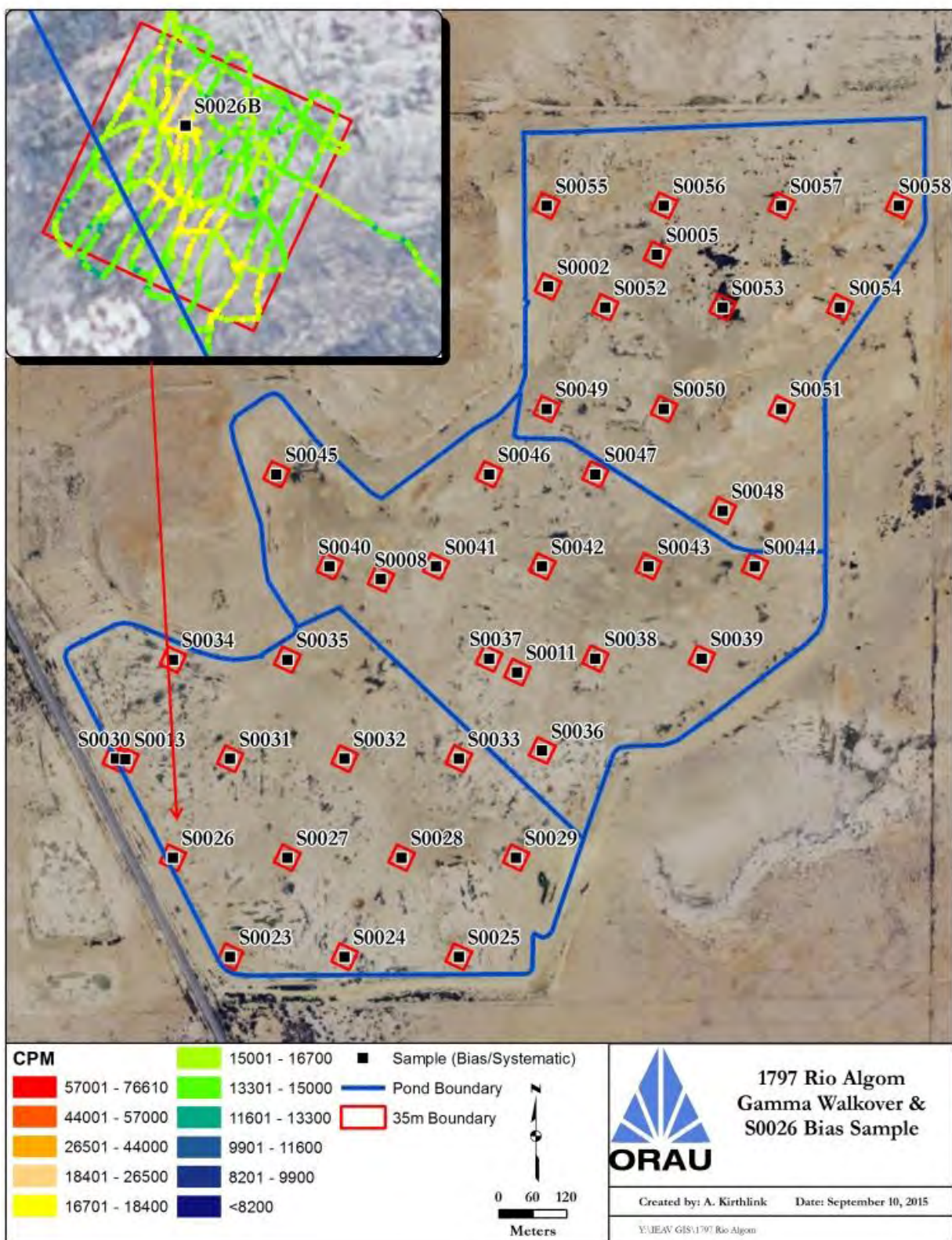


Figure A-11. CU S0026: Gamma Radiation Scans and Sample Location

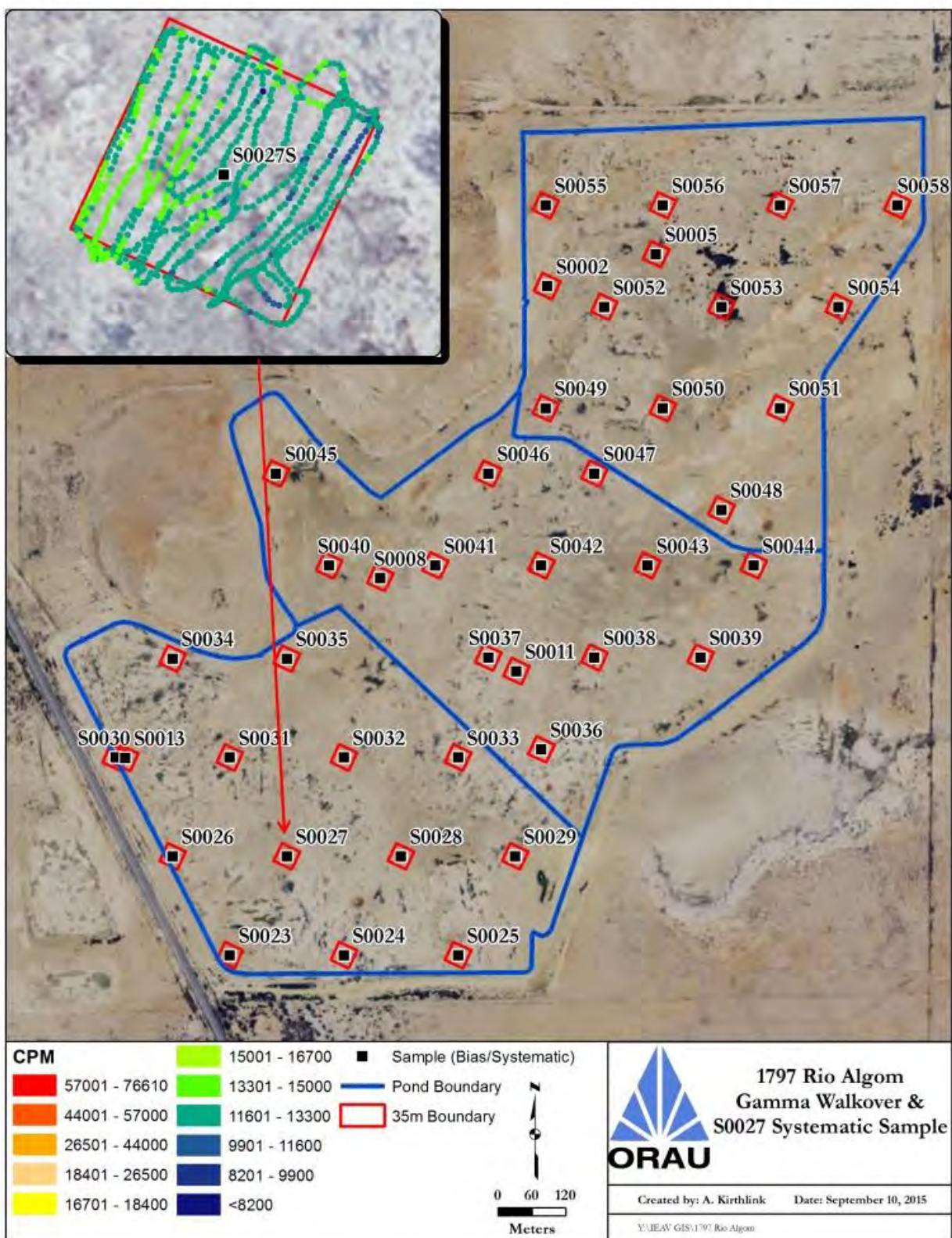


Figure A-12. CU S0027: Gamma Radiation Scans and Sample Location

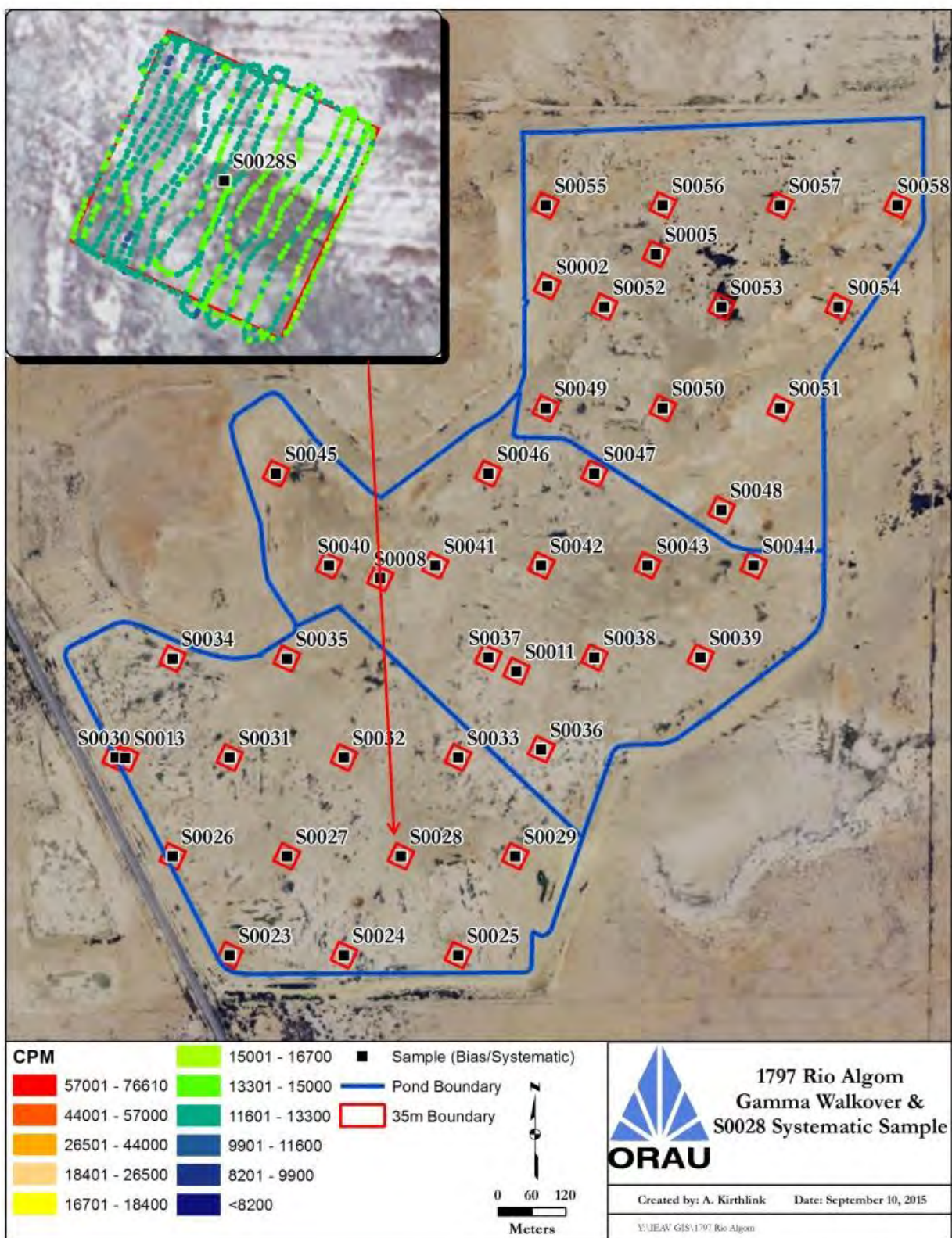


Figure A-13. CU S0028: Gamma Radiation Scans and Sample Location

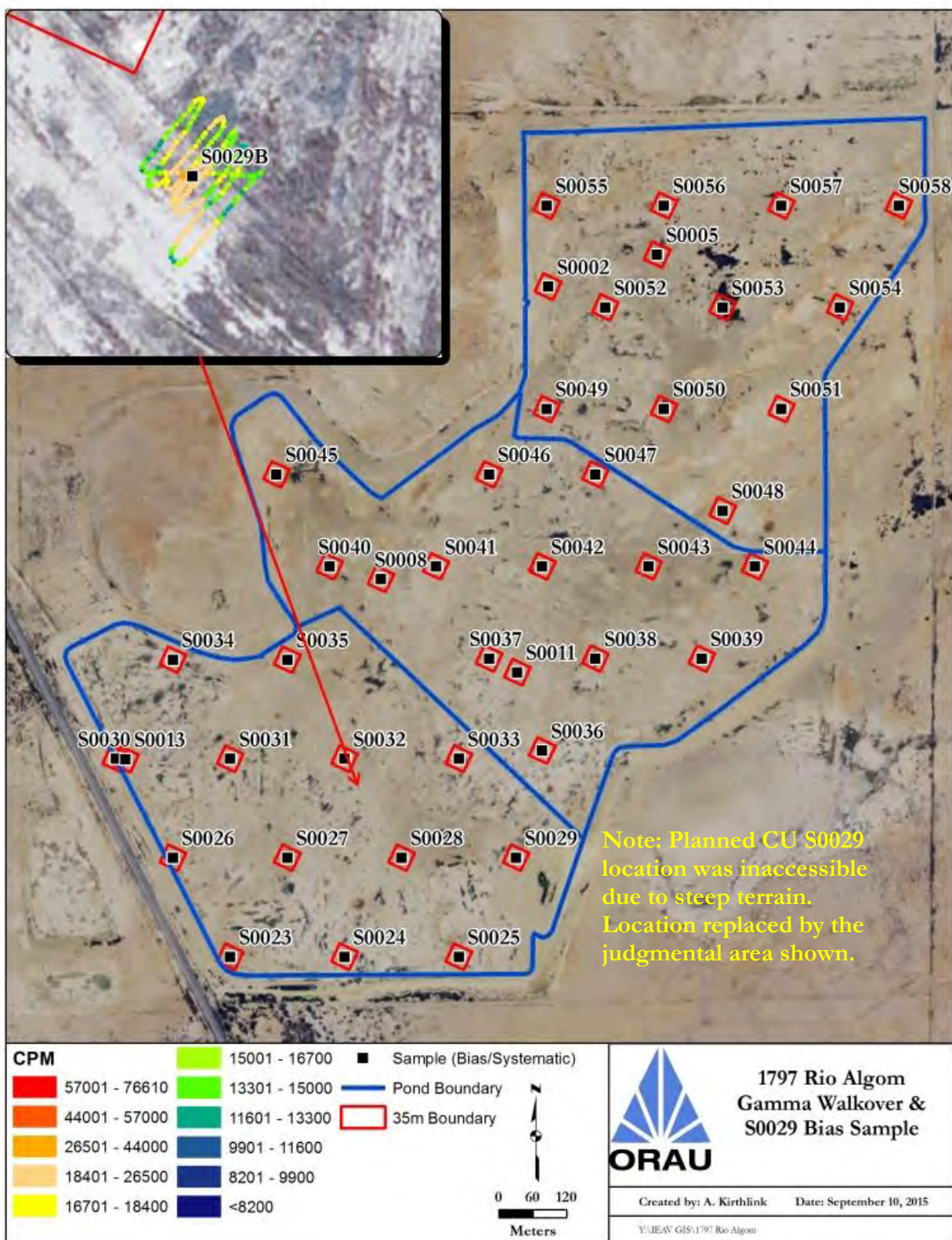


Figure A-14. CU S0029: Gamma Radiation Scans and Sample Location

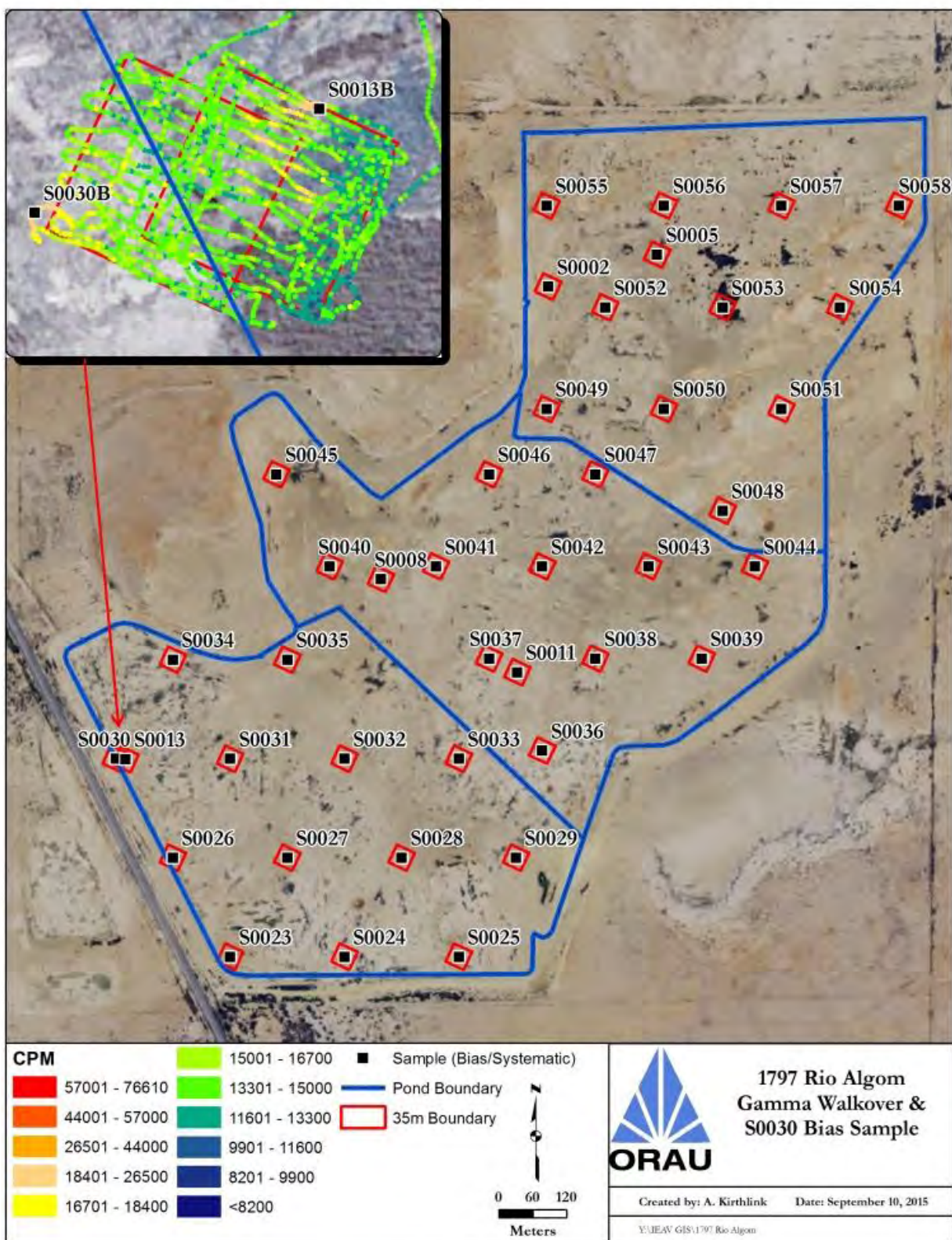


Figure A-15. CU S0030: Gamma Radiation Scans and Sample Location

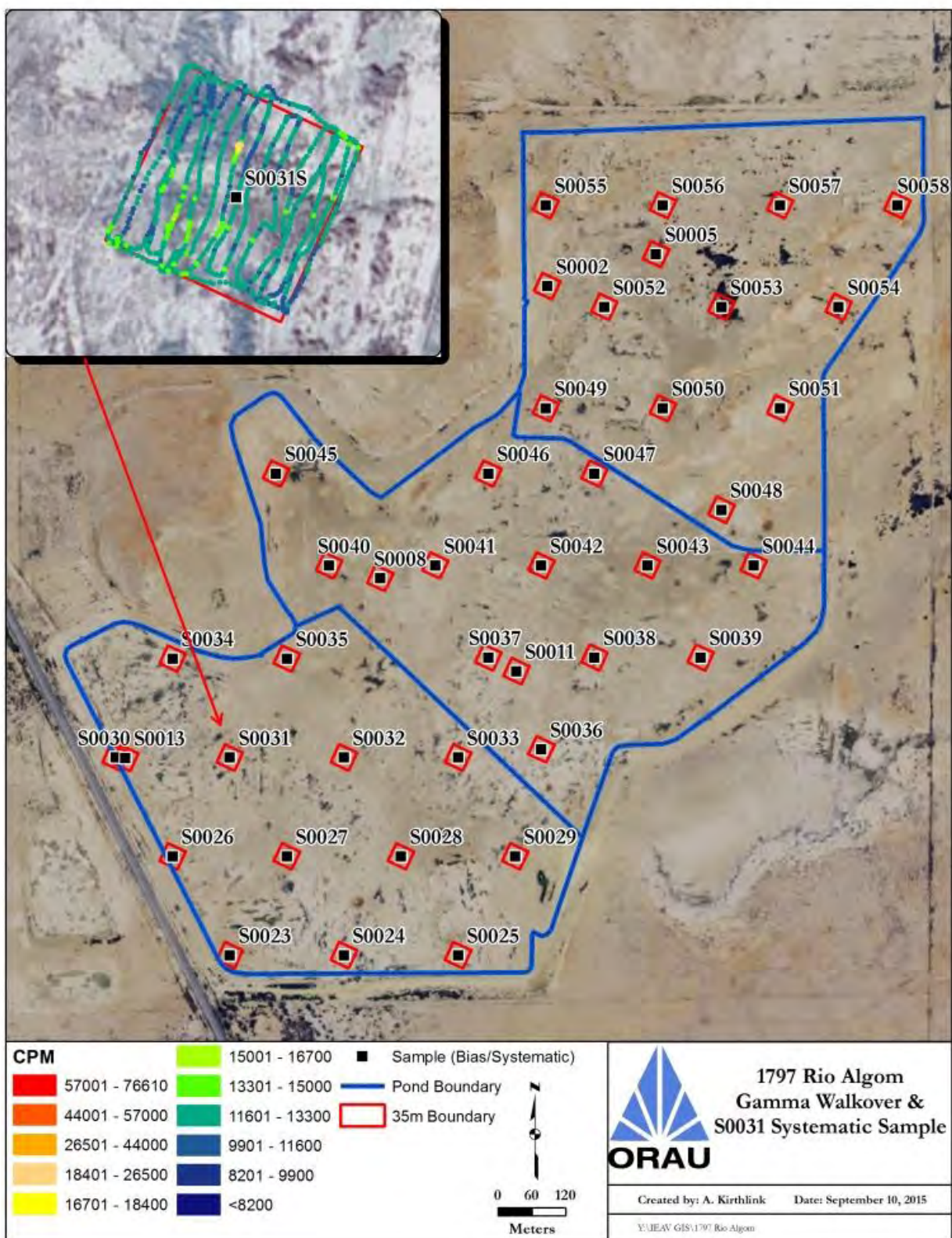


Figure A-16. CU S0031: Gamma Radiation Scans and Sample Location

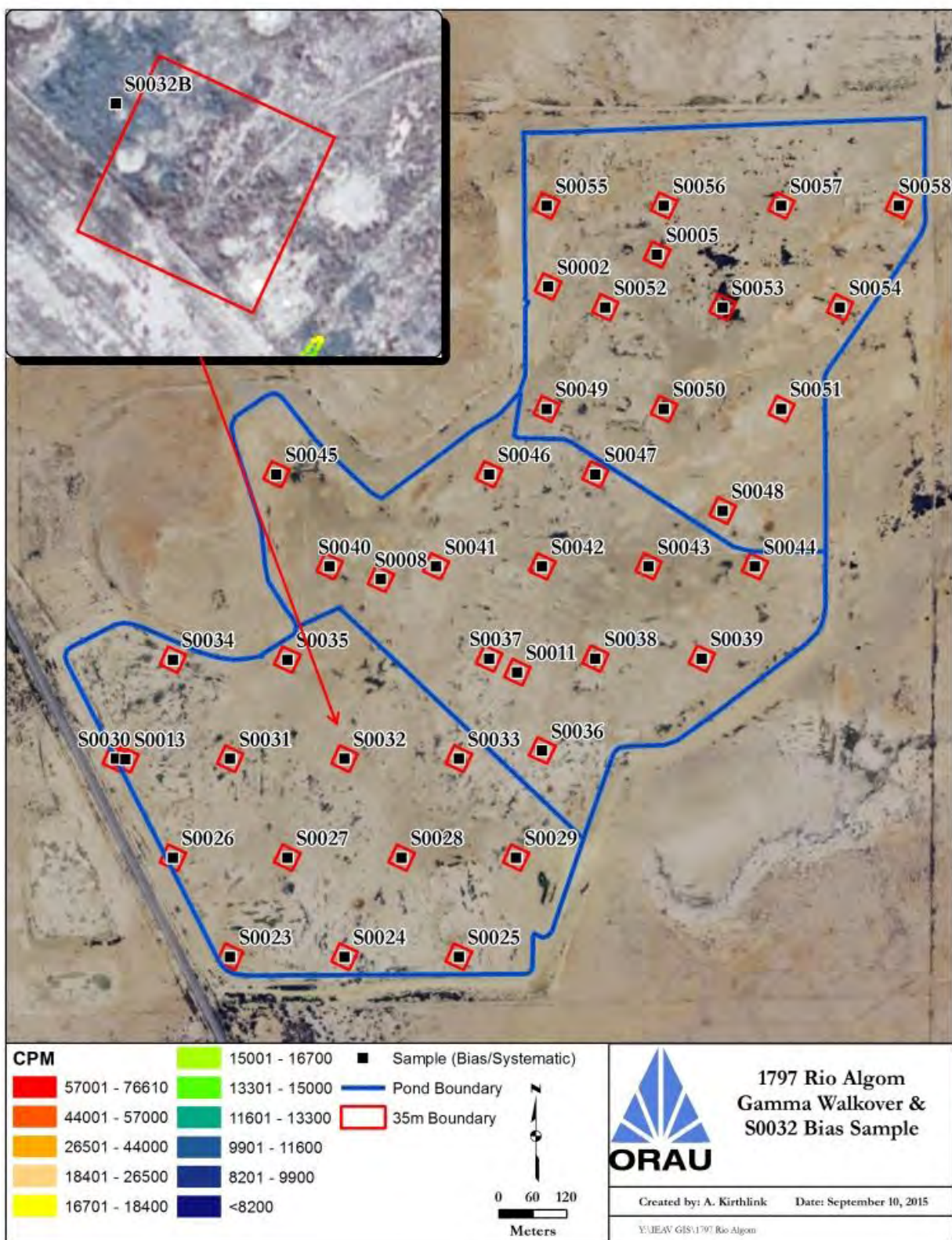


Figure A-17. CU S0032: Sample Location

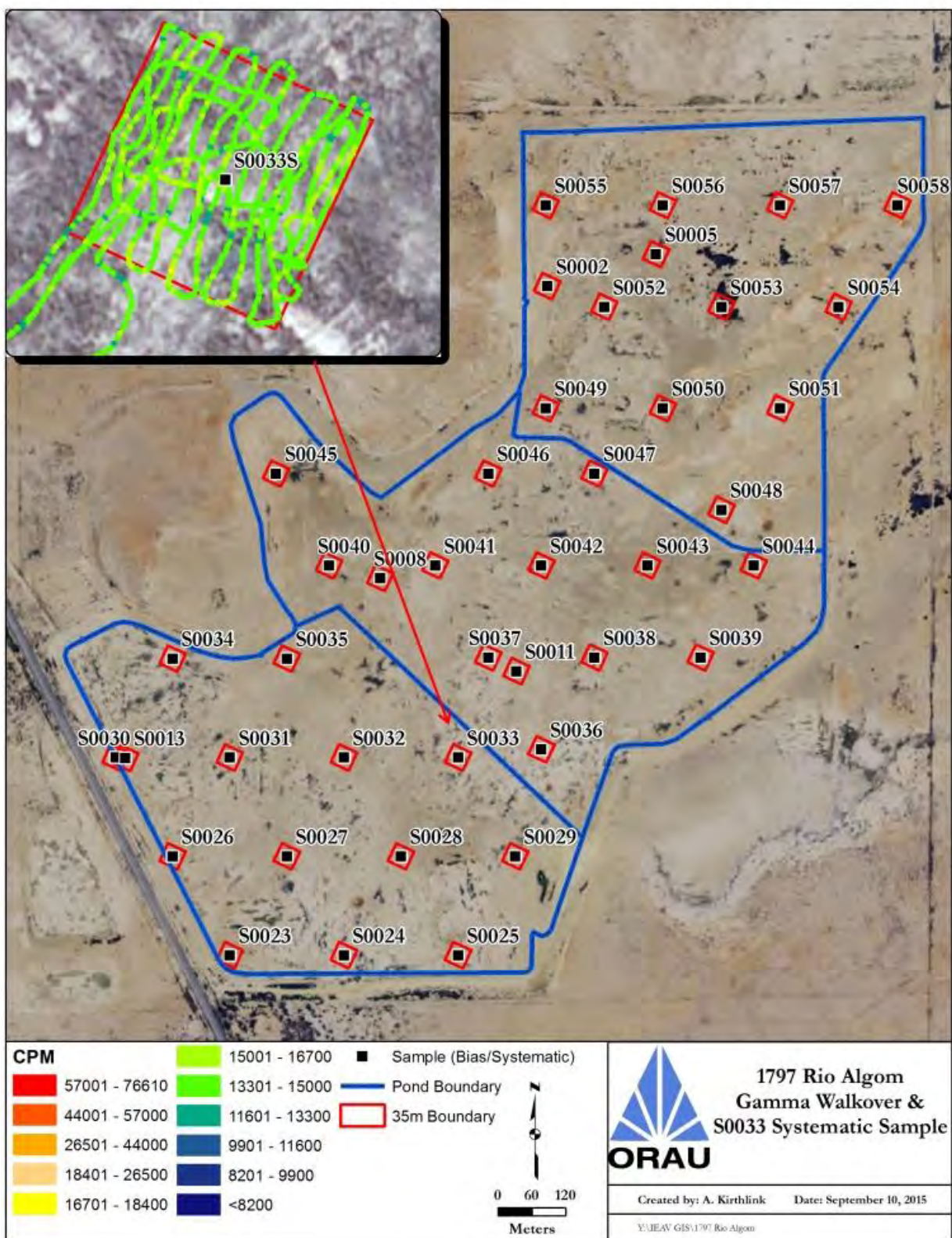


Figure A-18. CU S0033: Gamma Radiation Scans and Sample Location

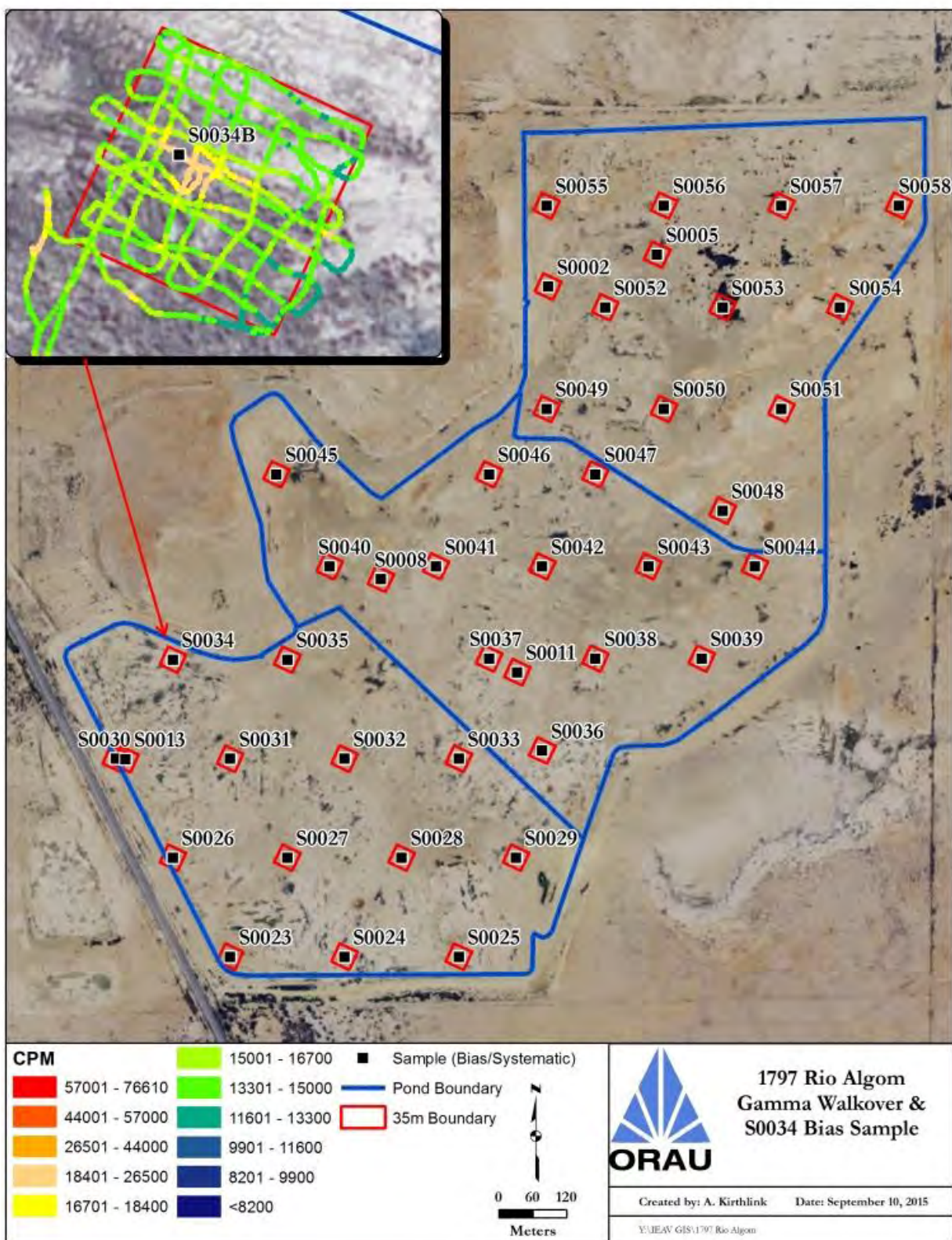


Figure A-19. CU S0034: Gamma Radiation Scans and Sample Location

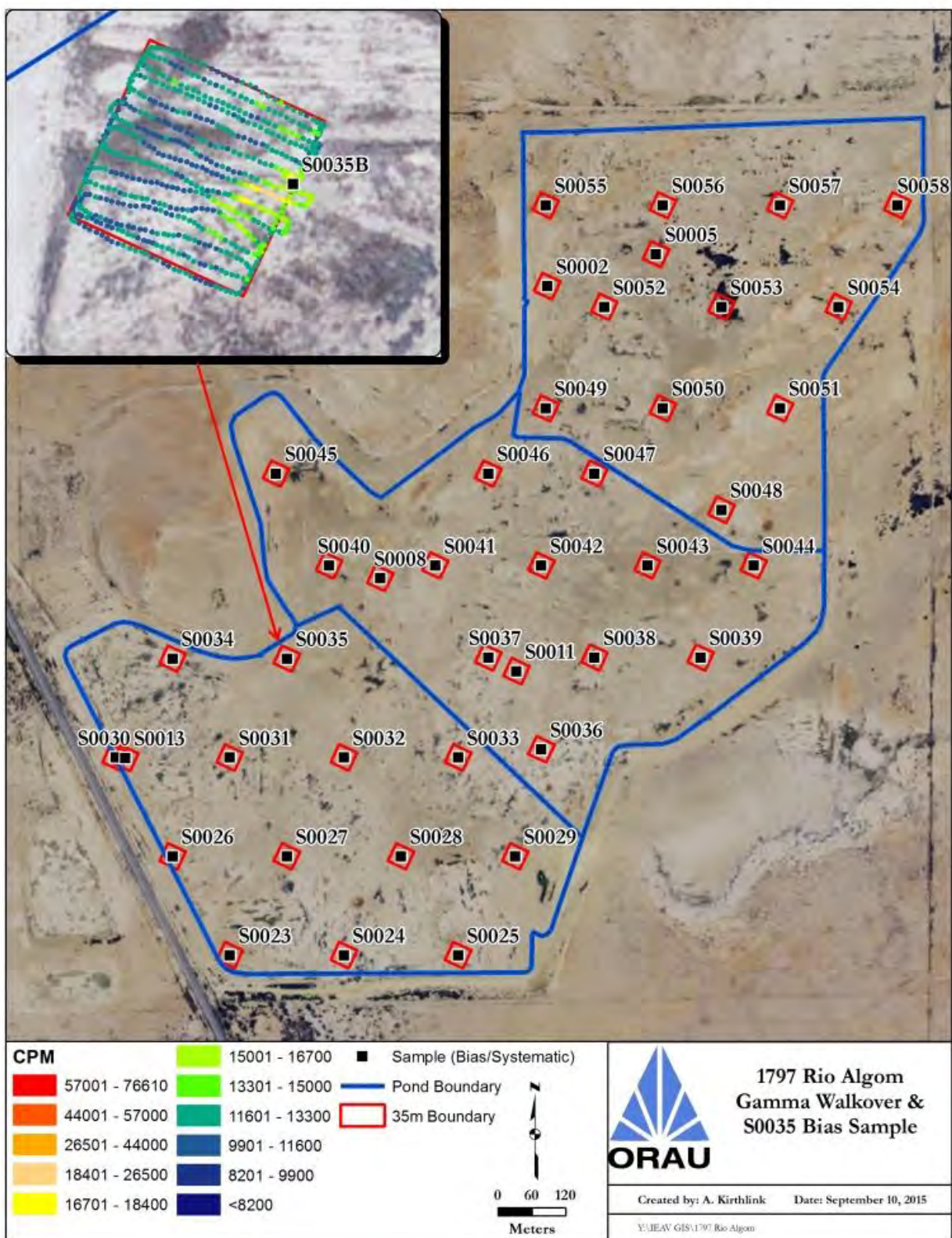


Figure A-20. CU S0035: Gamma Radiation Scans and Sample Location

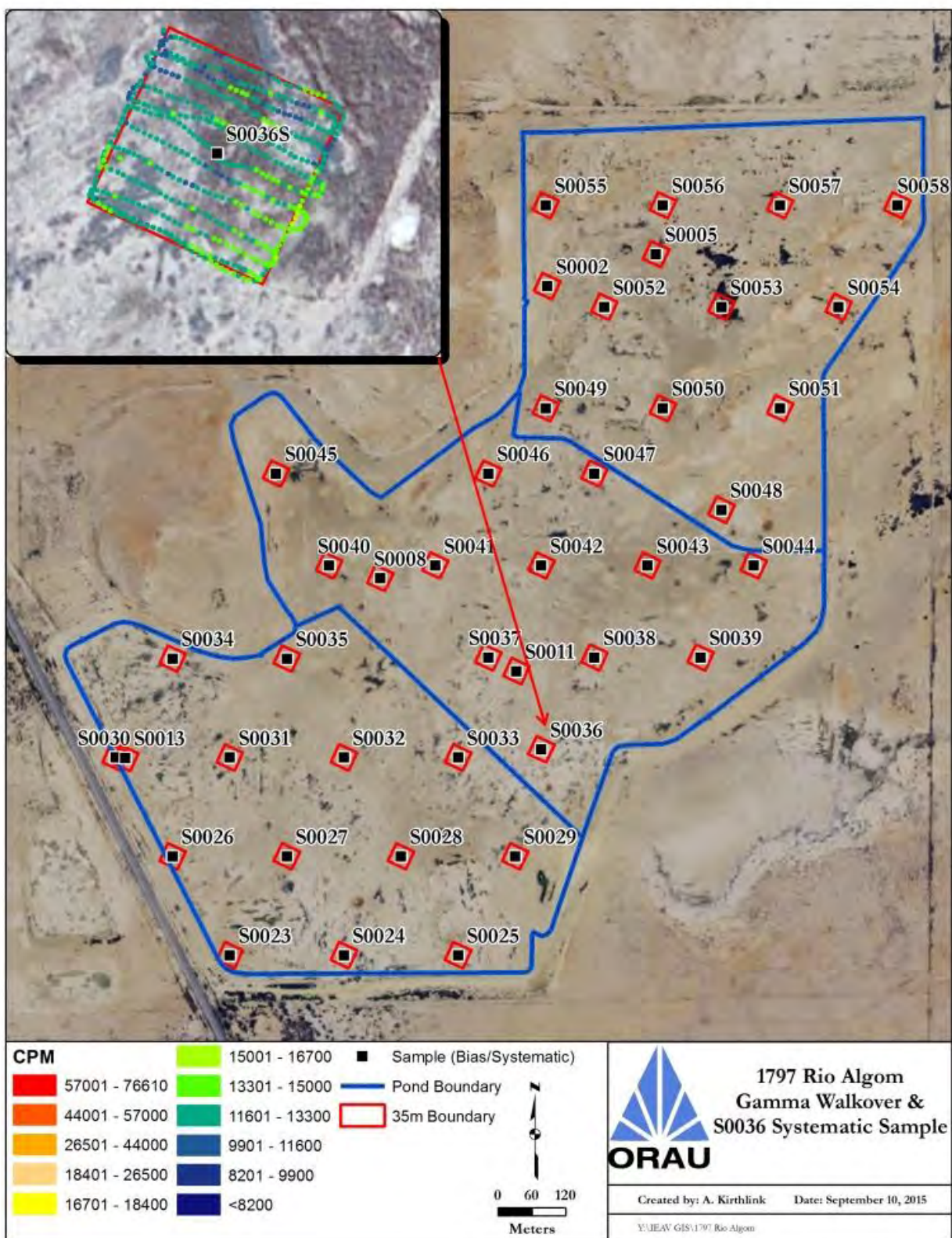


Figure A-21. CU S0036: Gamma Radiation Scans and Sample Location

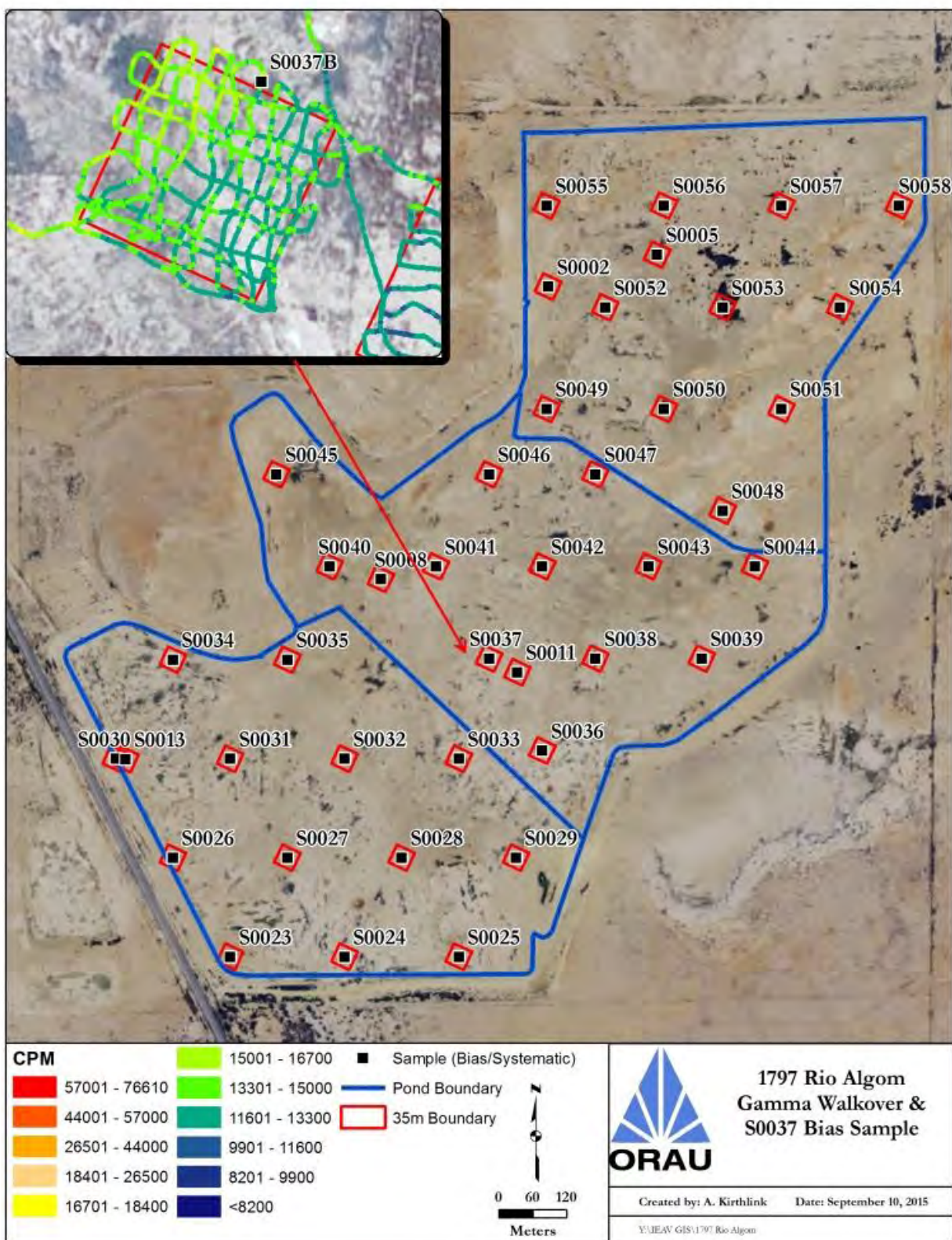


Figure A-22. CU S0037: Gamma Radiation Scans and Sample Location

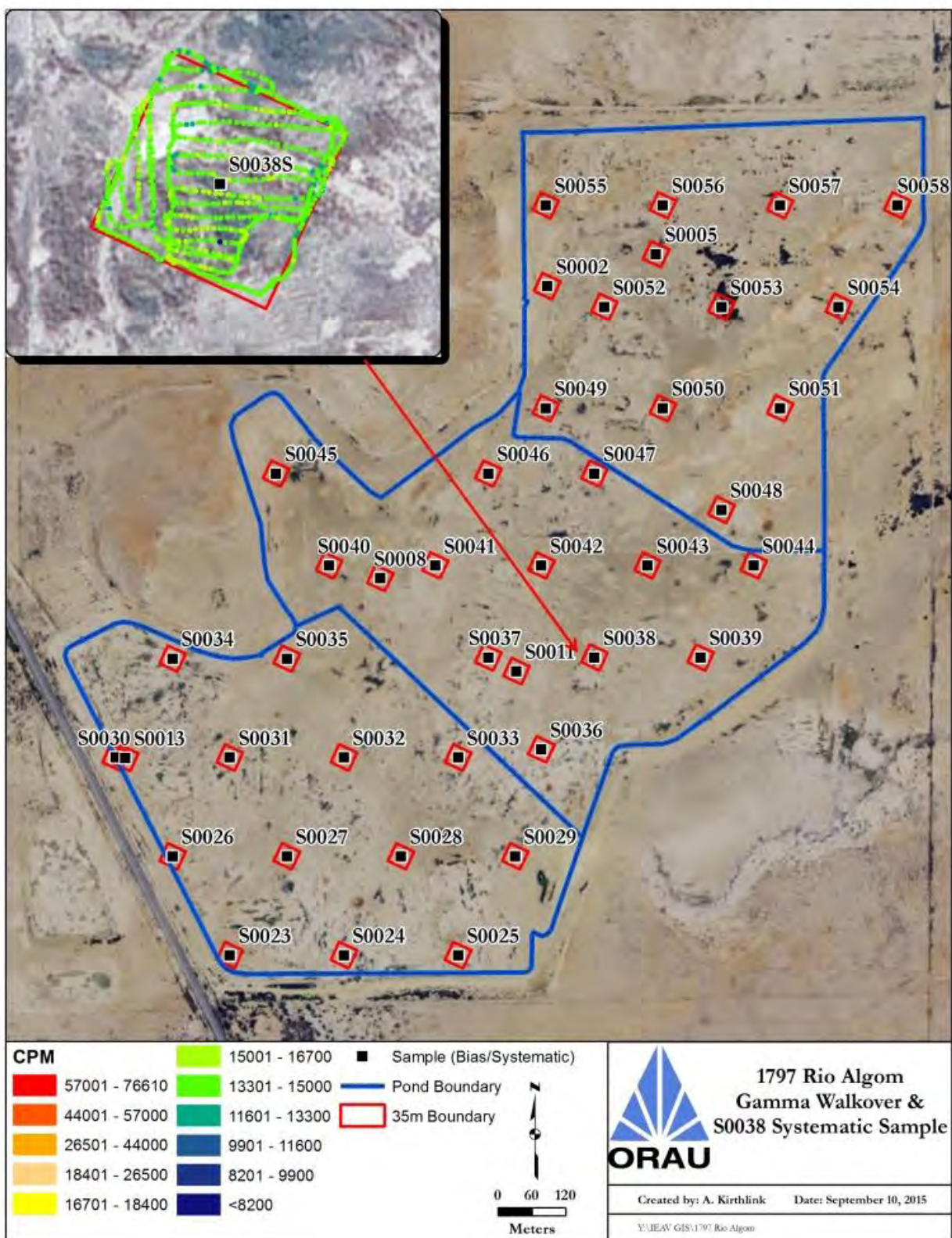


Figure A-23. CU S0038: Gamma Radiation Scans and Sample Location

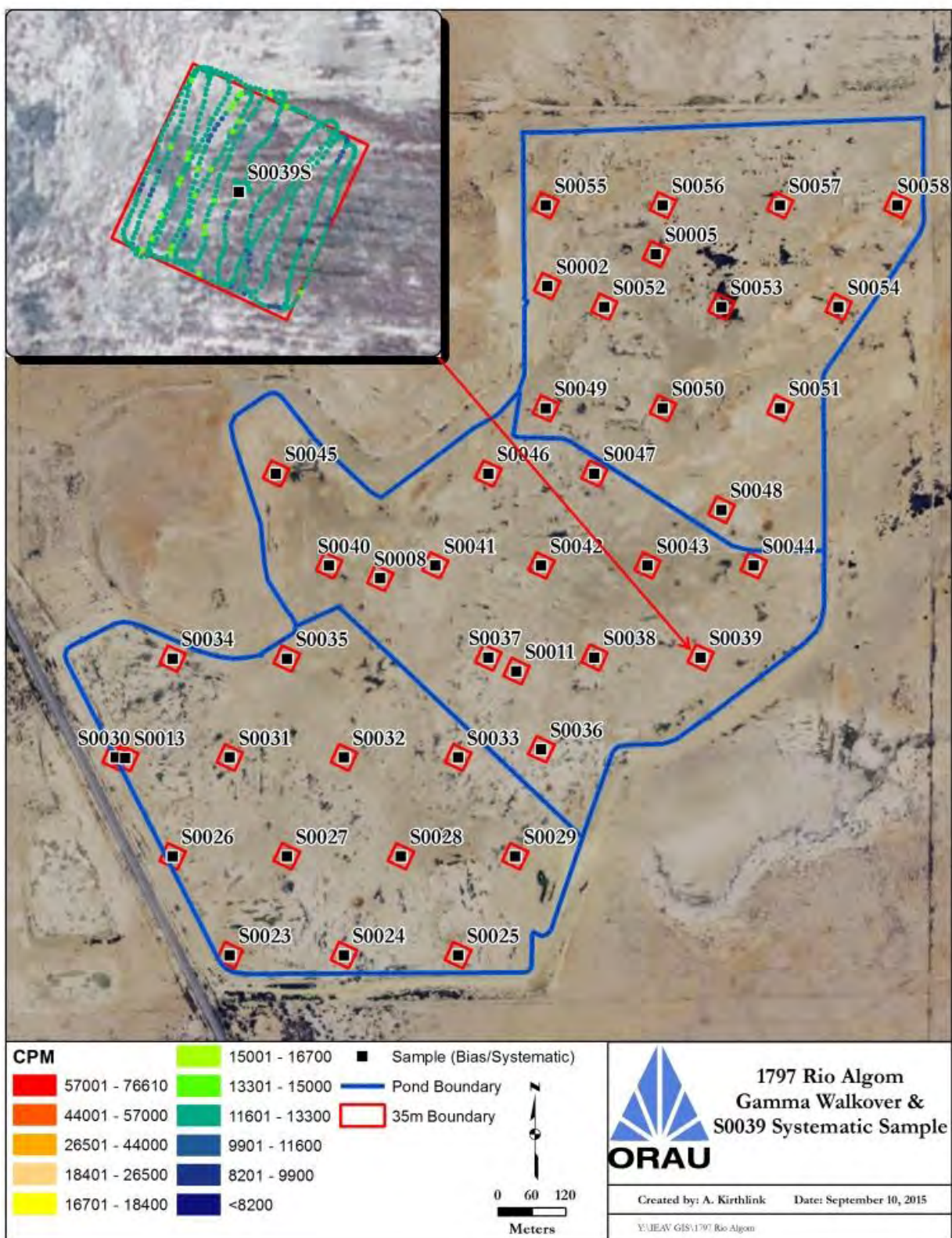


Figure A-24. CU S0039: Gamma Radiation Scans and Sample Location

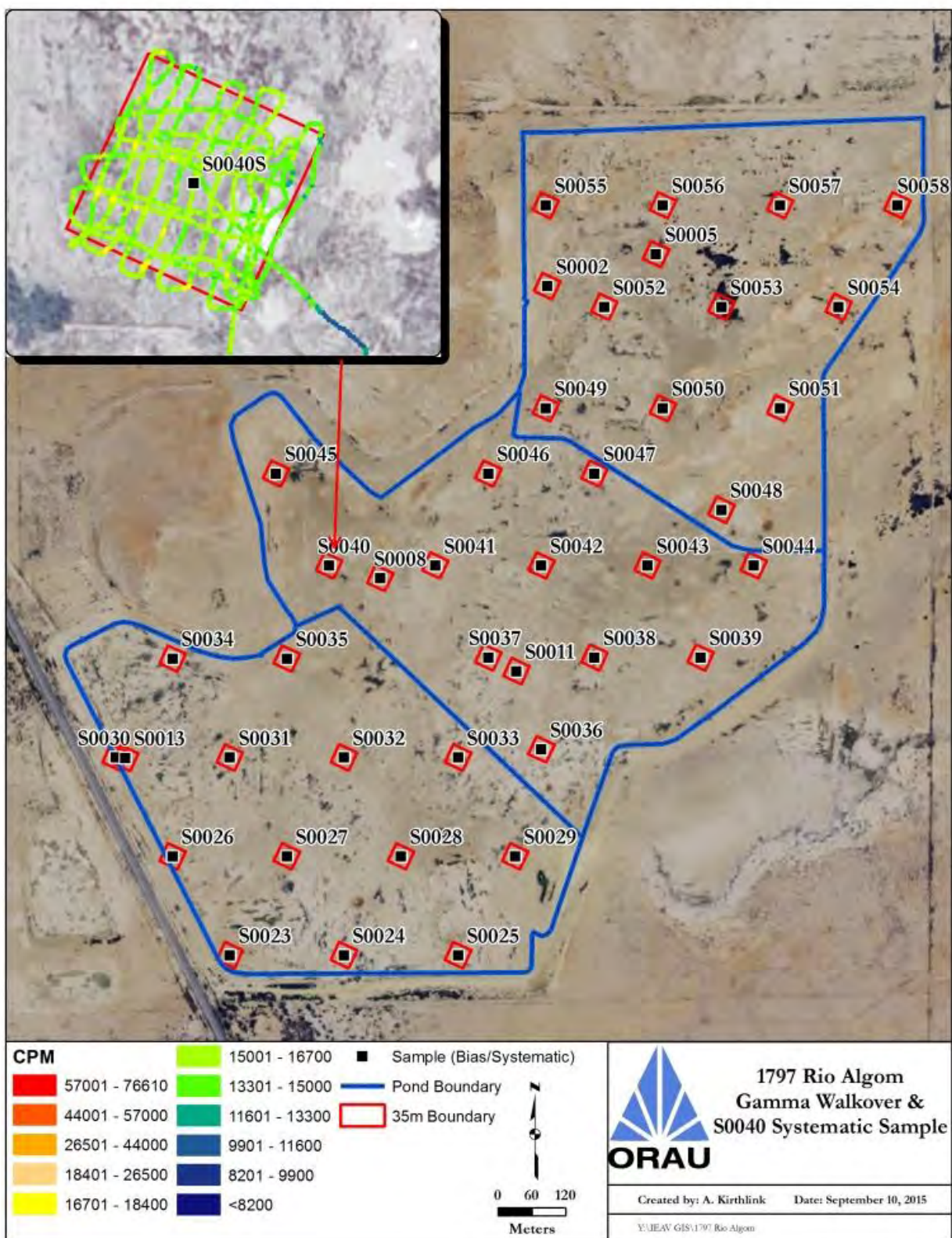


Figure A-25. CU S0040: Gamma Radiation Scans and Sample Location

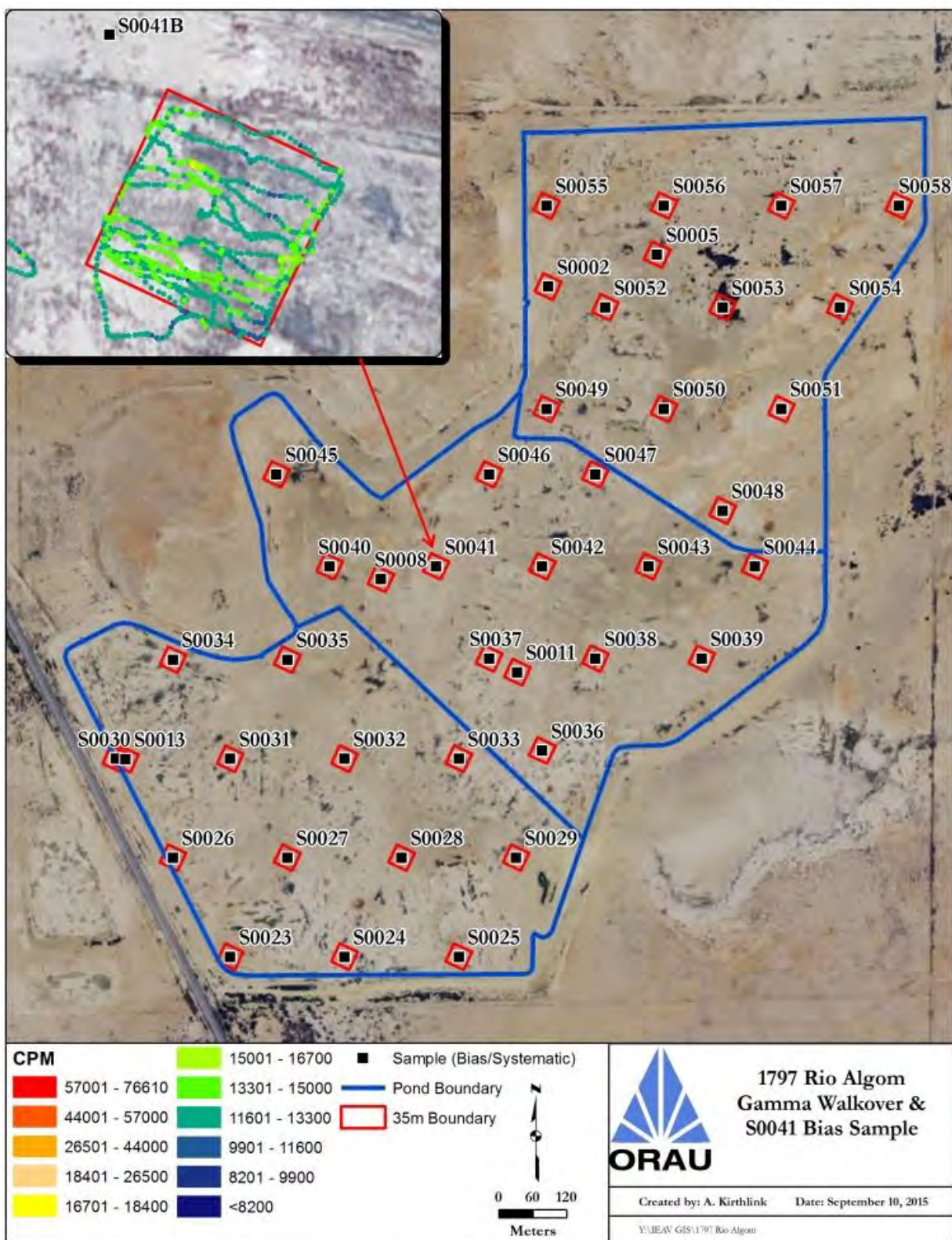


Figure A-26. CU S0041: Gamma Radiation Scans and Sample Location

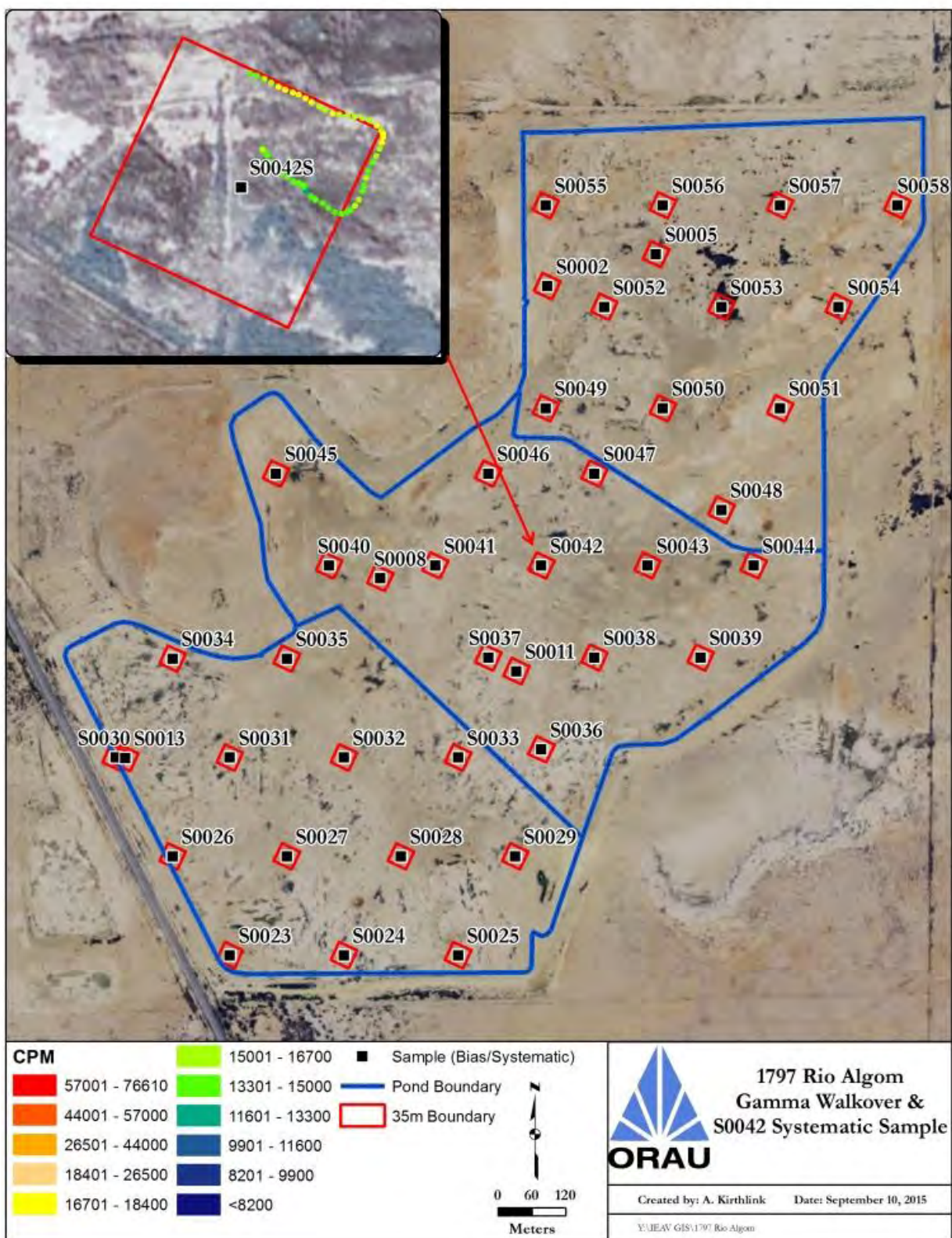


Figure A-27. CU S0042: Gamma Radiation Scans and Sample Location

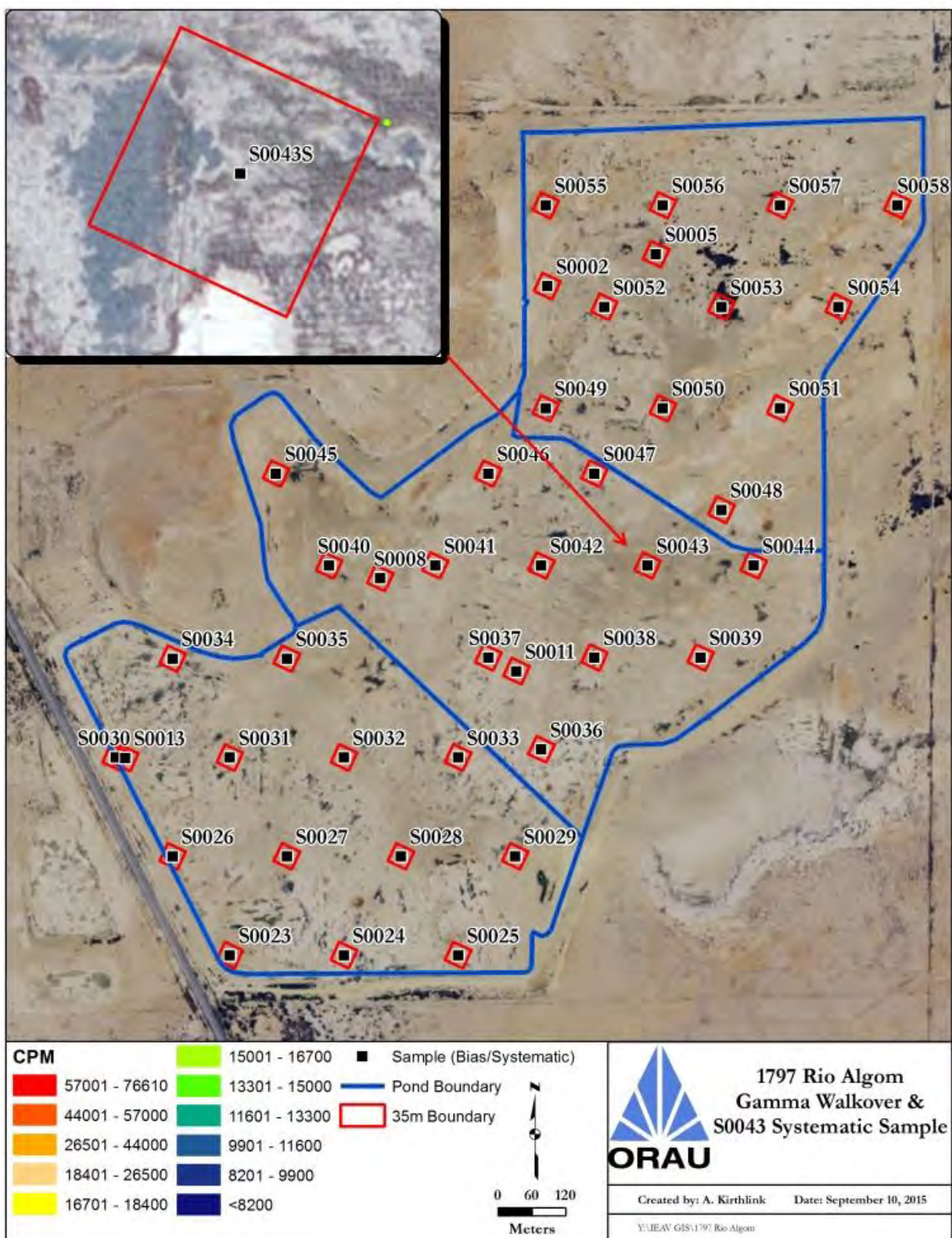


