Comparison of Site Characterization Using In-Situ Gamma Spectroscopy, Laboratory Gamma Spectroscopy, ICP-Mass Spectroscopy, and GPS/Gamma Surveys at a Radiologically Contaminated Site

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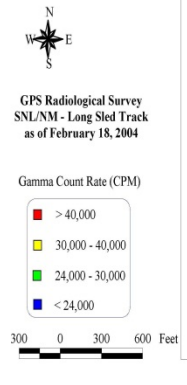

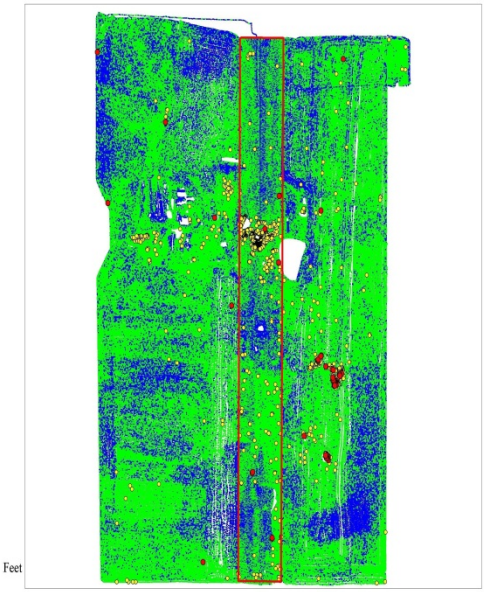

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Introduction

A radiologically contaminated site at Sandia National Laboratories (SNL) was partially characterized using four different methods to determine the relative efficacy, accuracy and precision of each. The four methods were:

1) In-situ gamma spectroscopy,
2) Laboratory gamma spectroscopy,
3) Laboratory inductively-coupled plasma mass spectroscopy (ICP-MS), and
4) Global-positioning system (GPS)/gamma field surveys.

The characterization methods are discussed, along with the results of the investigation.

Site Description

- SNL Environmental Restoration Site 83, used for rocket sled impact tests.
- Primary contaminant: depleted uranium (DU)
- Large DU fragments on the surface were identified and removed in 1994.
- Remaining DU are very heterogeneously distributed.

Current Situation

- Site is still used for non-radiological impact tests.
- Spatial and depth distribution of remaining DU have not been mapped.
- Remaining DU requires RWP for intrusive work (digging, trenching, etc.). This leads to perpetual operational cost increases.

Basis for Study

- Need for cost-effective determination of the distribution of remaining DU.
- Area of concern: ~200 - 400 acres
- Heterogeneous distribution of DU suggests “hotspot” cleanups or risk-based no-further-action determination.

Study Approach

Number of sample locations: 26

Methods of characterization:

- In-situ gamma spectroscopy
- Laboratory gamma spectroscopy
- Laboratory ICP-MS
- GPS/gamma surveys w/ 2” X 2” NaI detector

In-situ gamma spectroscopy

- In-situ Ge(Li) (~2 hours per count)
- 10 m^2 “field of view”
- Assuming 6” contaminant depth, equivalent to 22.5 million grams

Laboratory gamma spectroscopy

- Laboratory Ge(Li) 6000-second count
- ~500 grams per sample (9-plug composite from 100 m^2 area)

Laboratory ICP-MS

- Laboratory ICP-MS Assay
- Minimal sample preparation (dissolve sample w/ HF plus HNO_3), directly into equipment
- Sample is only 0.1 gram

