REMEDIAL INVESTIGATIONS AND CLEAN-UP MADE EASY UTILIZING XRF TECHNOLOGY

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Historically, soil remedial investigations and cleanup activities have required significant waiting periods and a lot of experience based guesswork when determining if remedial excavation activities have achieved the desired depth and result.

Even with today's rapid turn-around timeframes for analytical results, excavation zones may be open for (2) two to (5) five days before post-remediation cleanup verification analytical results are available. During the interim time, excavations may be left open presenting a physical hazard, or the excavation zone may be backfilled presenting a potential for duplicating work re-excavating due to unanticipated analytical hits.

In either case, re-mobilization costs are a given. Adams and Wendt has recently conducted (3) three projects using XRF technologies to screen the extent of impacts during remedial activities for metal contaminated sites as well as Leaking Underground Storage Tank sites. These screening techniques have greatly simplified the cleanup process.

Bad News for Bagdad: Copper Concentrate Spill Bagdad, AZ

- May of 2019, a semi truck loaded with 20 tons of copper concentrate crashed, releasing the finely-grained concentrate onto the roadside and adjacent drainage.
- Copper concentrate was released in an environmentally sensitive area.
- The release occurred north of the Santa Maria River, that drains into Alamo Lake.
- Alamo Lake just so happens to designated as a Cat 5 impaired water system. Big Oops!

Big Problem in Bylas: Copper Concentrate Spill Bylas, AZ

- In October of 2019 a haul truck carrying 30 tons of copper concentrate crashed, releasing the concentrate on the roadside and in a railroad easement.
- Due to the consistency and characteristics of the concentrate, prompt cleanup was necessary.
- Basically, we did not have time to wait for the lab to produce results. A real-time method was required to characterize the extent of the copper contaminated soil.
- XRF to the rescue!

Metal Plating Mayhem: Metal Plating Facility Phoenix, AZ

In June of 2015, a metal plating facility caught fire and was extinguished by copious amounts of water from the local fire department, despite the obvious placards on the doors that illustrated the flammability, reactivity, and oxidation potential of the materials inside . The contaminated water impacted the soil below the concrete pad and the exterior portions of the building.

Procedure for Cleanup Using On-Site XRF Data & Evaluation

- **Task 1: Determine Background Readings and Impact Zone readings (20 or more is best)**
- Task 2: Identify Key Indicator Chemicals of Concern
- Task 3: Decide on Data Quality Objectives (DQOs), Cleanup Goals and Quality Assurance (QA) Requirements
- Task 4: Decide on Evaluative Method
  - Contrastive Evaluation
  - Statistical Evaluation
- Task 5: Implement Cleanup
  - Excavate
  - Regular XRF Readings to Determine if DQOs have been met.

Where to Start? Let's Get Some Background.

Table 1
Summary of XRF Data - Key Metal Indicators
May 24, 2019
Cu Concentrate Spill
Milepost 158, Highway 97, Bagdad, Arizona

Sample #	Description	Ag Conc (PPM)	As Conc (PPM)	Cu Conc (PPM)	Mo Conc (PPM)	Pb Conc (PPM)	S Conc (PPM)	Sb Conc (PPM)	Se Conc (PPM)	Zn Conc (PPM)
AZ Appendix A SRL Residential Non-Carcinogen (PPM)		**390.0**	**10.0**	**3100.0**	**390.0**	**400.0**	**NE**	**31.0**	**390.0**	**23000.0**
ADEQ Minimum GPLs for Metals (PPM)		**NE**	**290.0**	**NE**	**NE**	**290.0**	**NE**	**35.0**	**290.0**	**NE**
1	Background	0	2	1007	0	19	5689	0	0	31
2	Background	0	2	1007	0	19	5689	0	0	31
3	Background	0	0	24	0	67	1562	0	0	20
4	Background	0	0	22	0	33	726	0	0	34
8	Background	0	0	43	0	33	884	0	0	26
9	Background	0	0	242	0	20	1620	0	0	34
10	Background	0	4	272	0	31	1658	0	0	64
11	Background	0	4	16	0	22	623	0	0	53
12	Background	0	0	18	0	47	1030	0	0	28
13	Background	0	0	13	0	26	563	0	0	38
14	Background	0	0	53	0	35	940	0	0	45
15	Background	0	0	33	0	34	512	0	0	72
16	Background	0	0	40	0	24	882	0	0	41
17	Background	0	0	41	0	35	938	0	0	46
18	Background	0	0	66	0	34	866	0	0	95
19	Background	0	0	1015	0	20	4750	0	0	34
21	Background	0	6	128	0	28	974	0	0	91