Figure A-28. CU S0043: Sample Location

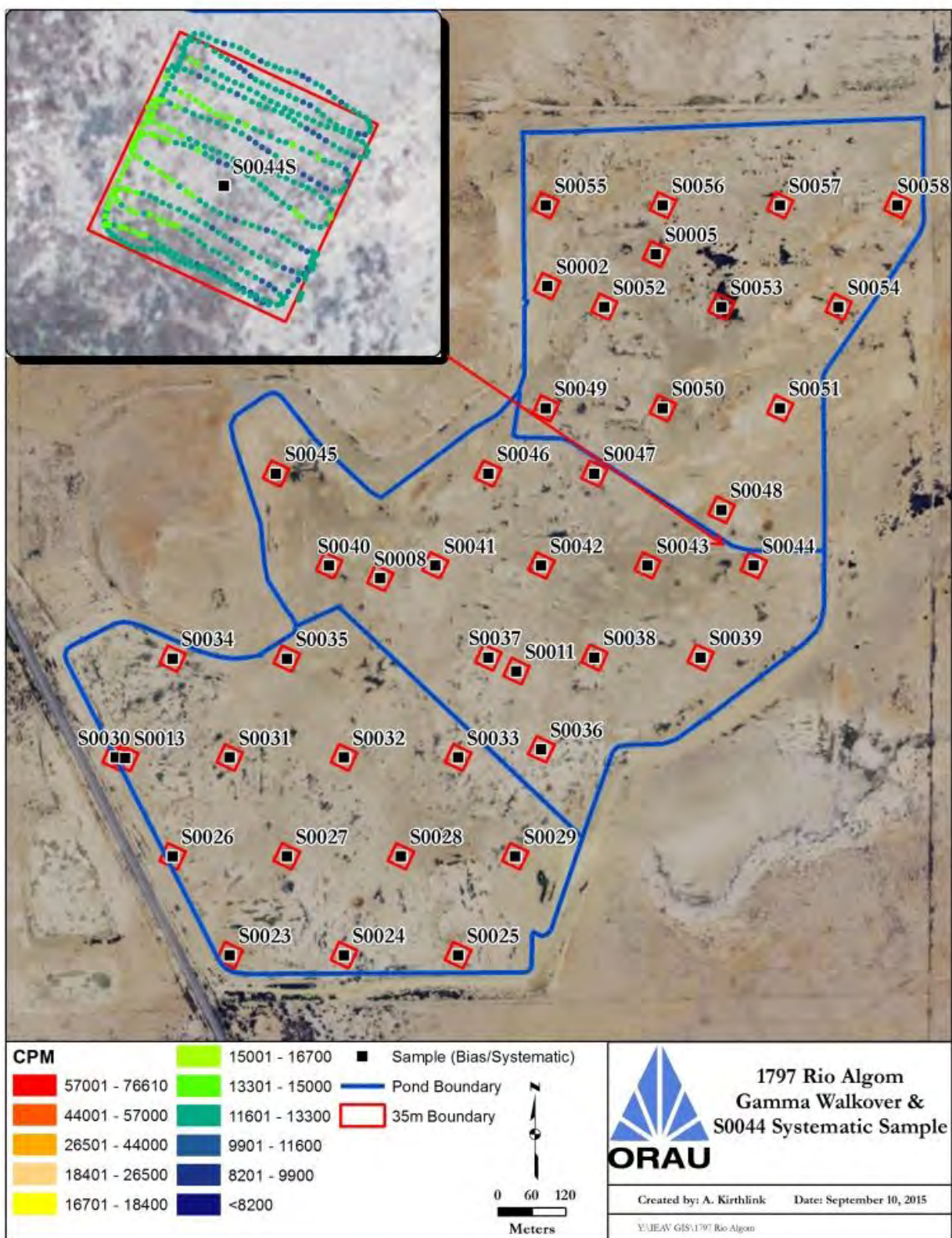


Figure A-29. CU S0044: Gamma Radiation Scans and Sample Location

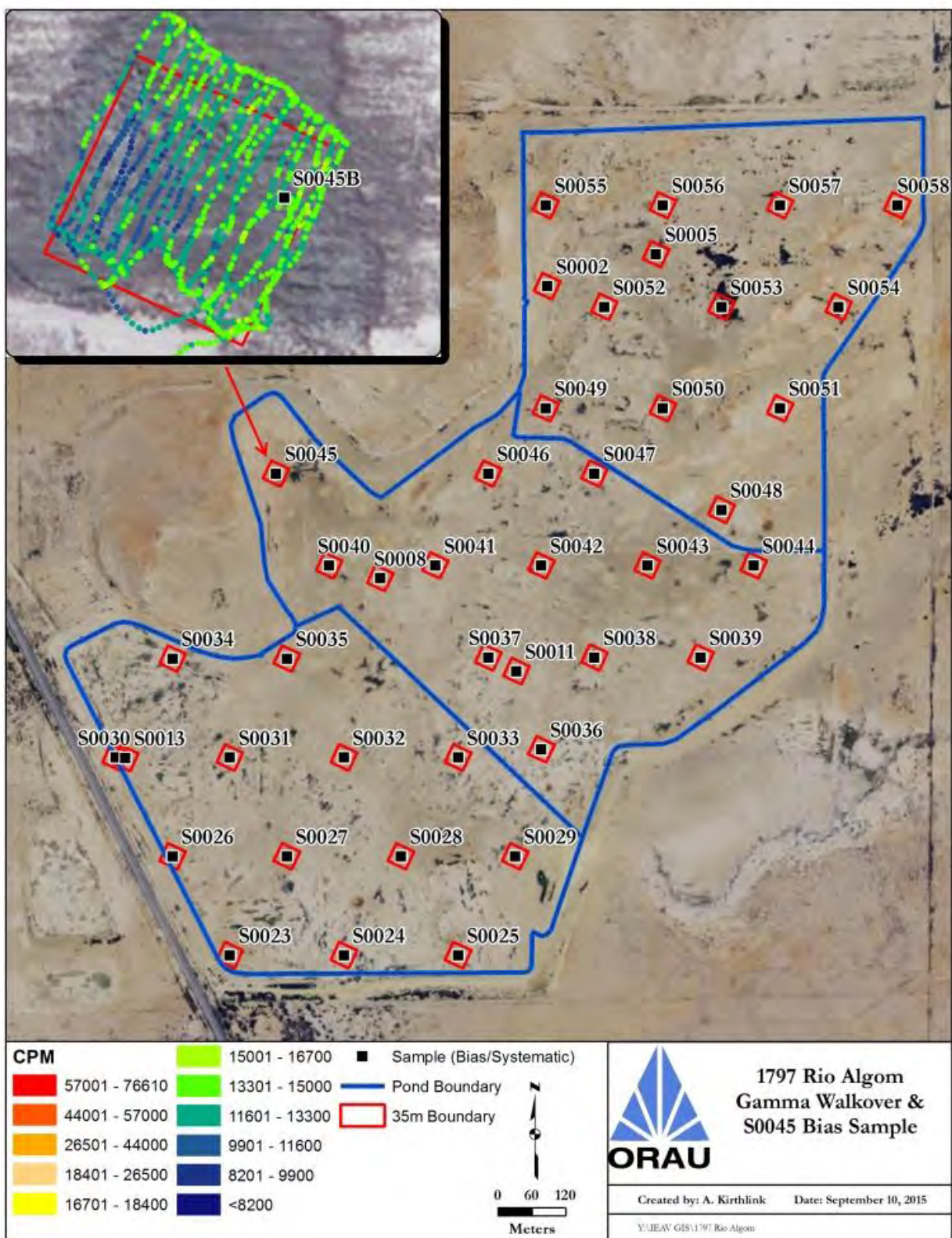


Figure A-30. CU S0045: Gamma Radiation Scans and Sample Location

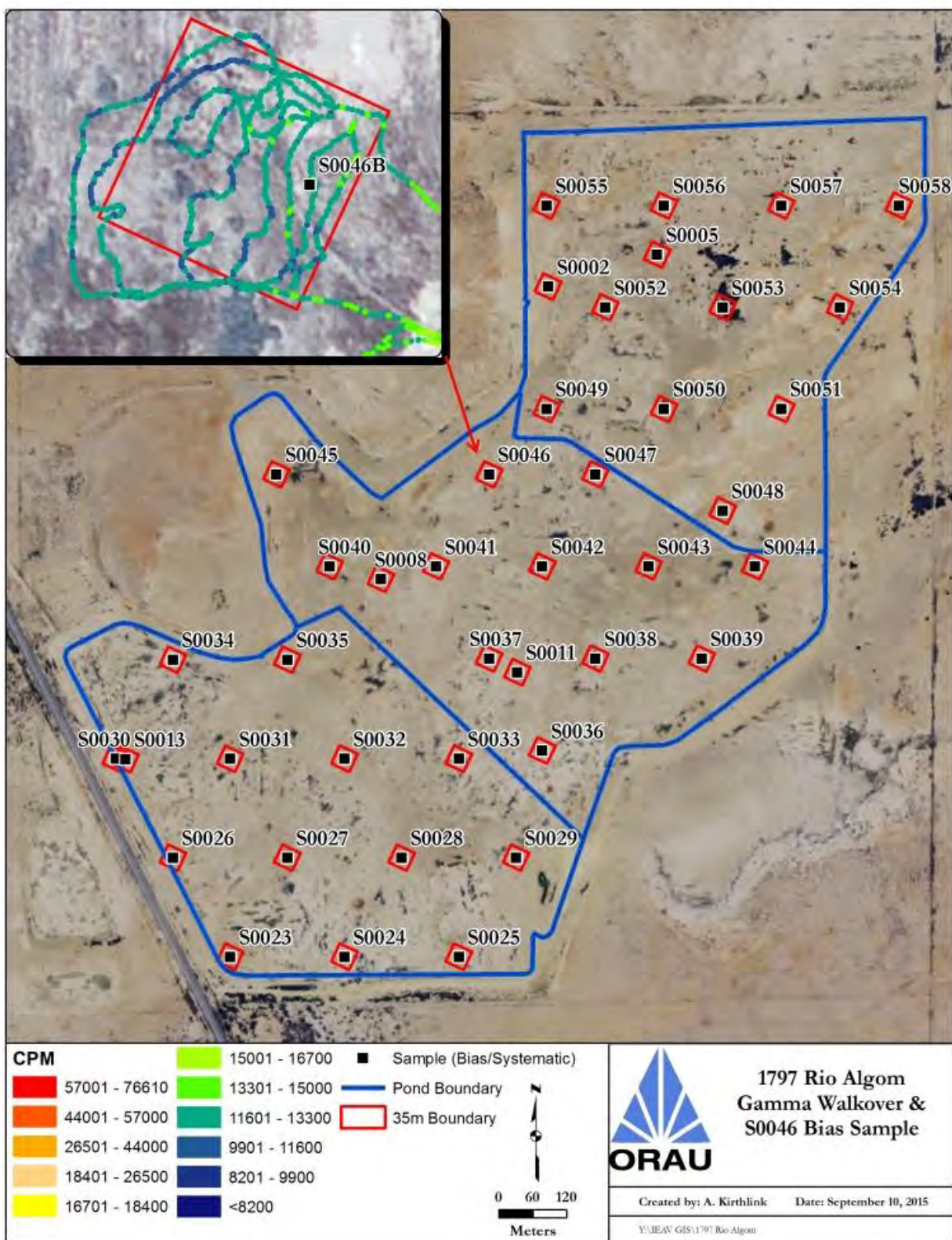


Figure A-31. CU S0046: Gamma Radiation Scans and Sample Location

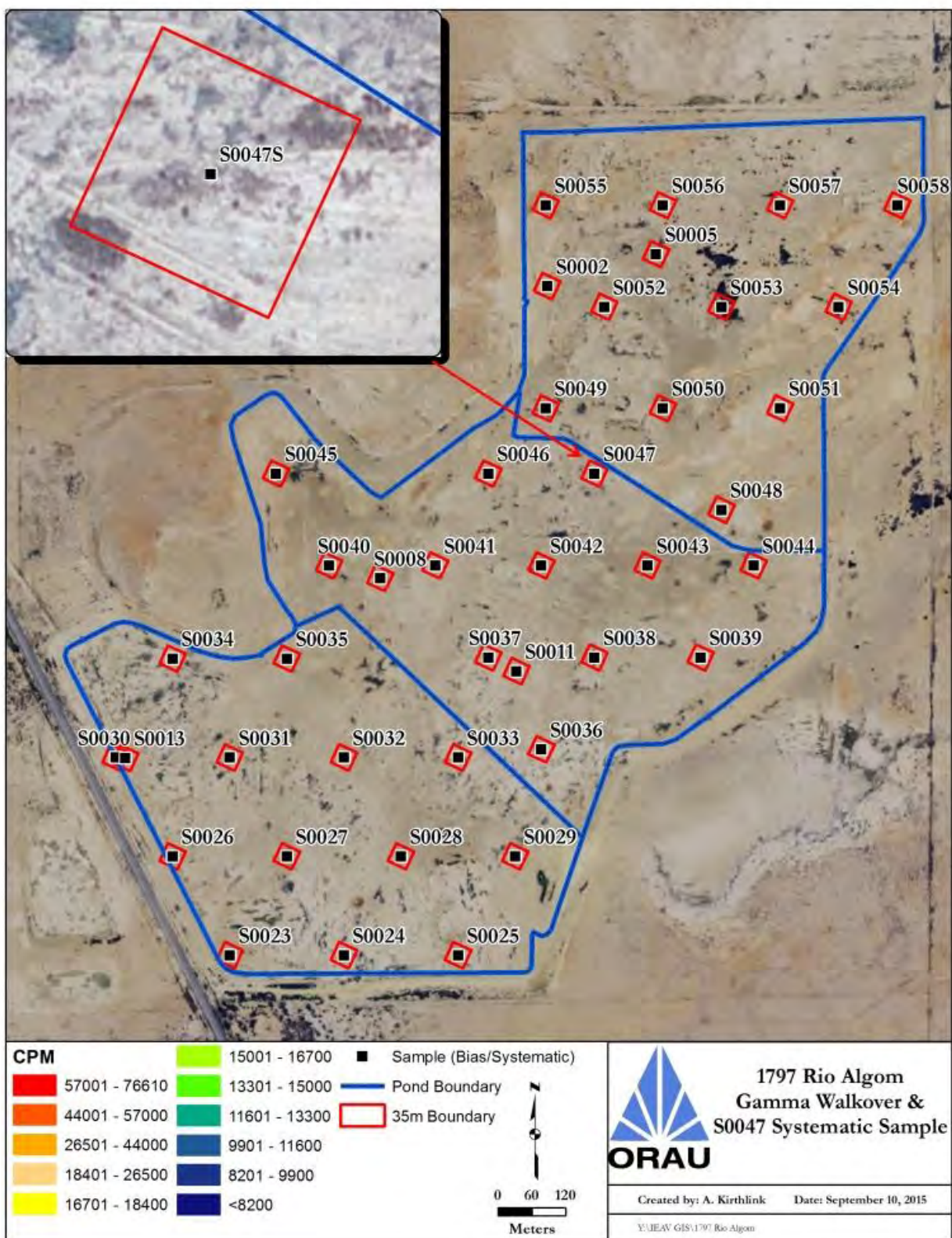


Figure A-32. CU S0047: Sample Location

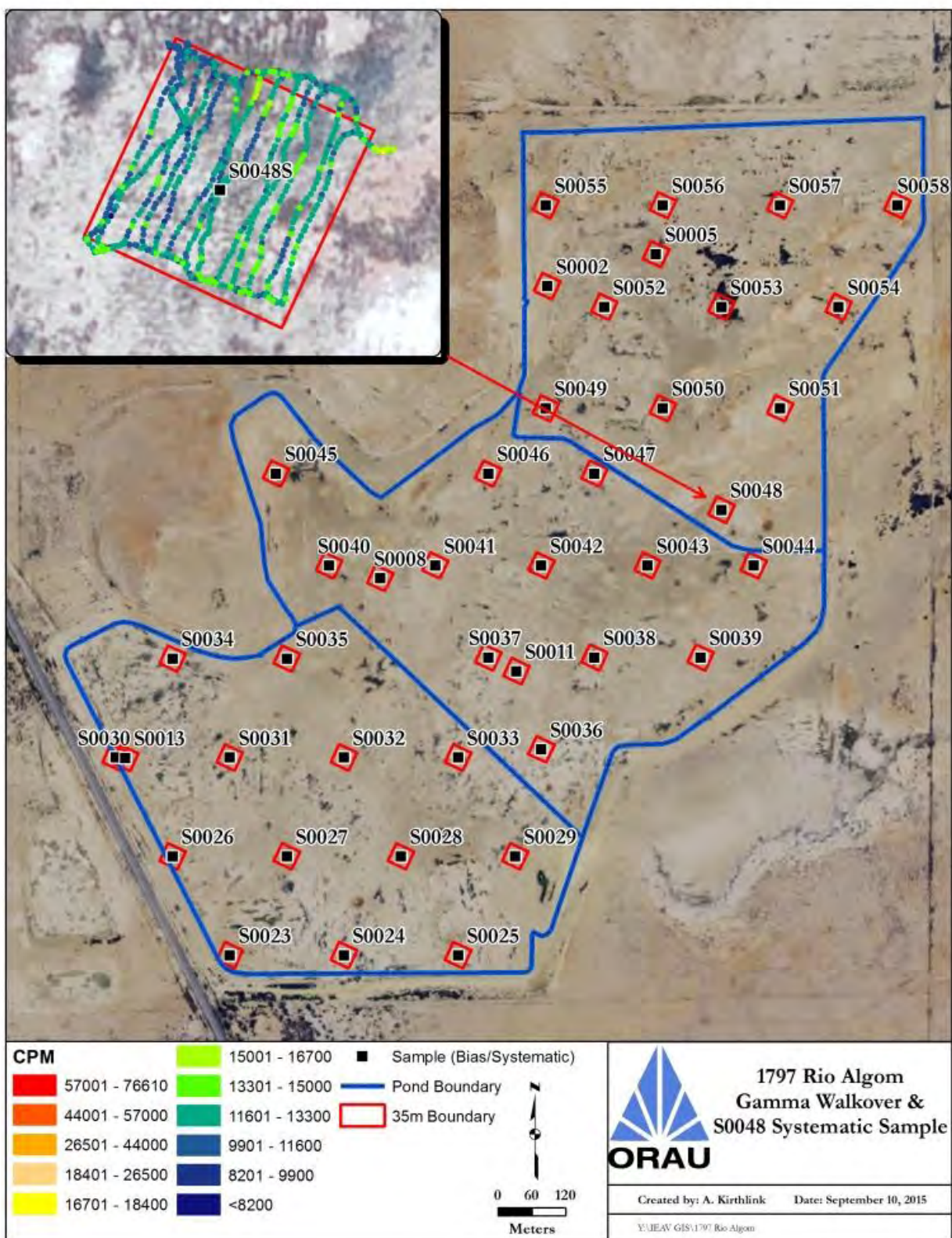


Figure A-33. CU S0048: Gamma Radiation Scans and Sample Location

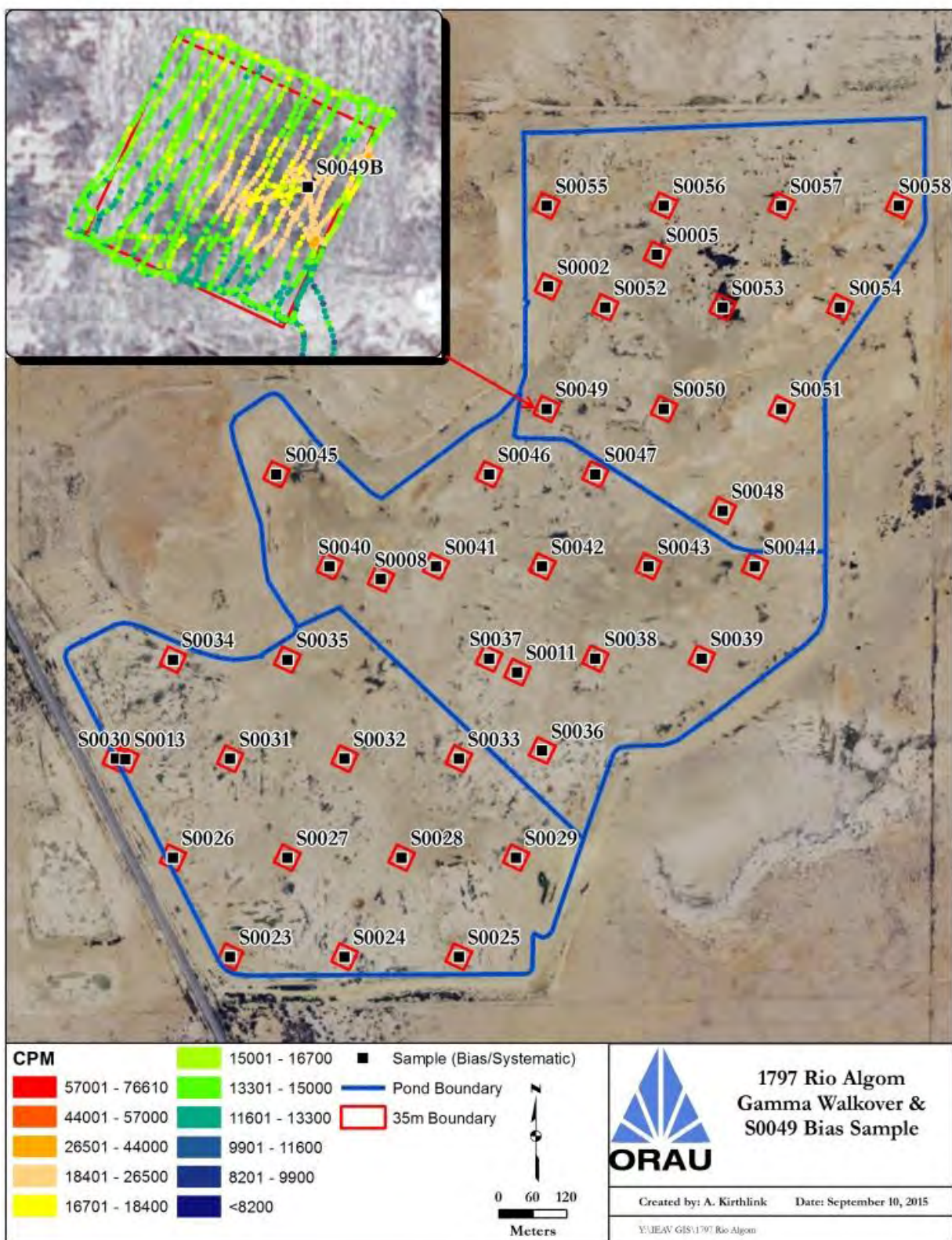


Figure A-34. CU S0049: Gamma Radiation Scans and Sample Location

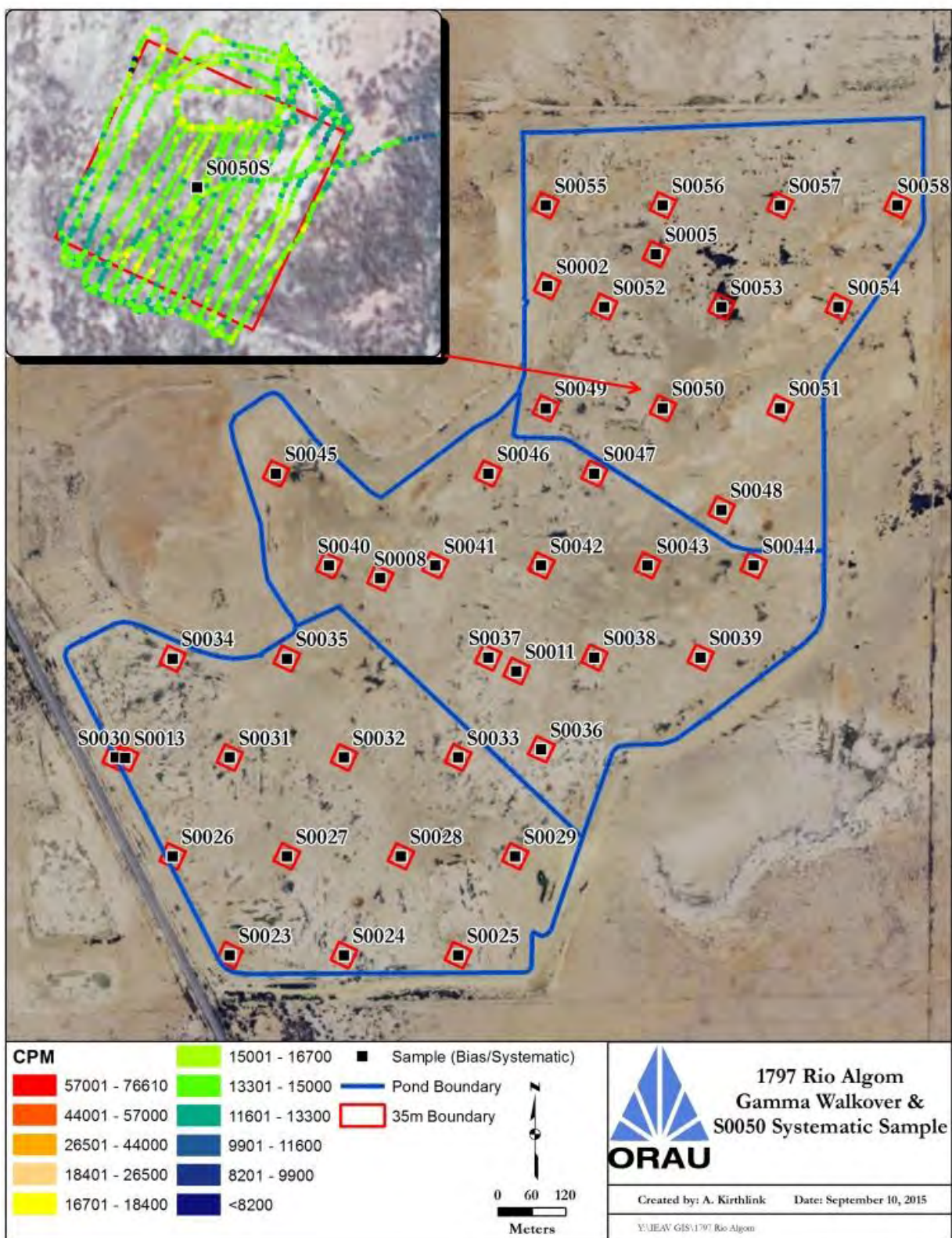


Figure A-35. CU S0050: Gamma Radiation Scans and Sample Location

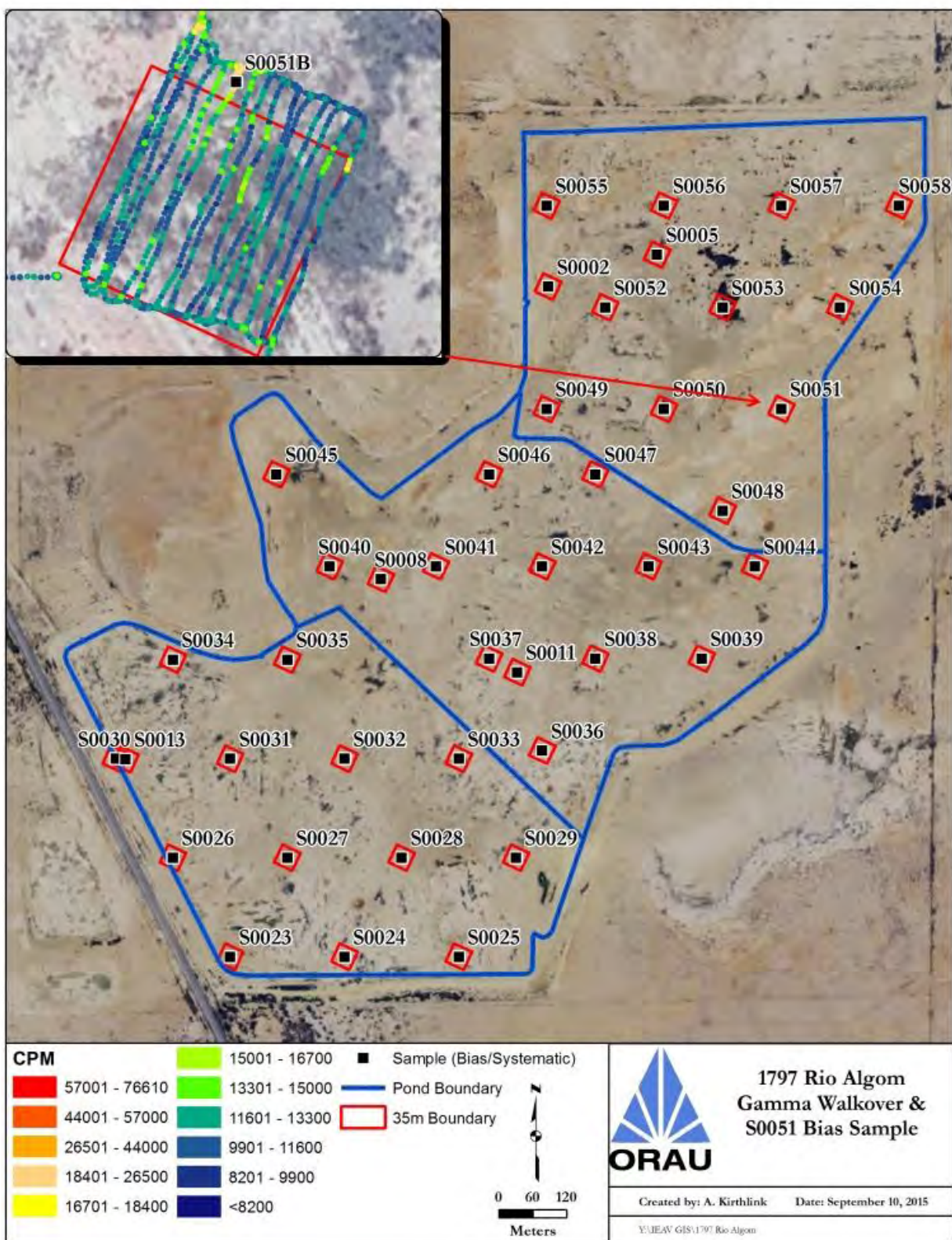


Figure A-36. CU S0051: Gamma Radiation Scans and Sample Location

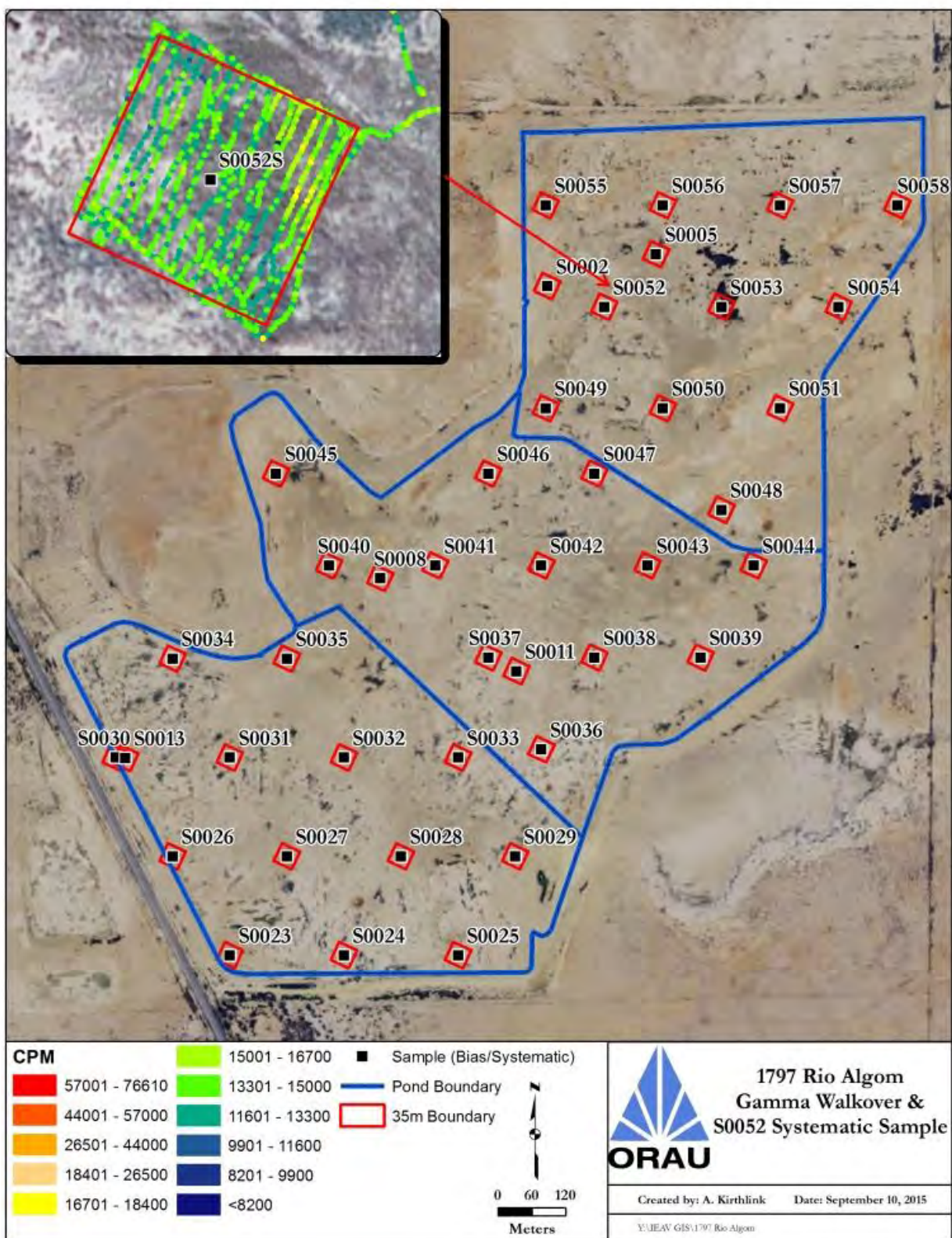


Figure A-37. CU S0052: Gamma Radiation Scans and Sample Location

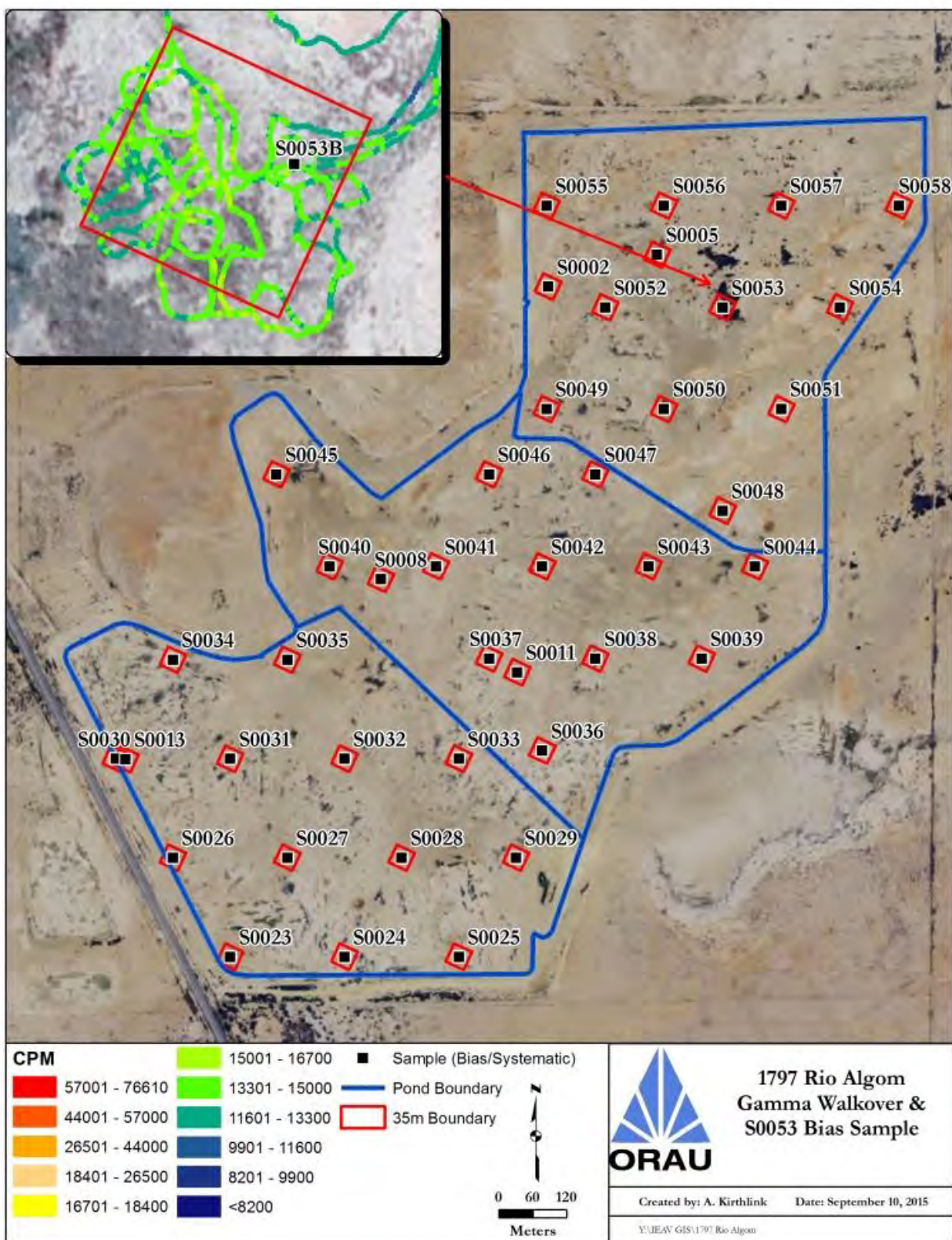


Figure A-38. CU S0053: Gamma Radiation Scans and Sample Location

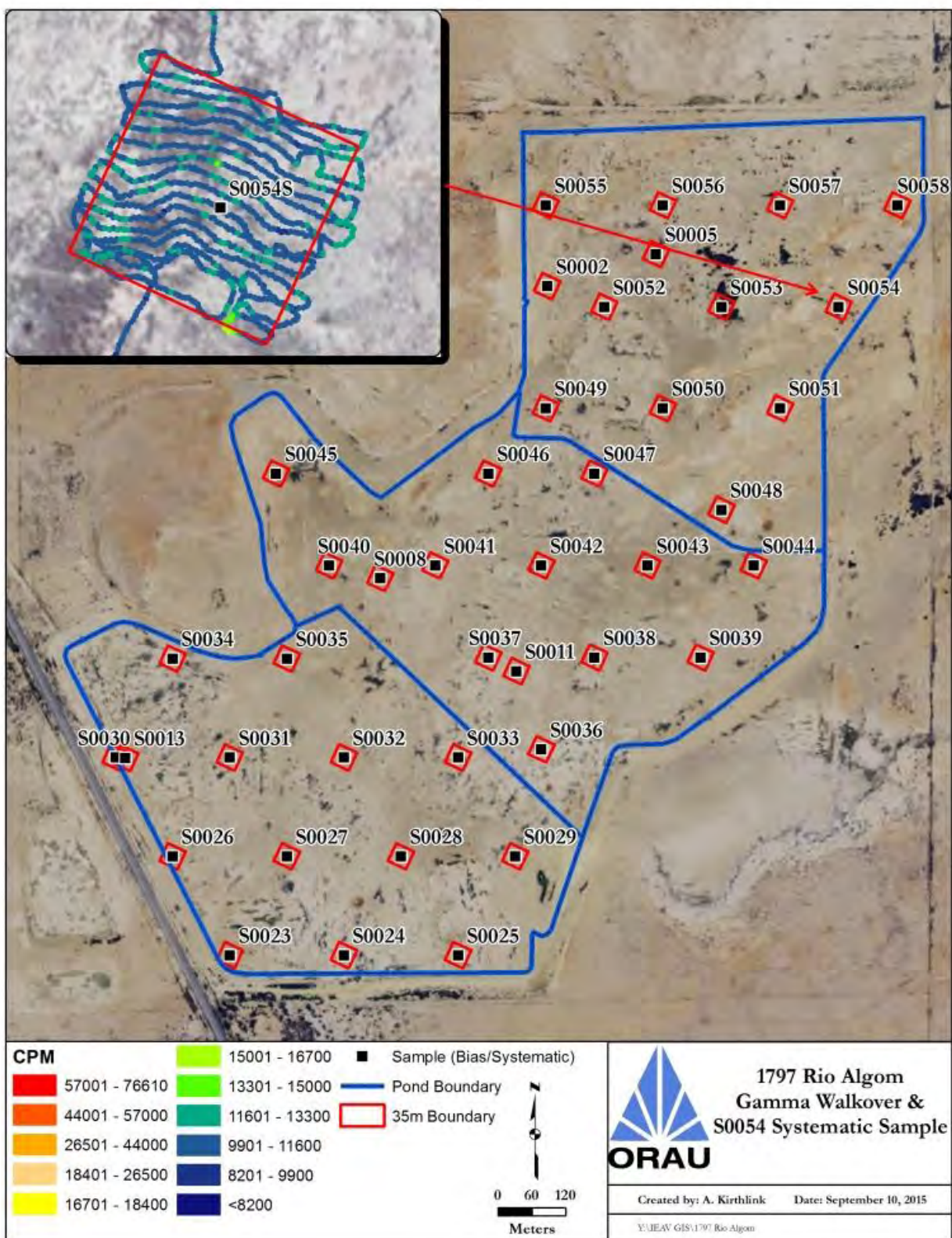


Figure A-39. CU S0054: Gamma Radiation Scans and Sample Location

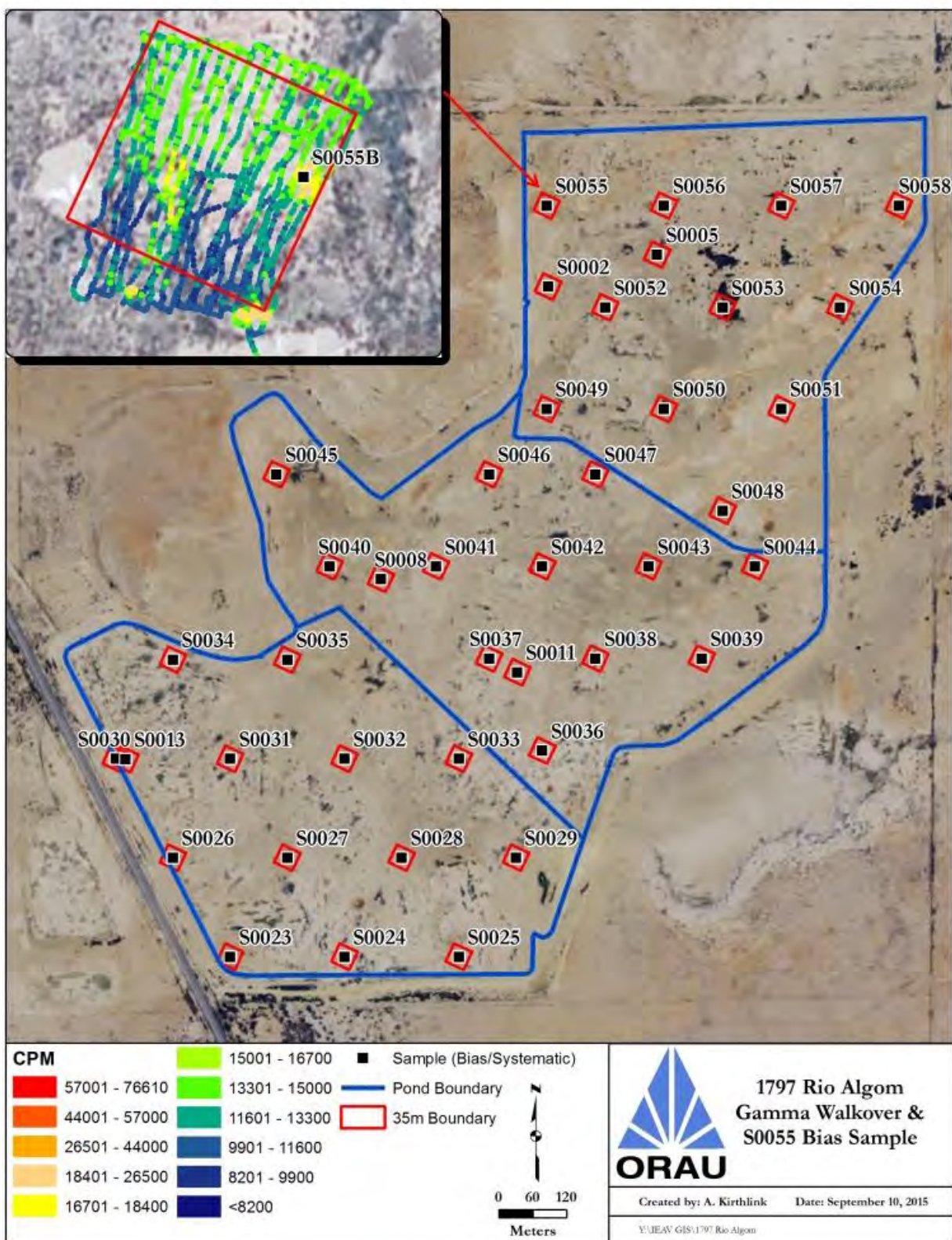


Figure A-40. CU S0055: Gamma Radiation Scans and Sample Location

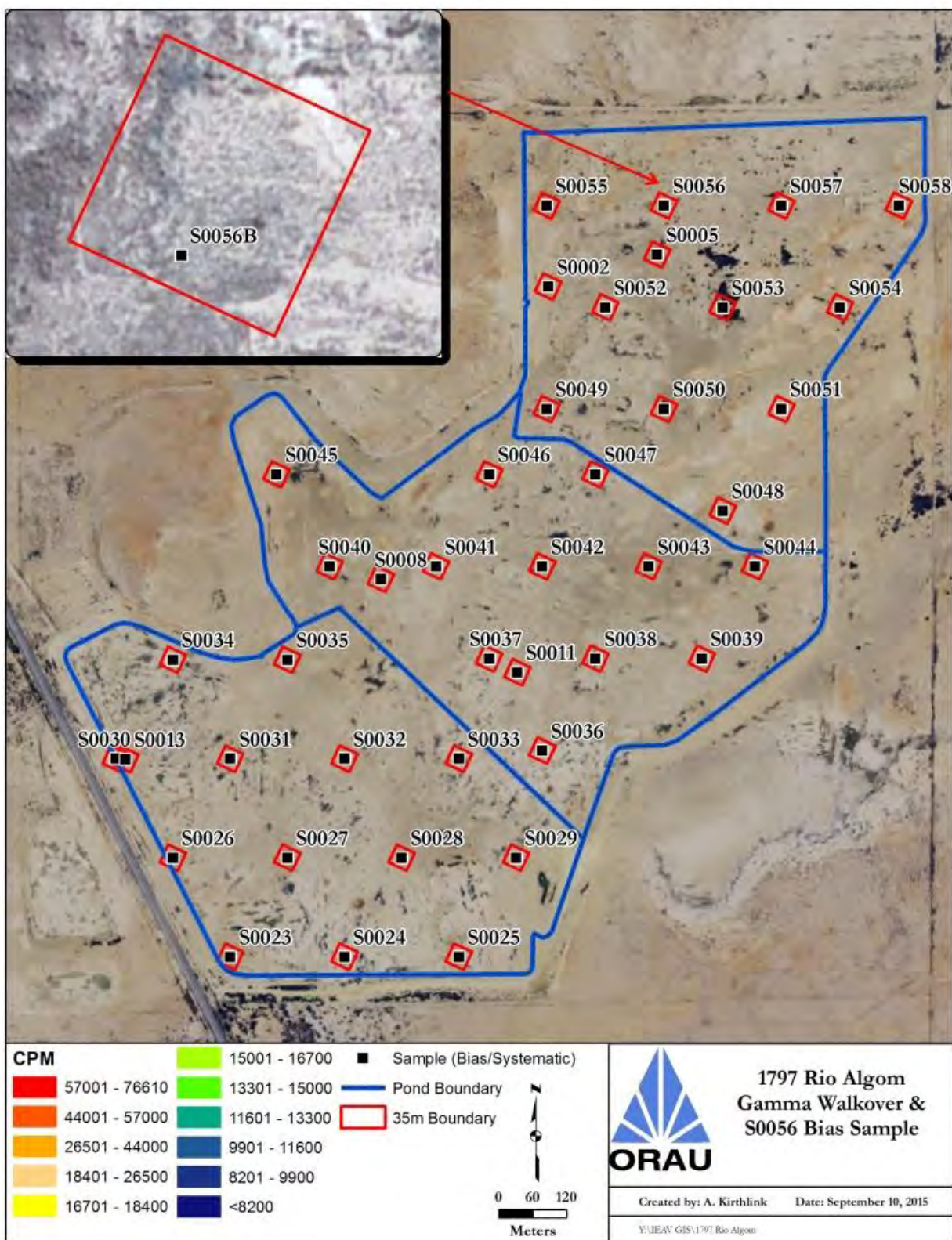


Figure A-41. CU S0056: Sample Location

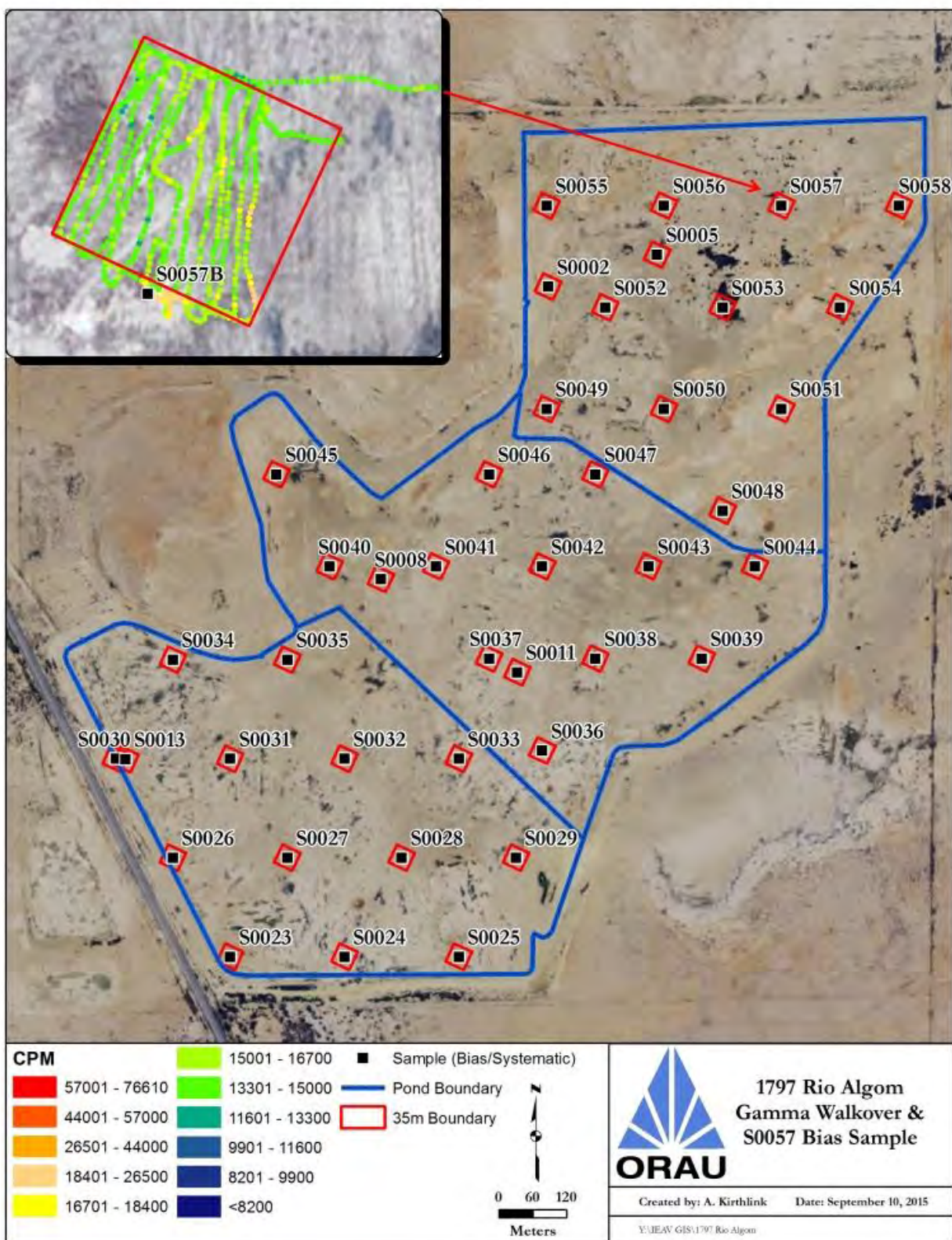


Figure A-42. CU S0057: Gamma Radiation Scans and Sample Location

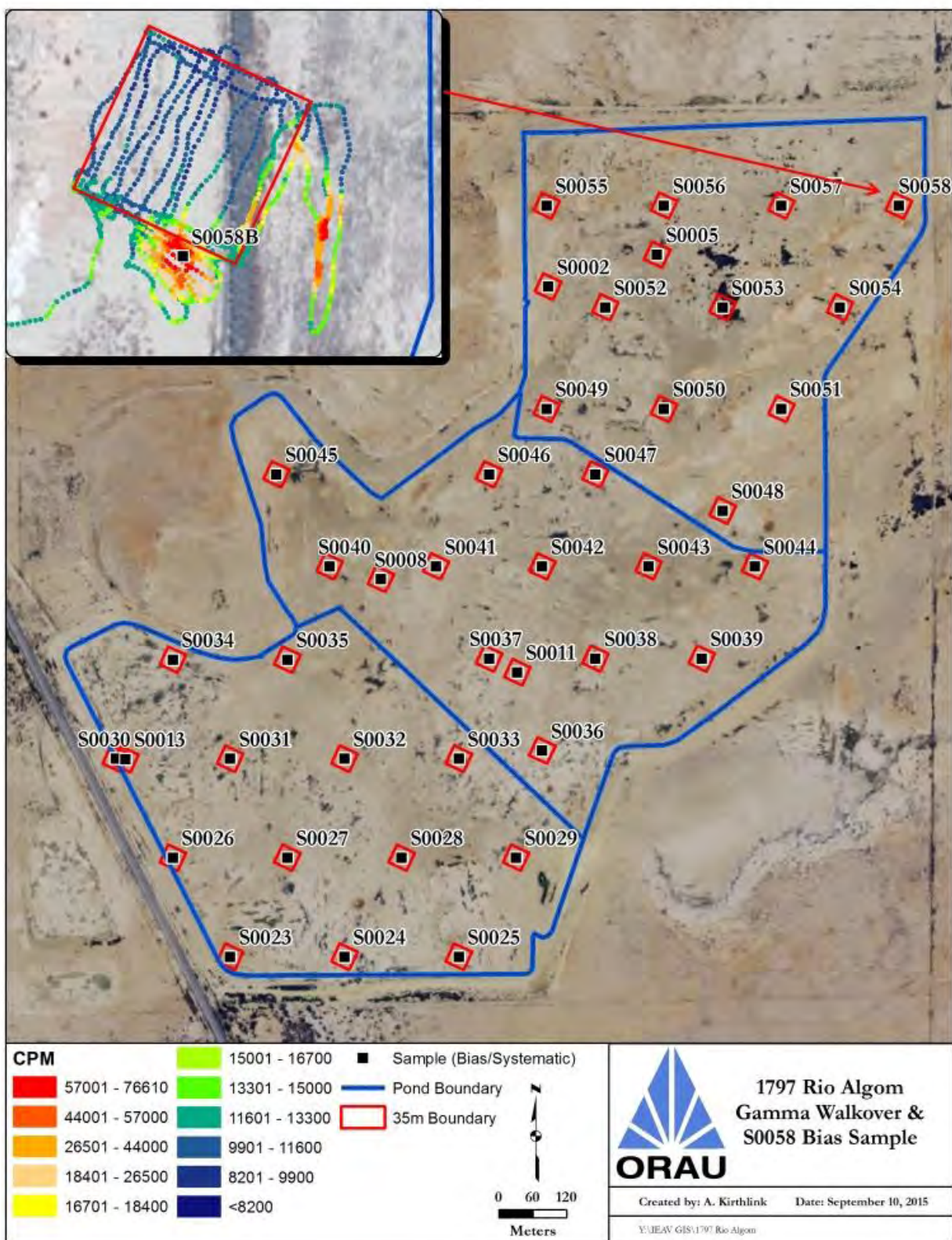


Figure A-43. CU S0058: Gamma Radiation Scans and Sample Location



Figure A-44. Area 1: Gamma Radiation Scan Overview

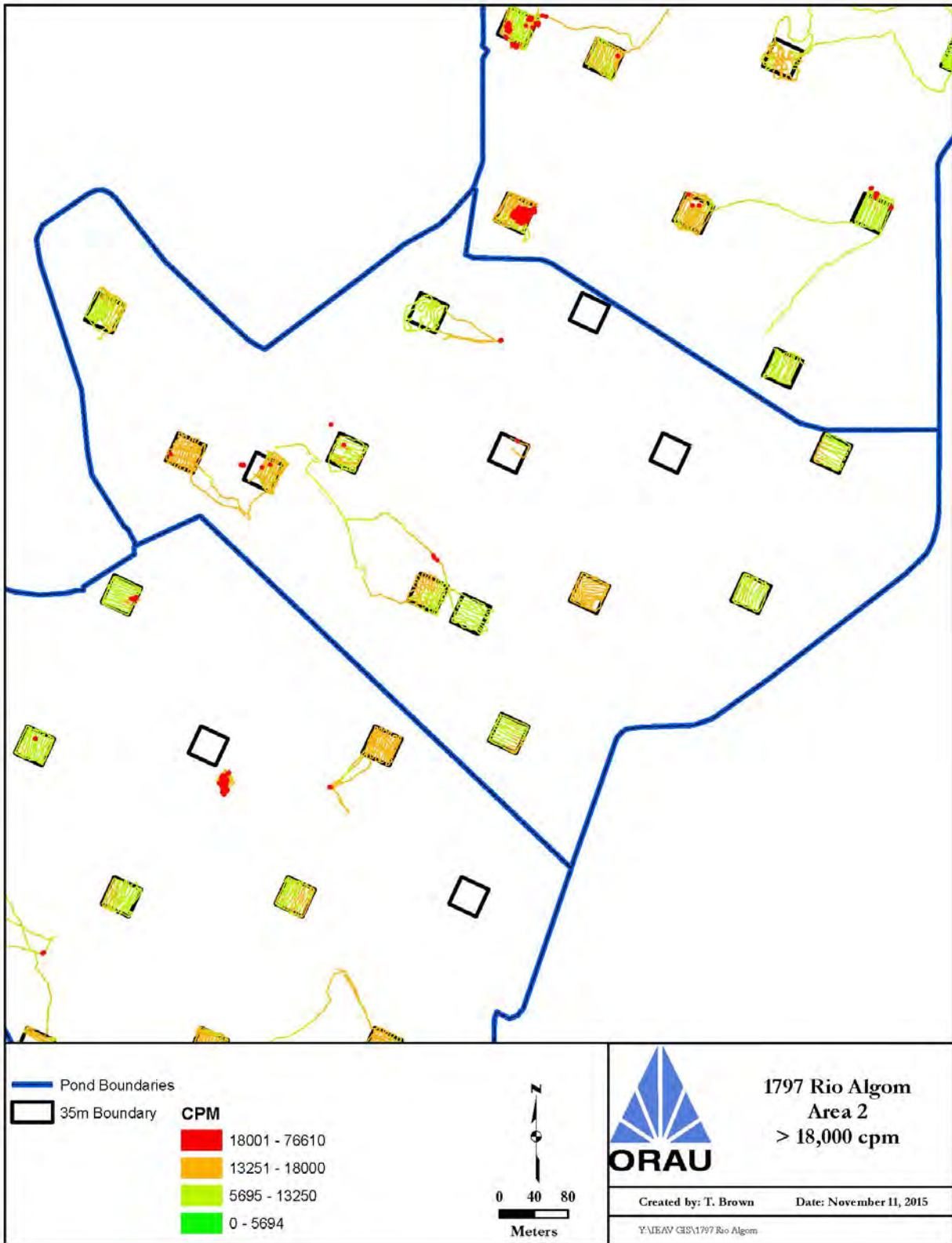


Figure A-45. Area 2: Gamma Radiation Scan Overview

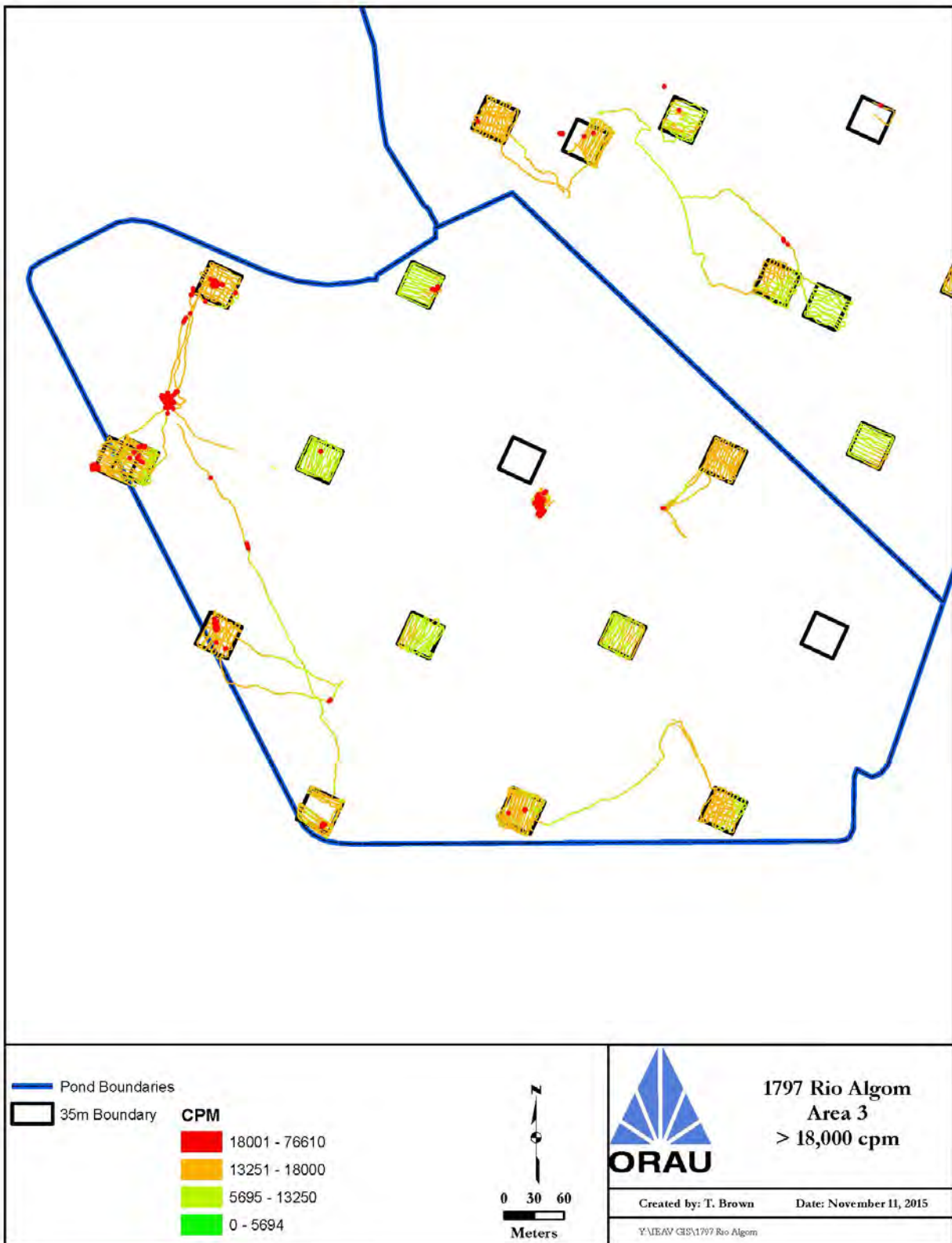


Figure A-46. Area 3: Gamma Radiation Scan Overview

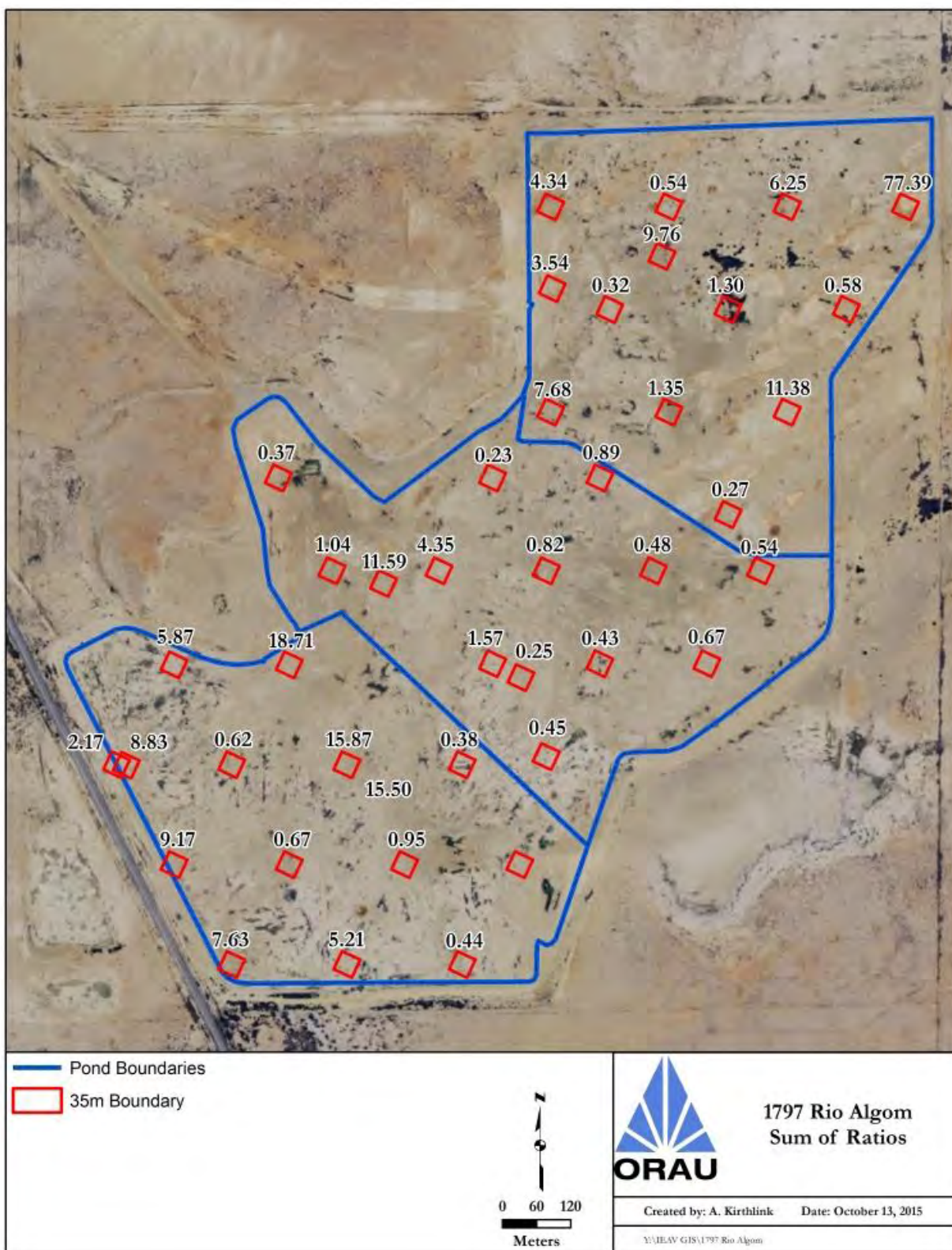