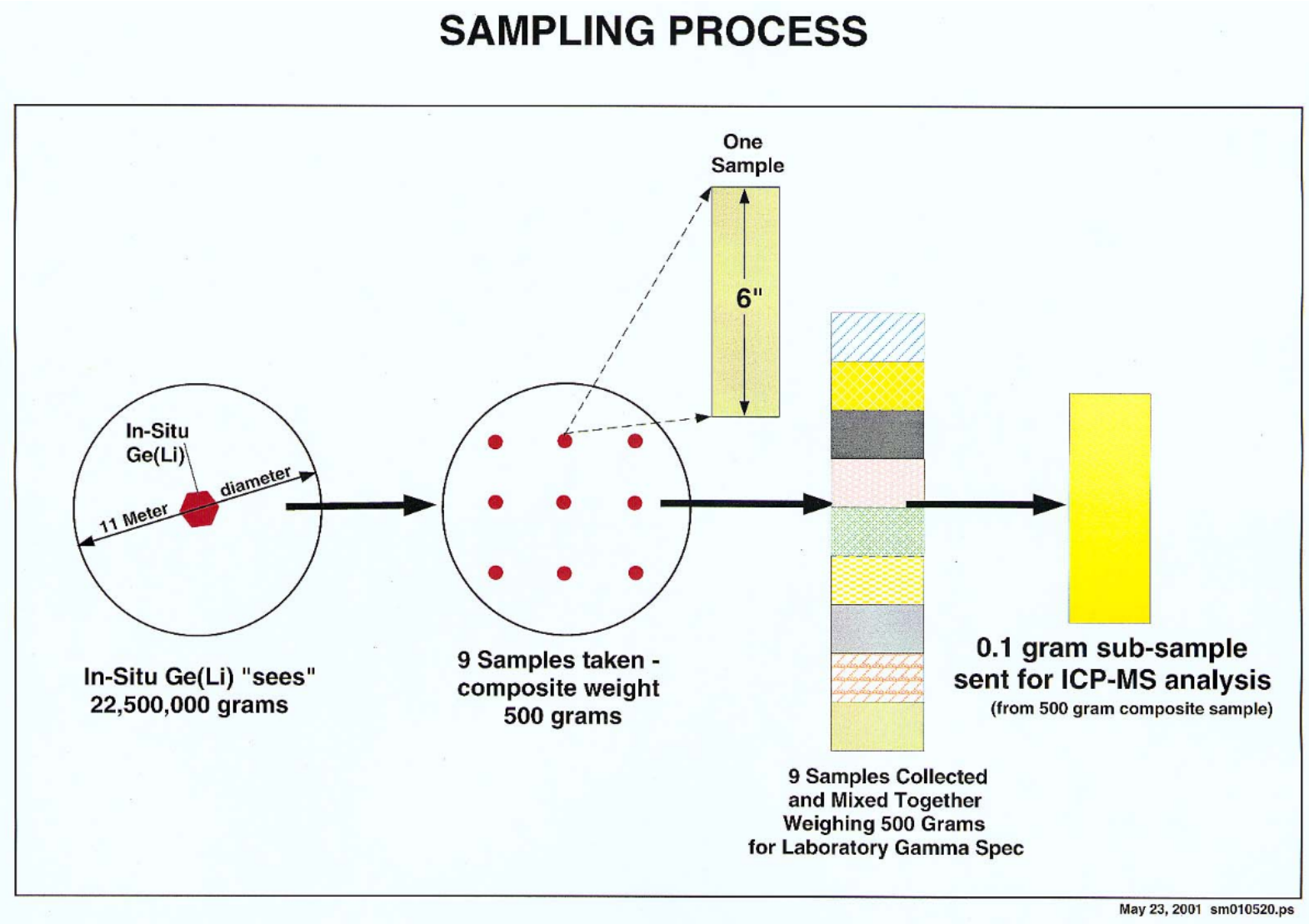
GPS/gamma surveys w/ 2” X 2” NaI detector

- Detector ~ 6” high
- Hand-held, stroller mount, or vehicle mount, as determined by site
- ~20 acres/day
- ~22,000 data points/day
- More detectors or slower movement gives greater data density

Results

- All four approaches produced “comparable” results (considering low concentrations and analytical uncertainties). *(See Table and Graph.)*
- Sample “aliquoting” may be a major contributor to variance when contamination is extremely heterogeneously distributed. (See illustration.)