BACKGROUND

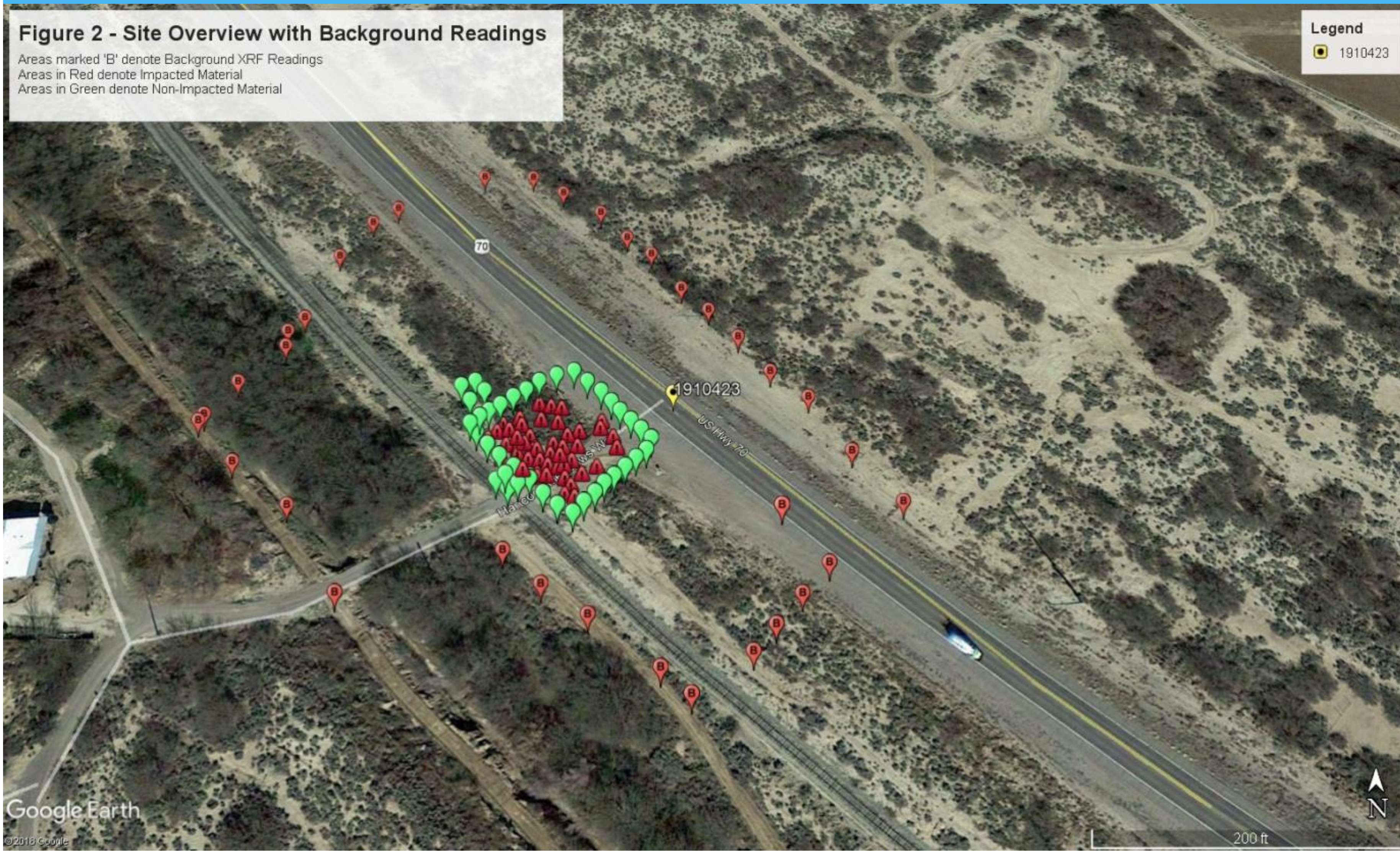
Figure 2 - Site Overview with Background Readings
Areas marked 'B' denote Background XRF Readings
Areas in Red denote Impacted Material
Areas in Green denote Non-Impacted Material
Legend
1910423
70
1910423
US Hwy 70
Google Earth
©2018 Google
200 ft
N

