

**Old Church Rock Mine
Eastern Abandoned Uranium Mine Region**

**OCRM Removal Assessment
Appendix C
XRF Verification and Validation Report**

Response, Assessment, and Evaluation Services

Contract No. EP-S9-17-03

Task Order 0035

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U.S. Environmental Protection Agency**

**Submitted by
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ATTACHMENTS

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Attachment C-2: Certified Reference Material
Attachment C-3: XRF (Electronic)

ACRONYMS AND ABBREVIATIONS

CRM	Certified reference material
OCRM	Old Church Rock Mine
QA	Quality assurance
QC	Quality control
RPD	Relative percent difference
SAP	Sampling and analysis plan
Tetra Tech	Tetra Tech, Inc.
XRF	X-ray fluorescence
USEPA	U.S. Environmental Protection Agency



1.0 INTRODUCTION

This document presents the quality assurance (QA), quality control (QC), and verification methods and results of the in situ X-ray fluorescence (XRF) surveys performed during the 2022 field investigation at the Old Church Rock Mine (OCRM) in New Mexico. This document is included as Appendix C of the OCRM removal assessment report.

QA includes qualitative factors that provide confidence in the results while QC involves quantitative field evidence that supports the validity of results. During the in situ XRF surveys at OCRM, Tetra Tech, Inc. (Tetra Tech) adhered to the QA/QC procedures for collecting in situ XRF measurements in the U.S. Environmental Protection Agency (USEPA)-approved removal assessment sampling and analysis plan (SAP) (Tetra Tech 2022). To assess the validity of the data collected, Tetra Tech used the data quality indicators described in Appendix B of the 2018 removal site evaluation report (Tetra Tech 2018).

2.0 OVERVIEW OF THE IN SITU X-RAY FLUORESCENCE SURVEYS

This section provides an overview of the in situ XRF surveys performed at OCRM during the 2022 field investigation.

2.1 X-RAY FLUORESCENCE INSTRUMENTATION

XRF survey measurements were performed using a Niton XL5 XRF with a soil guard installed over the primary window of the instrument. XRF measurements were collected using an XRF filter setting in seconds of 60s:0s:0s (Main:High:Low). [Table C-1](#) summarizes the individual instruments used during the removal assessments and dates of use.

Table C-1. XRF Instrumentation Used During Field Investigation

Manufacturer	Model	Serial Number	Dates of Use
Niton	XL5	X500940	11/16/2022
			11/17/2022
			11/18/2022
			11/19/2022

Note:

XRF X-ray fluorescence

2.2 SURVEYS PERFORMED

The XRF surveys were intended to collect screening-level data. Screening-level data were used to support soil sample collection and estimate the extent of metal contamination at the site. Areas at OCRM investigated during XRF survey activities were:

- The fenced area
- The adjacent area to the southeast across State Route 566
- The background study area

In addition to these areas, XRF measurements were also collected along radial transects in cardinal and ordinal directions originating from the center of the site.

XRF surveys were conducted following the methodology described in Section 4.1.2.3 of the removal assessment SAP (Tetra Tech 2022).

3.0 QUALITY ASSURANCE AND QUALITY CONTROL

This section presents the QA/QC methods and results.

3.1 QUALITY ASSURANCE

An important QA protocol for in-field XRF surveys involves instrument calibration. All XRF instruments used for screening data collection purposes during fieldwork were factory calibrated within the previous 12 months. Copies of factory calibration documentation for all detectors used during the survey are provided in [Attachment C-1](#).

3.2 QUALITY CONTROL

This subsection summarizes the methods and results of the QC analyses performed for those detectors that were used during the XRF surveys. One detector was used for screening. The QC protocol involved pre-trip baseline and daily function QC checks. The purpose of these QC analyses was to quantify the consistency of the instrument's response to a known source for instrument consistency and functionality during the course of the fieldwork. QC data measurements were recorded for all detectors that were used during the survey.

An explanation of the QC methods for the detectors, including results of the QC checks, data validation and categorization, and duplicate error analysis, are presented in the following subsections.