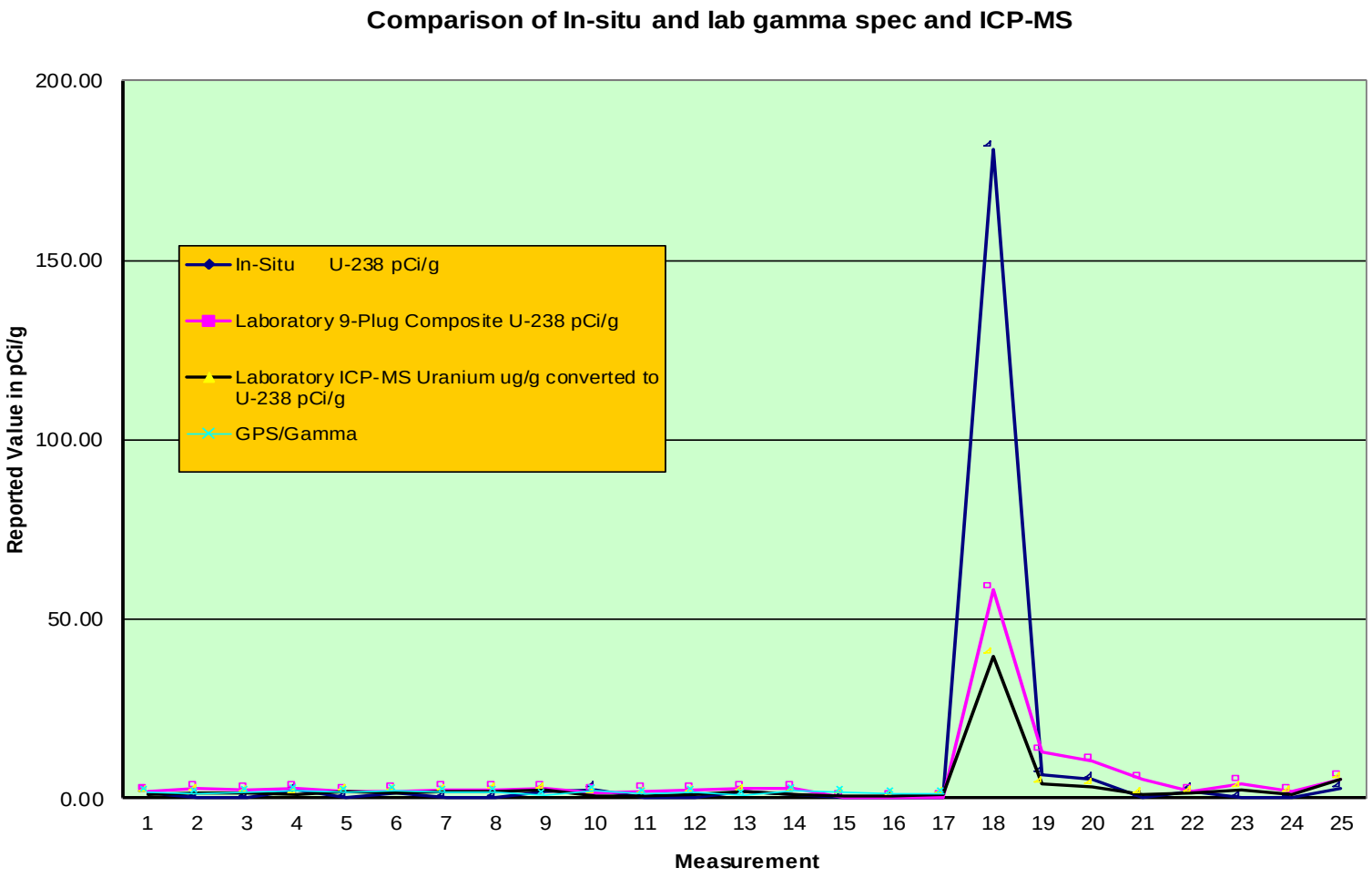
Illustration of Aliquoting Error



Data Summary Table

Coordinates	Customer Sample ID	In-Situ U-238 pCi/g	In-situ 2-Sigma Error	In-situ MDA	Laboratory 9-Plug Composite U-238 pCi/g	Lab 2-Sigma Error	Lab MDA	Laboratory ICP-MS Uranium ug/g converted to U-238 pCi/g	ICP-MS 2-Sigma Error	GPS/Gamma CMP converted to pCi/g
408562.78 E 1449986.5N	054592-003	**1.29**	1.35	0.61	**1.76**	0.50	0.80	**1.09**	0.02	**1.55**
408618.469 E 1449990.62N	054593-003	**ND**	NA	0.70	**2.51**	0.61	0.94	**1.46**	0.10	**1.30**
408675.719 E 1449974.5N	054594-003	**ND**	NA	0.71	**2.07**	0.62	1.05	**1.26**	0.07	**1.63**
408649.594 E 14499112.75N	054595-003	**2.13**	0.74	0.98	**2.52**	0.65	0.95	**0.84**	0.02	**1.85**
408603.5E 1449925.0N	054596-003	**ND**	NA	0.84	**1.73**	0.51	0.90	**1.82**	0.09	**1.59**
408557.78 E 1449923.875N	054597-003	**1.40**	0.55	0.74	**2.04**	0.55	0.93	**1.49**	0.05	**1.92**
408583.125 E 1449855.5N	054598-003	**ND**	NA	0.81	**2.33**	0.57	0.94	**1.74**	0.06	**1.54**
408632.313 E 1449853.125N	054599-003	**ND**	NA	0.66	**2.41**	0.66	0.95	**1.91**	0.09	**1.52**
408619.25 E 1449825.5N	054600-003	**1.97**	2.10	0.61	**2.53**	0.65	0.94	**2.07**	0.11	**0.84**
408617.25 E 1449689.625N	054601-003	**2.26**	0.80	0.59	**1.58**	0.51	0.92	**0.57**	0.00	**1.94**
408743.438 E 1449785.625N	054602-003	**ND**	NA	0.71	**1.89**	0.54	0.96	**0.68**	0.03	**1.26**
408785.5 E 1449907.375N	054603-003	**ND**	NA	0.55	**2.05**	0.54	0.91	**1.13**	0.03	**1.79**
408774.844 E 1450071.25N	054604-003	**1.73**	0.60	0.80	**2.66**	0.72	1.01	**1.71**	0.00	**0.87**
408617.25 E 1450130.25N	054605-003	**1.19**	0.58	0.82	**2.67**	0.63	0.88	**1.13**	0.04	**1.85**
408481.0 E 1450071.25N	054606-003	**ND**	NA	0.65	**ND**	NA	1.17	**0.60**	0.01	**1.46**
408425.125 E 1449908.0N	054607-003	**ND**	NA	0.65	**ND**	NA	1.13	**0.49**	0.00	**1.18**
408475.375 E 1449785.625N	054608-003	**ND**	NA	0.63	**ND**	NA	1.15	**0.83**	0.01	**1.19**
408797 E 1449310N	054609-003	**181.00**	25.80	2.88	**58.00**	12.6	1.46	**39.70**	1.02	
408948.594 E 1449248N	054610-003	**6.68**	1.32	1.27	**12.70**	3.49	1.36	**3.80**	0.04	