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Impacted Zone Readings

Table 2

Summary of Remediation and Cleanup Verification XRF Data - Key Metal Indicators

May 31, 2019

Cu Concentrate Spill

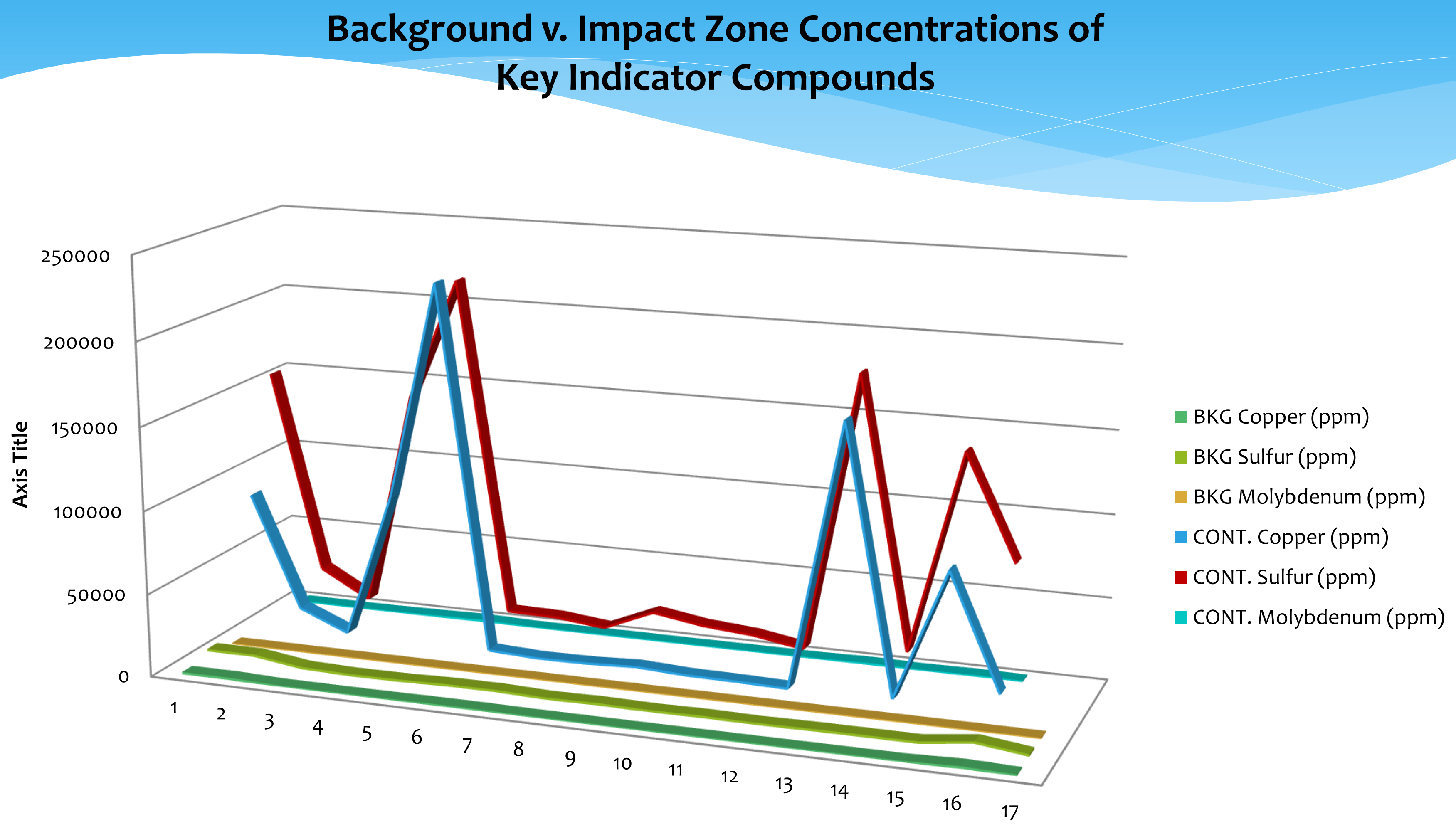
Milepost 158, Highway 97, Bagdad, Arizona