3.2.1 Pre-Trip Baseline Quality Control Checks

Pre-trip baseline QC checks were collected at an indoor location for each detector that could be potentially used during the XRF survey. The purpose of these measurements was to quantify the response of the instrument to sources. A total of 12 60s:0s:0s counts were collected on a certified reference material (CRM), provided to Tetra Tech by USEPA, with known concentrations of copper, uranium, and vanadium. The baseline checks then served as a reference to compare daily function checks. The pre-trip baseline QC check was performed on November 14, 2022. The CRM used for the pre-trip baseline QC check is DC73319a. A copy of the elemental composition of the CRM is included in [Attachment C-2](#).

The results of the baseline measurements are summarized in [Table C-2](#), including the mean and standard deviation baseline response for copper, uranium, and vanadium. The mean and standard deviation can be used to assess the daily function checks.

Table C-2. XRF Baseline Response

Date	XRF Serial Number	Run Number	Analyte Results (ppm)		
			Copper	Uranium	Vanadium
11/14/2022	X500940	918	37.7	8.1	64.4
		919	37.0	6.9	93.5
		920	36.1	5.3	65.0
		921	35.6	6.9	53.9
		922	33.1	4.8	50.6
		923	35.8	8.0	72.1
		924	34.2	6.2	81.2
		925	38.2	5.5	65.5
		926	33.8	8.6	61.7
		927	32.5	6.3	46.5
		928	33.1	7.2	62.3
		929	36.5	5.9	58.4
Baseline Average:			35.3	6.6	64.6
Baseline Standard Deviation			1.9	1.2	13.0

Notes:

Run number 919 was excluded from the baseline response dataset as its measurement duration was too short.

Exclusion of datapoints from the XRF dataset is discussed in [Section 3.2.3.2](#).

ppm Parts per million

XRF X-ray fluorescence

3.2.2 Daily Function Quality Control Checks

Under the QC program, factory-calibrated instruments must also meet onsite field test criteria. Daily instrument function checks are measurements performed to verify instrument performance each time an instrument is used. The instrument function checks consist of collecting five 60s:0s:0s measurements on a CRM with the instrument used to conduct XRF surveys. For this project, the field checks were performed in Gallup, New Mexico, within room 214 of the Gallup Holiday Inn Express.

For normally distributed data, 99 percent of all measurements are expected to fall within ± 3 standard deviations from the mean. Any instrument with a QC measurement result falling outside ± 3 standard deviations from the mean of all QC measurements on the field check control chart required investigation. A detector exceeding control limits on any QC function check would be replaced with a spare detector and sent back to the manufacturer for evaluation, repair, and recalibration.

The daily QC checks for each instrument are summarized in [Table C-3](#). A QC chart for the daily QC background measurements, including the initial baseline QC measurements, is provided in [Figure C-1](#), [Figure C-2](#), and [Figure C-3](#) for copper, uranium, and vanadium, respectively.

The average of each daily function check for each analyte (copper, uranium, and vanadium) was within one standard deviation of the baseline mean with no error bar exceeding two standard deviations of the measured baseline response mean.