408711 E 1448890N	054611-003	**5.20**	1.46	0.53	**10.20**	2.33	0.99	**3.19**	0.01	
408869 E 1448780N	054612-003	**ND**	NA	0.66	**5.19**	1.34	0.99	**0.77**	0.01	
408420 E 1450319N	054615-003	**1.94**	1.84	0.51	**1.73**	0.52	1.00	**1.34**	0.05	
408418.875 E 1450319N	054616-003	**ND**	NA	0.64	**3.97**	1.03	1.87	**2.39**	0.02	
408327 E 1449931N	054613-003	**ND**	NA	0.67	**1.68**	0.53	0.88	**0.98**	0.07	
408344 E 1449753N	054614-003	**2.66**	1.78	0.60	**5.25**	1.33	1.01	**5.08**	0.22	
		17.45			**5.89**			**3.12**		
		2.59			**3.31**			**3.12**		
Column Mean		**18.84**			**5.89**			**3.12**		**1.49**
Column S.D.		**51.53**			**11.98**			**7.69**		**0.34**
Relative Shift w/all		**3.88**			**16.70**			**25.99**		**586.72**
S.D. w/o highest value		**1.75**			**2.89**			**1.10**		**0.34**
Relative Shift w/o Highest		**114.56**			**69.12**			**181.95**		**586.72**
Number of Samples Needed per 100 sq. meter per MARSSIM		**14**			**14**			**14**		**14**
Number of Samples Needed per acre (4047 sq. meter) per MARSSIM		**40**			**40**			**40**		**NA**
Projected sample cost per acre		**$3,840**			**$3,840**			**$1,280**		**$100**

Four-Way Comparison Graph



Conclusions

- GPS/gamma surveys are the most comprehensive and cost-effective for large sites (if gamma emitters are present). Projected sample cost per acre:
  In-Situ gamma: $3,840 Lab gamma: $3,840 ICP-MS: $1,280 GPS/gamma: $100

- GPS/gamma surveys are cheaper and better than “traditional” characterization that rely on statistical survey designs described in Multi-Agency Radiation Site Survey Implementation Manual (MARSSIM).

- Any field measurement must demonstrate the ability to detect ~10% of derived concentration cleanup guideline (DCLG).

- ICP-MS is more accurate, precise and cost-effective than in-situ and lab gamma spectroscopy, especially for long-lived radionuclides (such as uranium).

- The appropriate survey method and instrumentation depends on the radionuclide(s) present.

- The vertical distribution of contamination needs to be addressed on a site-specific basis.