Sample #	Description	Ag Conc (PPM)	As Conc (PPM)	Cu Conc (PPM)	Mo Conc (PPM)	Pb Conc (PPM)	S Conc (PPM)	Sb Conc (PPM)	Se Conc (PPM)	Zn Conc (PPM)
	AZ Appendix A SRL Residential Non-Carcinogen (PPM)	**390.0**	**10.0**	**3100.0**	**390.0**	**400.0**	**NE**	**31.0**	**390.0**	**23000.0**
	ADEQ Minimum GPLs for Metals (PPM)	**NE**	**290.0**	**NE**	**NE**	**290.0**	**NE**	**35.0**	**290.0**	**NE**
1	Retention Basin - During Remediation	0	0	**2241**	0	**29**	**32959**	0	0	**79**
2	Retention Basin - During Remediation	0	**4**	**2741**	0	**35**	**22393**	0	0	**63**
3	Retention Basin - During Remediation	0	**8**	**7029**	**19**	**39**	**34022**	0	**2**	**108**
4	Retention Basin - During Remediation	0	0	**4735**	0	**35**	**58434**	0	0	**74**
5	Retention Basin - During Remediation	0	**4**	**1752**	0	**33**	**25470**	0	0	**62**
6	Retention Basin - During Remediation	0	**8**	**3774**	**11**	**27**	**24912**	0	0	**79**
7	Retention Basin - During Remediation	0	0	**3090**	0	**27**	**39040**	0	0	**95**
8	Retention Basin - During Remediation	0	0	**1081**	0	**41**	**15799**	0	**1**	**78**
9	Retention Basin - During Remediation	0	**5**	**3871**	0	**32**	**52755**	0	0	**54**
10	Retention Basin - During Remediation	0	**8**	**6209**	0	**32**	**79340**	0	0	**49**
11	Retention Basin - During Remediation	0	**6**	**4739**	0	0	**NA**	0	0	**793**
12	Retention Basin - During Remediation	0	0	**3128**	0	**24**	**NA**	0	0	**51**
14	Retention Basin - During Remediation	0	0	**2966**	0	**26**	**46259**	0	0	**35**
16	Retention Basin - During Remediation	0	0	**7304**	0	**39**	**87394**	0	0	**135**
17	Retention Basin - During Remediation	0	0	**1264**	0	**26**	**NA**	0	0	**89**
18	Retention Basin - During Remediation	0	0	**3281**	0	**33**	**46101**	0	0	**98**
19	Retention Basin - During Remediation	0	0	**912**	0	**34**	**13498**	0	0	**127**
20	Retention Basin - During Remediation	0	0	**1763**	0	**24**	**25207**	0	0	**51**
21	Retention Basin - During Remediation	0	**9**	**1700**	0	**35**	**23214**	0	0	**77**
22	Retention Basin - During Remediation	0	**6**	**1513**	0	**28**	**15164**	0	0	**102**

Identify Key Indicators

IDENTIFICATION OF KEY INDICATOR COCs						
Background				***Contaminated Zone***		
Copper	**Sulfide**	**Molybdenum**		**Copper**	**Sulfide**	**Molybdenum**
1007	5689	0		85705	154768	313
1007	5689	0		17089	33767	40
24	1562	0		4764	17341	0
22	726	0		93274	147579	380
43	884	0		224689	220394	827
242	1620	0		3842	19295	0
272	1658	0		2348	18721	0
16	623	0		2633	15471	102
18	1030	0		3948	28233	6
13	563	0		2369	23408	0
53	940	0		2023	20960	0
33	512	0		1315	15818	0
40	882	0		162659	183403	507
41	938	0		2194	20781	0
66	866	0		81664	142661	299
1015	4750	0		12160	80070	15
128	974	0				

Identify Key Indicators



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DQOs, Cleanup Goals and QA Evaluation

- Regulatory Limits (Arizona)
  - Residential Soil Remediation Levels (rSRLs)
  - Non-Residential Soil Remediation Levels (nr-SRLs)
  - Groundwater Protection Levels (GPLs)
- Background Concentrations
  - Site Specific Targets for Background
- Other Risk Based Limits
- What Quality Assurance Checks are Needed
  - Verification Samples from Fixed Based Laboratory