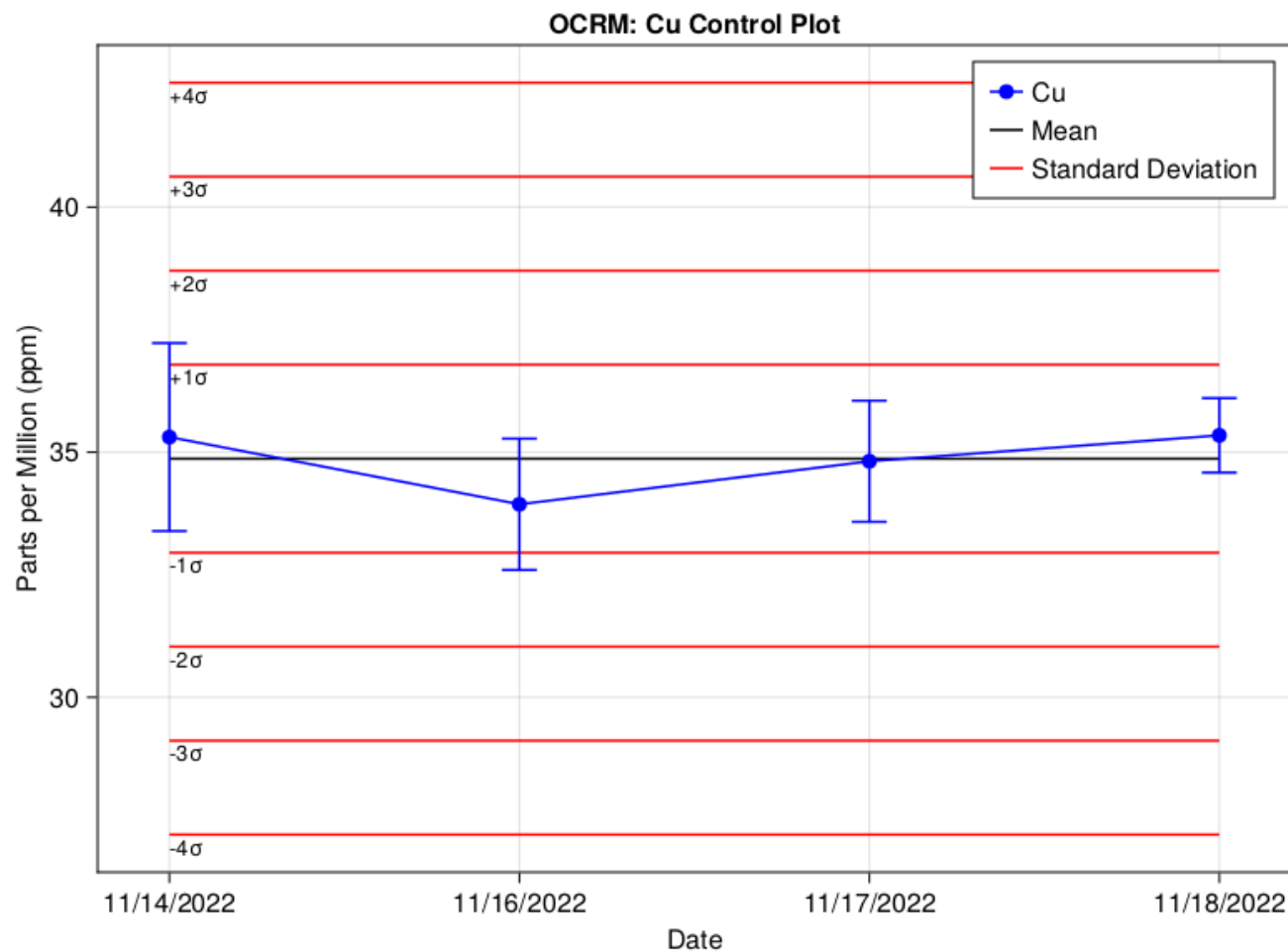
Table C-3. Daily Function Check Results

Date	XRF Serial Number	Run Number	Analyte Results (ppm)		
			Copper	Uranium	Vanadium
11/16/2022	X500940	979	35.1	9.8	86.5
	X500940	980	33.0	9.0	62.8
	X500940	981	36.3	8.5	72.0
	X500940	982	33.5	7.2	75.3
	X500940	983	34.6	5.5	75.9
	X500940	984	33.3	6.3	55.1
	X500940	985	32.1	9.6	71.1
	X500940	986	33.5	7.9	66.9
Daily Average:			33.9	8.0	70.7
11/17/2022	X500940	1031	35.8	6.5	76.7
	X500940	1032	34.8	7.7	58.0
	X500940	1033	35.6	7.2	73.8
	X500940	1034	33.1	6.5	51.0
Daily Average:			34.8	7.0	64.9
11/18/2022	X500940	1057	34.6	8.3	69.8
	X500940	1058	36.3	7.3	57.4
	X500940	1059	34.7	9.0	51.7
	X500940	1060	35.9	6.5	69.0
	X500940	1061	35.2	6.9	75.0
Daily Average:			35.3	7.6	64.6

Notes:

ppm Parts per million

XRF X-ray fluorescence

**Notes:**

Cu Copper
OCRM Old Church Rock Mine
ppm Parts per million

Figure C-1. X500940 XRF Daily Function Check Control Chart - Copper

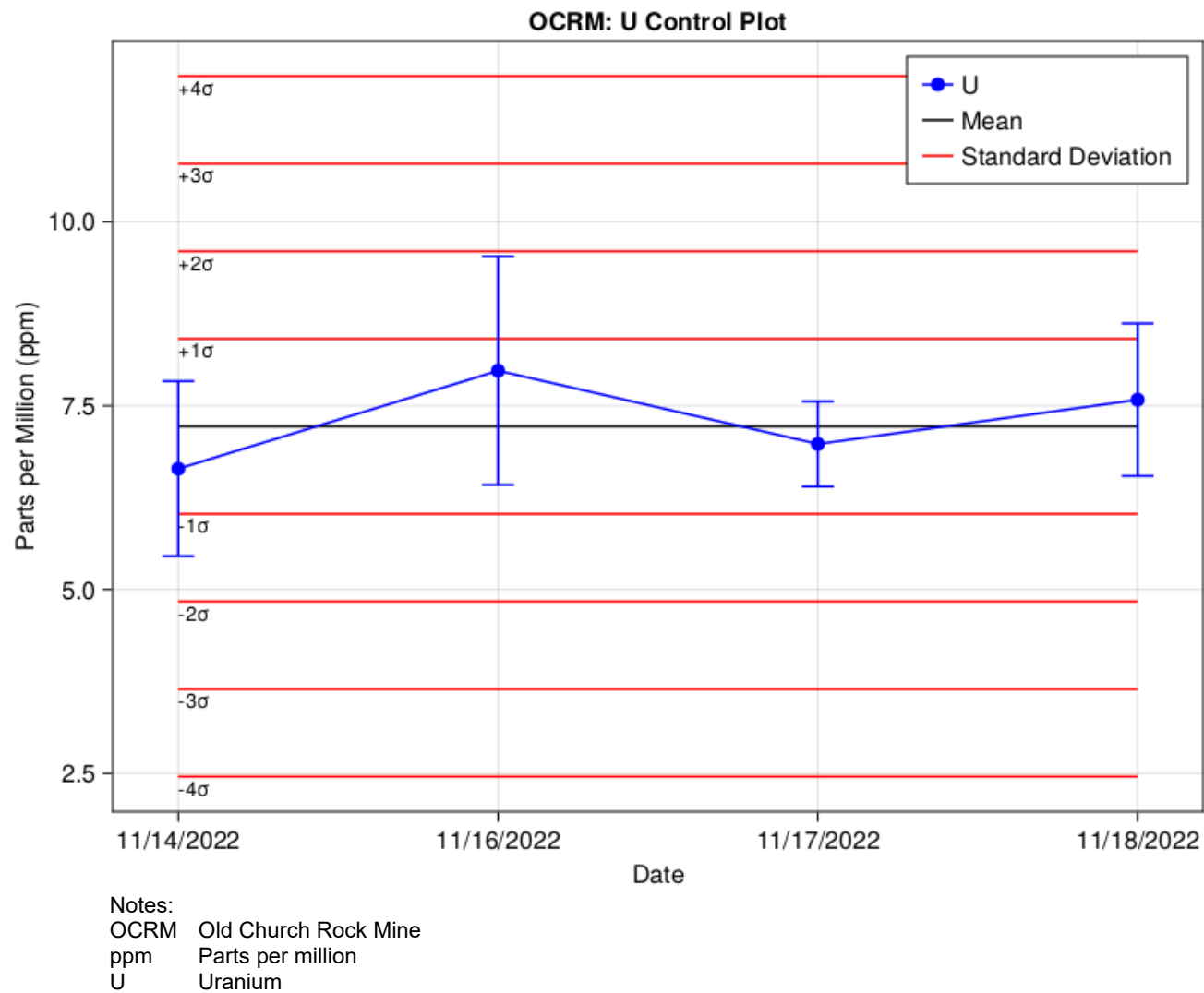


Figure C-2. X500940 XRF Daily Function Check Control Chart - Uranium

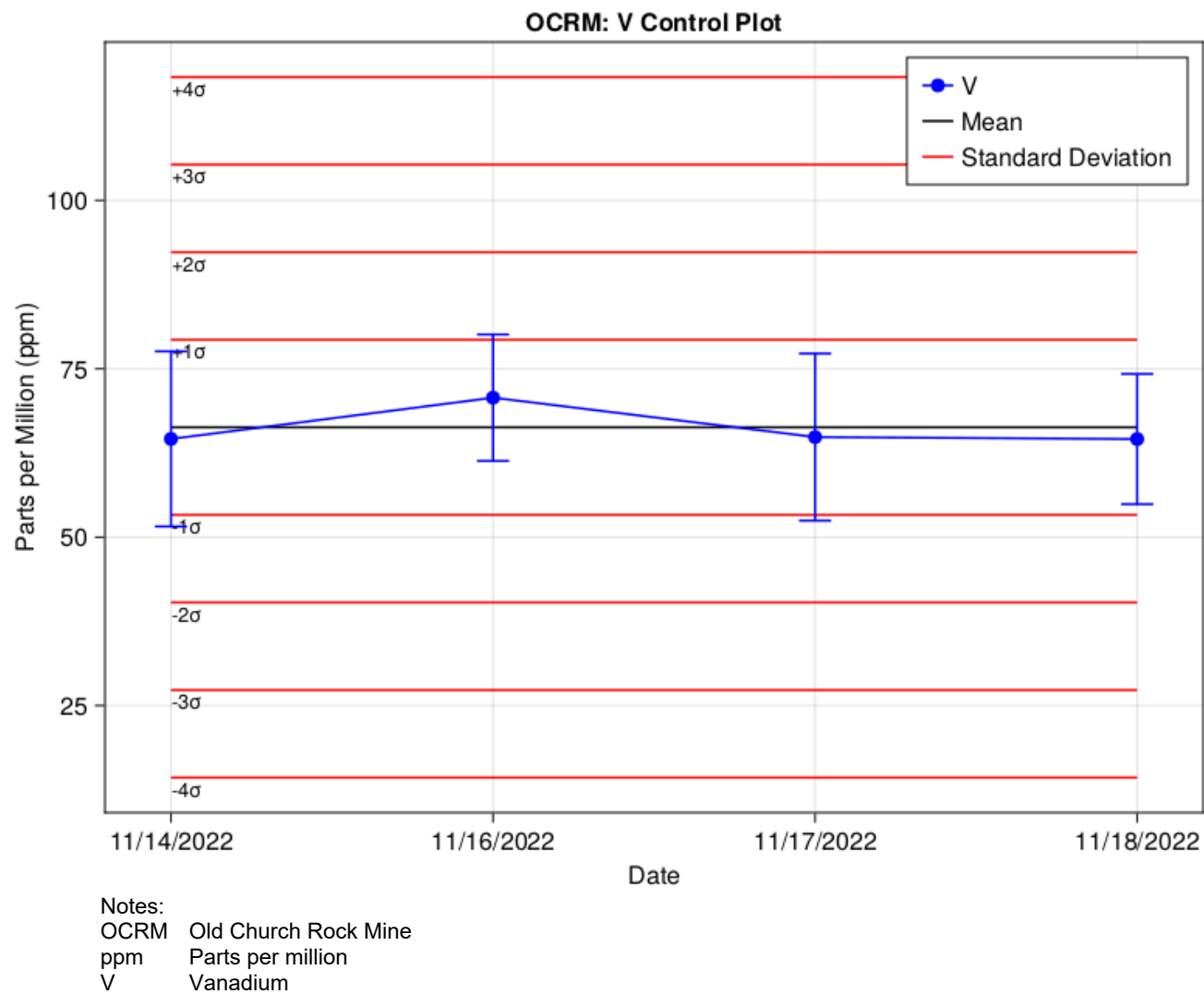


Figure C-3. X500940 XRF Daily Function Check Control Chart - Vanadium

3.2.3 Validating and Categorizing Data

A total of 206 XRF measurements were stored in the instrument's memory as part of the removal assessment. The raw export of the XRF data is included in [Attachment C-3](#). The following subsections detail the methods to clean up the data.

3.2.3.1 *Categorization*

Each measurement collected can be categorized into one of the following categories:

- System Check: An internal check the instrument completes on a daily basis on startup.
- QC-Baseline: Initial baseline response measurements on a CRM to compare with daily function checks.
- QC: Function check measurements on a CRM to compare with the baseline response.
- In Situ: A 60s:0s:0s measurement collected in the field to assess analytes at the site.
- In Situ-QC: Identical to an in situ measurement except with an associated duplicate pair.
- Duplicate: A 60s:0s:0s measurement collected in the field immediately after an in situ measurement was collected to assess precision of the instrument.
- Miscellaneous: Measurements collected that do not correspond to any activities identified in the SAP (such as accidental trigger pulls or operator curiosity).

3.2.3.2 *Data Exclusion*

Once categorized, several factors may disqualify a measurement from being included in the final dataset. Examples of disqualifying factors include:

- Measurement interrupted before intended duration of 60 seconds could be completed.
- Measurement not collected at appropriate location.
- Miscellaneous measurement taken in field that is not a part of the SAP.