Figure A-47. Section 4 Ponds Area Posting Plot

APPENDIX B TABLES

Table B-1. Soil Sample Number and Coordinates			
Sample Number ^a	Northing	Easting	Direct Gamma Measurement (cpm)
S0002B	1596727.0	511960.0	19,334
S0005B	1596888.3	512484.5	21,283
S0008B	1595028.3	510855.7	31,360
S0011S	1594457.8	511718.3	12,026
S0013B	1594001.1	509484.4	21,704
S0023B	1592761.5	510076.3	22,927
S0024B	1592809.2	510735.1	21,134
S0025S	1592806.6	511390.3	15,709
S0026B	1593407.2	509724.4	22,297
S0027S	1593380.9	510393.7	14,622
S0028S	1593383.9	511057.9	14,598
S0029B	1593820.1	510788.3	29,070
S0030B	1593939.5	509315.3	23,065
S0031S	1593954.6	510063.5	11,137
S0032B	1594004.6	510672.9	27,887
S0033S	1593954.9	511393.1	15,294
S0034B	1594545.1	509710.8	25,582
S0035B	1594522.4	510451.3	24,485
S0036S	1594005.2	511875.1	12,872
S0037B	1594592.2	511597.2	17,438
S0038S	1594536.7	512183.7	14,700
S0039S	1594538.4	512799.8	13,031
S0040S	1595072.4	510638.7	14,373
S0041B	1595181.9	511194.6	41,027
S0042S	1595070.8	511877.3	12,789
S0043S	1595072.4	512495.3	14,800
S0044S	1595068.4	513104.5	11,725
S0045B	1595609.3	510380.5	13,463
S0046B	1595597.2	511600.2	14,037
S0047S	1595607.3	512180.6	14,459
S0048S	1595393.4	512917.2	11,496
S0049B	1595985.0	511940.1	21,968
S0050S	1595986.1	512579.6	16,064
S0051B	1596054.8	513279.2	21,791
S0052S	1596578.1	512238.8	12,741
S0053S	1596582.1	512957.7	12,400
S0054S	1596573.2	513607.1	10,711
S0055B	1597162.2	511947.6	19,039
S0056B	1597132.8	512561.7	14,958
S0057B	1597108.9	513236.9	31,128
S0058B	1597096.9	513938.4	88,057

^aTask number portion of sample ID—1797—omitted for Table B-1

Table B-2. Radionuclide Concentrations in Composite Soil Samples

Table B-2. Radionuclide Concentrations in Composite Soil Samples						
Sample ID	Radionuclide Concentrations (pCi/g)					SOR
	Ra-226	Th-230	U-235	U-238	Total U ^a	
Area 1						