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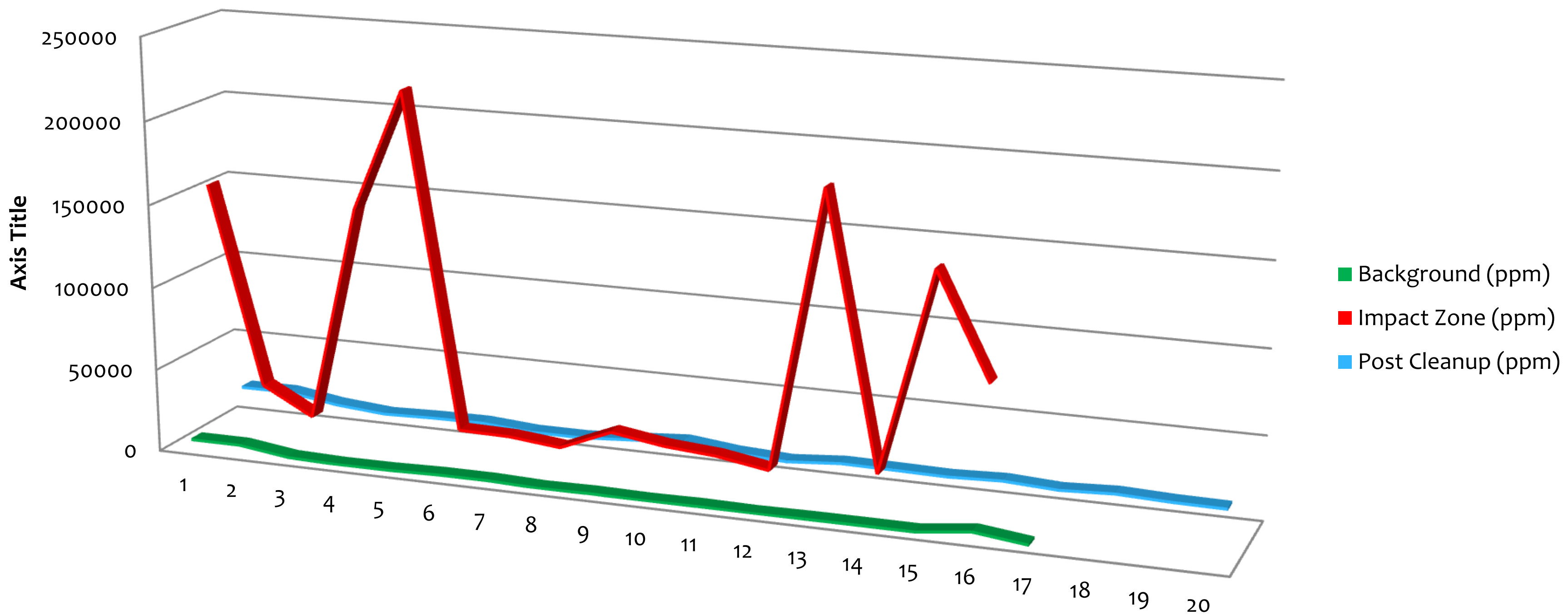
Contrastive Data Evaluation