A total of 13 of the 206 measurements were excluded from the final dataset. One QC-baseline, nine miscellaneous, and two in situ measurements were excluded because the measurement duration was too short. One in situ measurement was excluded because its results were not part of the scope of the project. The list of measurements excluded and associated justifications are included in [Attachment C-3](#).

3.2.3.3 *Sample Identification Correction*

Once the dataset is properly categorized with disqualified measurements excluded, the sample IDs that are stored in the instrument must be verified against other sources of record to confirm that the XRF operator logged the correct sample ID in the correct location. Checking sample IDs can be accomplished by comparing the recorded sample ID to the handwritten fieldnotes or completing a cross comparison with the timestamps and IDs of samples logged in ArcGIS Field

Maps. Fieldnotes documenting the XRF sample collection are included in Appendix F of the main report.

Samples identified as duplicates will have an “A” appended to the end of the sample name. Sample IDs for measurements categorized as system checks, QC-baseline, and QC do not need to have sample IDs corrected.

The final dataset with categorization, original and corrected sample IDs, and justifications for sample ID changes is included in [Attachment C-3](#).

3.2.4 Duplicate Error Analysis

Duplicate in situ measurements were collected at a minimum frequency of 1:20. To assess accuracy of the instrument, the relative percent difference (RPD) between the primary and duplicate measurement was calculated for a total of eight pairs. Based on Table B-3 of Appendix B and the 2018 removal site evaluation report (Tetra Tech 2018), a RPD of ≤ 30 percent is required for the data to be used as definitive data and a RPD of ≤ 50 percent is required for the data to be used as either quantitative or qualitative screening data.

[Table C-4](#) summarizes the findings of the duplicate error analysis.

Table C-4. XRF Duplicate Error Analysis

Location ID	Date	Primary Run #	Duplicate Run #	Copper			Uranium			Vanadium		
				Primary (ppm)	Duplicate (ppm)	RPD	Primary (ppm)	Duplicate (ppm)	RPD	Primary (ppm)	Duplicate (ppm)	RPD
OCRM-B02-X08	11/16/2022	938	939	10.7	9.8	9%	3.3	3.5	5%	72.3	80.7	11%
OCRM-B02-X20	11/16/2022	947	948	9.4	7.5	22%	3.4	4.1	20%	63.1	80.7	25%
OCRM-B02-X25	11/16/2022	957	958	10.1	9.4	8%	3.4	3.1	8%	68.6	65.0	5%
OCRM-X29	11/17/2022	1011	1012	6.2	5.0	20%	21.1	21.3	1%	<LOD	<LOD	-
OCRM-RTW-X09	11/18/2022	1052	1053	9.3	9.1	1%	3.6	2.6	30%	<LOD	<LOD	-
OCRM-RTE-X04	11/19/2022	1081	1082	5.9	2.7	73%	3.0	2.9	3%	66.4	49.5	29%
OCRM-RTNW-X07	11/19/2022	1098	1099	8.1	9.1	12%	1.4	1.7	20%	<LOD	<LOD	-
OCRM-RTN-X05	11/19/2022	1121	1122	9.2	7.6	20%	4.4	4.4	0%	<LOD	<LOD	-

Notes:

- Not applicable
<LOD Less than the limit of detection
ppm Parts per million
RDP Relative percent difference
XRF X-ray fluorescence



4.0 REFERENCES

Tetra Tech, Inc (Tetra Tech). 2018. "Appendix B, X-Ray Fluorescence Data Evaluation Report." Response, Assessment, and Evaluation Services. Contract No. EP-S9-17-02. Task Order 0001

Tetra Tech. 2022. "Old Church Rock Mine Removal Assessment Sampling and Analysis Plan." Response, Assessment, and Evaluation Services. Contract No. EP-S9-17-02. Task Order 0035.