1797S0002B	1.45 ± 0.10 ^b	49.8 ± 8.3	0.31 ± 0.19	7.6 ± 1.9	15.5 ± 3.8	3.54
1797S0005B	2.72 ± 0.26	155 ± 26	0.53 ± 0.26	4.5 ± 1.1	9.5 ± 2.3	9.76
1797S0048S	0.710 ± 0.062	1.9 ± 1.0	0.096 ± 0.075	1.10 ± 0.55	2.3 ± 1.1	0.27
1797S0049B	3.01 ± 0.20	119 ± 20	-0.03 ± 0.39	4.7 ± 1.2	9.4 ± 2.6	7.68
1797S0050S	1.470 ± 0.098	17.5 ± 3.3	0.248 ± 0.081	2.01 ± 0.59	4.3 ± 1.2	1.35
1797S0051B	3.40 ± 0.20	180 ± 30	0.40 ± 0.22	5.6 ± 1.3	11.6 ± 2.6	11.38
1797S0052S	0.907 ± 0.073	2.4 ± 1.2	0.05 ± 0.12	0.99 ± 0.62	2.0 ± 1.3	0.32
1797S0053S	1.193 ± 0.082	17.6 ± 3.7	0.196 ± 0.069	1.62 ± 0.50	3.4 ± 1.0	1.30
1797S0054S	0.749 ± 0.064	6.4 ± 1.5	0.091 ± 0.067	1.73 ± 0.54	3.6 ± 1.1	0.58
1797S0055B	1.92 ± 0.13	65 ± 11	0.18 ± 0.21	4.6 ± 1.3	9.4 ± 2.6	4.34
1797S0056B	1.154 ± 0.080	5.1 ± 1.5	0.112 ± 0.068	1.38 ± 0.43	2.87 ± 0.86	0.54
1797S0057B	3.43 ± 0.21	93 ± 16	0.30 ± 0.22	5.3 ± 1.3	10.9 ± 2.6	6.25
1797S0058B	23.4 ± 1.2	1,250 ± 200	1.63 ± 0.57	9.0 ± 3.1	19.6 ± 6.5	77.39
Area 2						
1797S0008B	3.14 ± 0.22	174 ± 28	0.79 ± 0.13	16.9 ± 3.7	34.6 ± 7.4	11.59
1797S0011S	0.776 ± 0.043	1.4 ± 2.6	0.054 ± 0.023	1.13 ± 0.27	2.31 ± 0.54	0.25
1797S0036S	0.91 ± 0.068	4.3 ± 2.9	0.084 ± 0.069	1.30 ± 0.40	2.70 ± 0.80	0.45
1797S0037B	2.06 ± 0.13	14.8 ± 5.4	0.55 ± 0.21	7.5 ± 1.7	15.6 ± 3.4	1.57
1797S0038S	1.48 ± 0.11	1.9 ± 1.4	0.11 ± 0.16	1.88 ± 0.90	3.9 ± 1.8	0.43

Table B-2. Radionuclide Concentrations in Composite Soil Samples

Sample ID	Radionuclide Concentrations (pCi/g)					SOR
	Ra-226	Th-230	U-235	U-238	Total U ^a	
1797S0039S	0.923 ± 0.067	7.5 ± 2.3	0.162 ± 0.064	1.70 ± 0.50	3.6 ± 1.0	0.67
1797S0040S	1.32 ± 0.11	12.5 ± 2.5	0.144 ± 0.084	2.08 ± 0.61	4.3 ± 1.2	1.04
1797S0041B	1.90 ± 0.13	67 ± 11	-0.26 ± 0.28	2.66 ± 0.69	5.1 ± 1.5	4.35
1797S0042S	1.054 ± 0.082	9.7 ± 2.5	0.19 ± 0.089	1.75 ± 0.71	3.7 ± 1.4	0.82
1797S0043S	1.48 ± 0.12	2.8 ± 1.5	0.16 ± 0.10	1.84 ± 0.59	3.8 ± 1.2	0.48
1797S0044S	0.897 ± 0.066	2.8 ± 1.2	0.229 ± 0.075	4.6 ± 1.1	9.4 ± 2.2	0.54