Background v. Impacted v. Post Cleanup

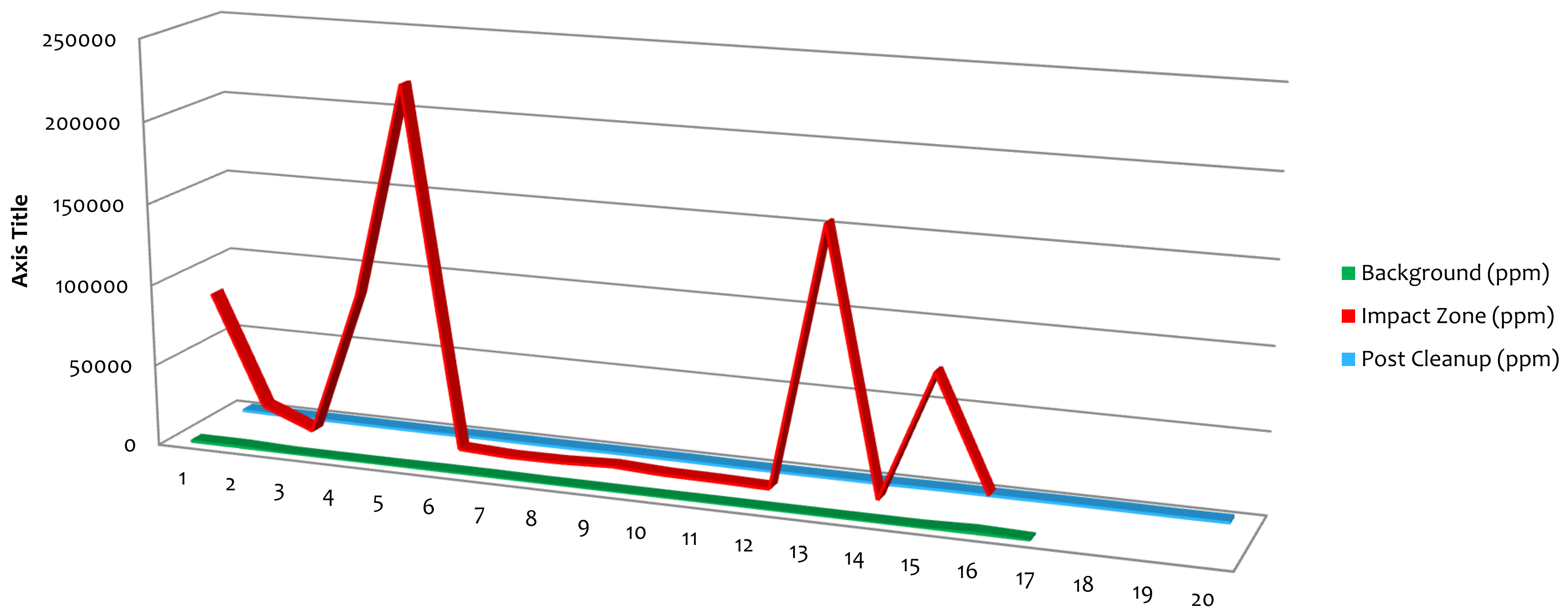
SULFUR



Contrastive Data Evaluation

Background v. Impacted v. Post Cleanup

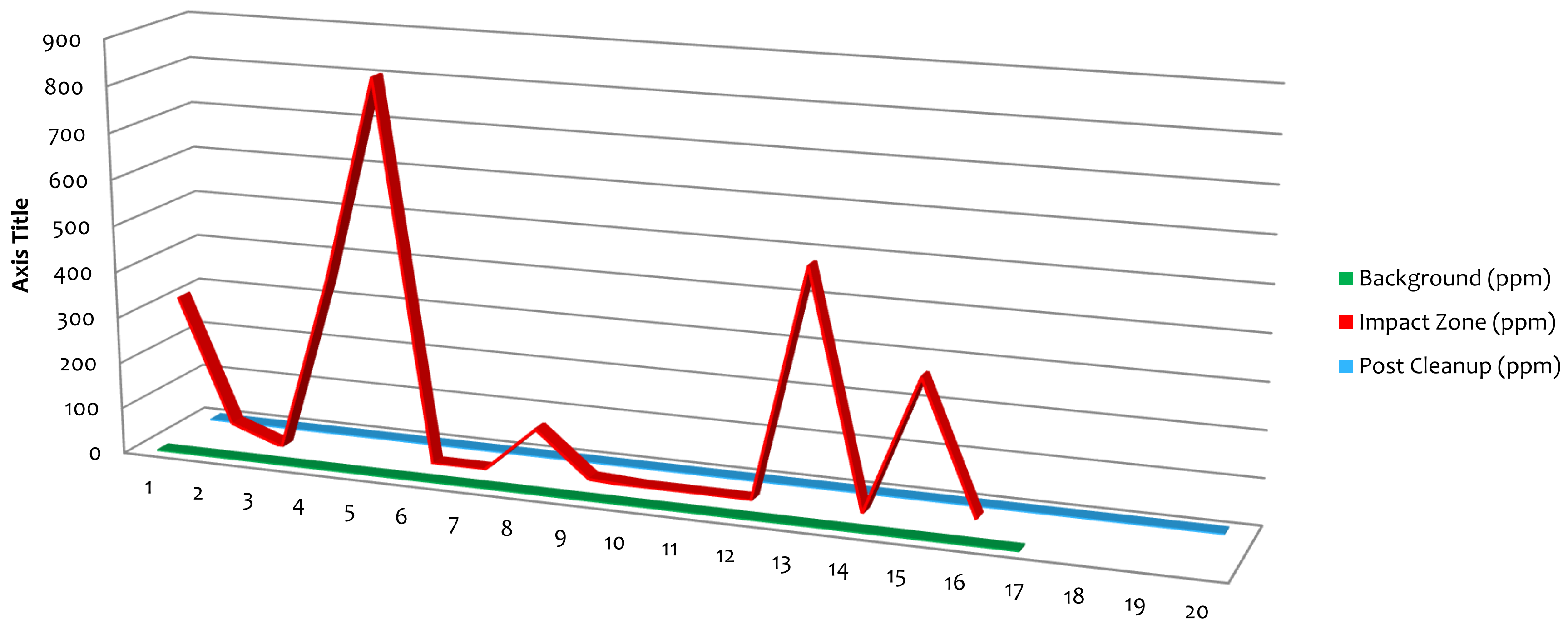
COPPER



Contrastive Data Evaluation

Background v Impacted v Post Cleanup

MOLYBDENUM



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Statistical Analysis

- ProUCL Statistical Software
  - Developed by EPA to enable evaluation of data sets
  - Simple and easy to use
  - Several statistical methods and graphical tools
  - Trend analyses
  - Evaluation for 95% confidence level for data sets
  - Needs multiple data points that XRF On-site provides

https://www.epa.gov/land-research/proucl-software

Statistical Analysis for Background

Gamma UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.112/23/2019 11:53:30 AM
From File	UCLs.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Background Readings

General Statistics

Total Number of Observations	36	Number of Distinct Observations	32
		Number of Missing Observations	0
Minimum	35	Mean	117.9
Maximum	358	Median	103
SD	74.96	SD of logged Data	0.587
Coefficient of Variation	0.636	Skewness	1.492

Gamma GOF Test

A-D Test Statistic	0.425	Anderson-Darling Gamma GOF Test
5% A-D Critical Value	0.754	Data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.129	Kolmogorov-Smirnov Gamma GOF Test
5% K-S Critical Value	0.148	Data appear Gamma Distributed at 5% Significance Level

Data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.071	k star (bias corrected MLE)	2.834
Theta hat (MLE)	38.39	Theta star (bias corrected MLE)	41.61
nu hat (MLE)	221.1	nu star (bias corrected)	204
MLE Mean (bias corrected)	117.9	MLE Sd (bias corrected)	70.03
		Approximate Chi Square Value (0.05)	172
Adjusted Level of Significance	0.0428	Adjusted Chi Square Value	170.6

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	139.9	95% Adjusted Gamma UCL (use when n<50)	141