1797S0045B	1.359 ± 0.096	-0.1 ± 2.4	0.232 ± 0.072	3.41 ± 0.83	7.1 ± 1.7	0.37
1797S0046B	0.899 ± 0.068	0.9 ± 1.3	0.025 ± 0.093	0.92 ± 0.35	1.87 ± 0.71	0.23
1797S0047S	1.014 ± 0.079	11.1 ± 2.8	0.204 ± 0.065	1.70 ± 0.48	3.6 ± 0.96	0.89
Area 3						
1797S0013B	2.73 ± 0.16	139 ± 23	0.299 ± 0.089	4.9 ± 1.1	10.1 ± 2.2	8.83
1797S0023B	2.30 ± 0.13	119 ± 20	0.330 ± 0.098	5.5 ± 1.3	11.3 ± 2.6	7.63
1797S0024B	1.84 ± 0.12	78 ± 13	0.407 ± 0.086	6.7 ± 1.5	13.8 ± 3.0	5.21
1797S0025S	2.02 ± 0.11	0.1 ± 3.3	0.168 ± 0.047	2.72 ± 0.63	5.6 ± 1.3	0.44
1797S0026B	2.60 ± 0.19	144 ± 23	0.32 ± 0.14	6.0 ± 1.3	12.3 ± 2.6	9.17
1797S0027S	1.131 ± 0.061	6.8 ± 2.4	0.127 ± 0.029	1.99 ± 0.46	4.11 ± 0.92	0.67
1797S0028S	1.054 ± 0.059	11.5 ± 2.3	0.188 ± 0.031	2.28 ± 0.51	4.7 ± 1.0	0.95
1797S0029B	6.68 ± 0.34	243 ± 41	0.52 ± 0.14	4.6 ± 1.2	9.7 ± 2.4	15.50
1797S0030B	8.24 ± 0.46	12.7 ± 2.9	0.36 ± 0.11	4.4 ± 1.1	9.2 ± 2.2	2.17
1797S0031S	0.848 ± 0.058	7.7 ± 2.2	0.147 ± 0.052	0.89 ± 0.28	1.93 ± 0.56	0.62
1797S0032B	3.75 ± 0.21	252 ± 41	0.53 ± 0.19	9.4 ± 2.1	19.3 ± 4.2	15.87

Table B-2. Radionuclide Concentrations in Composite Soil Samples

Sample ID	Radionuclide Concentrations (pCi/g)					SOR
	Ra-226	Th-230	U-235	U-238	Total U ^a	
1797S0033S	1.309 ± 0.088	2.0 ± 2.3	0.125 ± 0.070	1.45 ± 0.67	3.0 ± 1.3	0.38
1797S0034B	3.10 ± 0.20	89 ± 15	-0.23 ± 0.39	3.67 ± 0.97	7.1 ± 2.1	5.87
1797S0035B	4.38 ± 0.35	301 ± 49	0.42 ± 0.27	7.0 ± 1.6	14.4 ± 3.3	18.71

^aTotal uranium concentration determined as follows: ([U-238]*2 + [U-235])

^bUncertainties are based on total propagated uncertainties at the 95% confidence level

APPENDIX C
MAJOR INSTRUMENTATION

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

C.1. SCANNING AND MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS

Ludlum NaI Scintillation Detector Model 44-10, Crystal: 5.1 cm × 5.1 cm

(Ludlum Measurements, Inc., Sweetwater, TX)

coupled to:

Ludlum Ratemeter-scaler Model 2221

(Ludlum Measurements, Inc., Sweetwater, TX)

coupled to:

Trimble Data Logger (Trimble Navigation Limited, Sunnyvale, CA)

C.2. LABORATORY ANALYTICAL INSTRUMENTATION

High-Purity, Extended Range Intrinsic Detector

CANBERRA/Tennelec Model No: ERVDS30-25195

(Canberra, Meriden, CT)

Used in conjunction with:

Lead Shield Model G-11

(Nuclear Lead, Oak Ridge, Tennessee) and

Multichannel Analyzer

Canberra's Gamma Software

Dell Workstation

(Canberra, Meriden, CT)

High-Purity, Intrinsic Detector

Model No. GMX-45200-5

CANBERRA Model No: GC4020

(Canberra, Meriden, CT)

Used in conjunction with:

Lead Shield Model G-11

Lead Shield Model SPG-16-K8

(Nuclear Data)

Multichannel Analyzer

Canberra's Gamma Software

Dell Workstation

(Canberra, Meriden, CT)

APPENDIX D
SURVEY AND ANALYTICAL PROCEDURES

D.1 PROJECT HEALTH AND SAFETY

ORAU performed all survey activities in accordance with the *ORAU Radiation Protection Manual*, the *ORAU Health and Safety Manual*, and the *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2014, ORAU 2015e, and ORAU 2015b). Prior to on-site activities, a work-specific hazard checklist was completed for the project and discussed with field personnel. The planned activities were thoroughly discussed with site personnel prior to implementation to identify hazards present. Additionally, prior to performing work, a pre-job briefing and walkdown of the survey areas were completed with field personnel to identify hazards present and discuss safety concerns. Should ORAU have identified a hazard not covered in the *ORAU Radiological and Environmental Survey Procedures Manual* or the project's work-specific hazard checklist for the planned survey and sampling procedures, work would not have been initiated or continued until it was addressed by an appropriate job hazard analysis and hazard controls.