Suggested UCL to Use

95% Adjusted Gamma UCL	141

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

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Reading While Cleaning

Other Applications: Tetraethyl Lead Contamination Associated with LUSTs

Other Applications: Tetraethyl Lead Contamination

Other Applications: Tetraethyl Lead Contamination

- **Lessons Learned for TEL Sites**
  - XRF systems are easy to use but detection limits are above cleanup levels.
  - Good at identifying significant lead contaminated soil.
  - Opportunity to evaluate numerous sample locations instead of guessing and waiting for results from laboratory.
  - Needs to be (1) one of multiple screening tools on-site.
  - Should not be the only tool used until detection capability is lower.

CONCLUSIONS

- **PROs**
  - Quick means of screening soil to assist in determining when excavation post remediation samples are appropriate.
  - Sample reading time is 1 to 2 minutes thus enabling the collection of numerous sample locations for cleanup determination and statistical analyses in real time on site.
  - Reduced open excavation times and costs for remobilizations to project sites.
  - Reduced analytical costs and down time for analysis.
  - Numerous compounds may be evaluated (85+ for Olympus Model).
  - Data may be downloaded to a laptop or tablet for evaluation at the site during excavation activities.

CONCLUSIONS

- **CONs**
  - XRF testing is not an approved analytical method for cleanup verification sampling by the ADEQ.
  - XRF detection levels are typically above residential soil remediation levels for TEL and some other compounds.
  - Cost of rental of XRF gun is typically $1,500 per week and purchase may be above 25K.
  - XRF cannot be used as the sole means of evaluation for TEL at UST sites.
  - Full evaluation of data is not provided on equipment, must download and evaluate data on computer or laptop.

WARNER VAUGHAN

GREGORY DOZER