D.2 CALIBRATION AND QUALITY ASSURANCE

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

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

ORAU Radiological and Environmental Survey Procedures Manual (ORAU 2015b)

ORAU Radiological and Environmental Analytical Laboratory Procedures Manual (ORAU 2015d)

ORAU Environmental Services and Radiation Training Quality Program Manual (ORAU 2015c)

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

Quality control procedures include:

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations
- Participation in Mixed-Analyte Performance Evaluation Program, NIST Radiochemistry Intercomparison Testing Program, and Intercomparison Testing Program Laboratory Quality Assurance Programs
- Training and certification of all individuals performing procedures
- Periodic internal and external audits

D.3 SURVEY PROCEDURES

D.3.1 SURFACE SCANS

Scans for elevated gamma radiation were performed by passing the detector slowly over the surface. The distance between the detector and surface was maintained at a minimum. Specific scan minimum detectable concentration (MDCs) for the sodium iodide scintillation detectors (NaI) were not determined as the instruments were used solely as a qualitative means to identify elevated gamma radiation levels in excess of background. Identifications of elevated radiation levels that could exceed the site criteria were determined based on an increase in the audible signal from the indicating instrument.

The detectors used had a general background of 11,000 cpm. The minimum detectable count rate (MDCR) was calculated as:

$$b_i = (11,000)(2 \text{ s})(1 \text{ min}/60 \text{ s}) = 370 \text{ counts}$$

$$\text{MDCR} = (2.32)(370 \text{ counts})^{1/2}[(60 \text{ s}/\text{min})/2\text{s}] = 1,340 \text{ cpm}$$

$$\text{MDCR}_{\text{surveyor}} = 222/(0.5)^{1/2} = 1,900 \text{ cpm}$$

$$\text{Th-230 Scan MDC} = 2280 \text{ pCi/g}$$

$$\text{Ra-226 Scan MDC} = 3.2 \text{ pCi/g}$$

$$\text{Gross Activity Scan MDC} = 83.5 \text{ pCi/g}$$

D.3.3 SOIL SAMPLING

Soil samples (approximately 0.5 kilogram each) were collected using a clean garden trowel. Within each 100 m² area, the five increments were first homogenized within the sample hole, then an equal volume aliquot was collected from each location, placed in a clean stainless steel bowl, homogenized, quartered, and an equal volume aliquot taken from each quarter and placed into the sample container. The container was then labeled and security sealed in accordance with ORAU procedures. ORAU personnel shipped samples under chain-of-custody to the ORAU laboratory for analysis.

D.4 RADIOLOGICAL ANALYSIS

D.4.1 GAMMA SPECTROSCOPY

Samples were analyzed as received, mixed, crushed, and/or homogenized as necessary, and a portion sealed in a 0.5-liter Marinelli beaker. The quantity placed in the beaker was chosen to reproduce the calibrated counting geometry. Net material weights were determined and the samples counted using intrinsic, high purity, germanium detectors coupled to a pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. All total absorption peaks (TAPs) associated with the ROCs were reviewed for consistency of activity. Spectra were also reviewed for other identifiable TAPs. TAPs used for determining the activities of ROCs and the typical associated MDCs, based on a six-hour count time for Th-230 and one- to six-hour count times for other ROCs following a 28-day ingrowth period, were:

Table D-1. Analytical MDCs		
Radionuclide	TAP (MeV)	MDC (pCi/g)
U-238 by Th-234	63.3	0.5
U-235	143.8 or 205	0.1
Th-230	67.7	5.0
Ra-226 (by Pb-214)	351.9	0.1

D.4.2 DETECTION LIMITS

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