ATTACHMENT C-1: INSTRUMENT CALIBRATION SHEETS

Serial Number: X500940
 Resolution: 153.911 143.059

 Model: Niton XL5 Standard
 Escalate: 7.417 7.429

 Software: 1.7.2.7548
 Spot Size: 8mm

 Date of Q.C.: 8/2/2022
 Inspector: AS

30 second analysis time Main Filter only, 3 analysis each

Pure Fe

	Low	High	Measured	Err	OK
Bi			0.000	0.0019	<LOD
Pb			0.022	0.0128	
Au			0.003	0.0009	
Re			0.000		OK
W			0.000	0.0060	<LOD
Ta			0.000		OK
Hf			0.000		OK
Te			0.000	0.0000	<LOD
Sb			0.000	0.0032	<LOD
Sn			0.000	0.0031	<LOD
Cd			0.000	0.0028	<LOD
Ag			0.000	0.0033	<LOD
Pd			0.000	0.0036	<LOD
Ru			0.000	0.0007	<LOD
Mo			0.000	0.0005	<LOD
Nb			0.001	0.0004	
Zr			0.000	0.0005	<LOD
Y			0.000	0.0003	<LOD
Se			0.000	0.0007	<LOD
Zn			0.000	0.0025	<LOD
Cu			0.000	0.0042	<LOD
Ni			0.000	0.0167	<LOD
Co			0.041	0.0521	<LOD
Fe	99.5	100	99.957	0.0665	OK
Mn			0.000	0.0117	<LOD
Cr			0.000	0.0125	<LOD
V			0.008	0.0164	<LOD
Ti			0.016	0.0246	<LOD
Al (Bal)			0.000	0.0000	OK
LEC			0.000		

Pure Ta

	Low	High	Measured	Err	OK
			0.000	0.0035	<LOD
			0.000		OK
			0.000	0.0000	<LOD
			0.023	0.0216	<LOD
			0.000	0.0948	<LOD
99	100		99.989	0.1784	OK
			0.000	0.0882	<LOD
			0.000	0.0092	<LOD
			0.000	0.0070	<LOD
			0.000	0.0075	<LOD
			0.000	0.0055	<LOD
			0.000	0.0083	<LOD
			0.000	0.0062	<LOD
			0.000	0.0016	<LOD
			0.005	0.0020	
			0.000	0.0013	<LOD
			0.001	0.0014	<LOD
			0.000	0.0008	<LOD
			0.000	0.0229	<LOD
			0.000		OK
			0.000		OK
			0.000	0.0122	<LOD
			0.000	0.0271	<LOD
			0.000	0.0171	<LOD
			0.000	0.0226	<LOD
			0.000	0.0316	<LOD
			0.000	0.0512	<LOD
			0.000	0.0914	<LOD
			0.000	0.0000	OK

Pure Sn

	Low	High	Measured	Err	OK
Bi			0.008	0.0042	
Pb			0.000	0.0045	<LOD
Au			0.000	0.0032	<LOD
Re			0.000		OK
W			0.000	0.0153	<LOD
Ta			0.000		OK
Hf			0.000		OK
Te			0.000	0.0215	<LOD
Sb			0.024	0.0235	<LOD
Sn	99	100	99.930	0.4077	OK
Cd			0.000	0.0170	<LOD
Ag			0.000	0.0089	<LOD
Pd			0.000	0.0074	<LOD
Ru			0.000	0.0019	<LOD
Mo			0.000	0.0012	<LOD
Nb			0.000	0.0011	<LOD
Zr			0.000	0.0015	<LOD
Y			0.000	0.0009	<LOD
Se			0.000	0.0026	<LOD
Zn			0.000	0.0094	<LOD
Cu			0.012	0.0147	<LOD
Ni			0.000	0.0155	<LOD
Co			0.000	0.0223	<LOD
Fe			0.000	0.0369	<LOD
Mn			0.000	0.0604	<LOD
Cr			0.000	0.0833	<LOD
V			0.168	0.1469	<LOD
Ti			0.000	0.3602	<LOD
Al (Bal)			0.000	0.0000	<LOD
LEC			0.000		

Pure Cu

	Low	High	Measured	Err	OK
			0.003	0.0021	
			0.000	0.0024	<LOD
			0.000	0.0058	<LOD
			0.000		OK
			0.000	0.0175	<LOD
			0.000		OK
			0.000		OK
			0.000	0.0074	<LOD
			0.000	0.0053	<LOD
			0.000	0.0061	<LOD
			0.000	0.0052	<LOD
			0.000	0.0058	<LOD
			0.000	0.0055	<LOD
			0.002	0.0015	<LOD
			0.001	0.0010	<LOD
			0.000	0.0009	<LOD
			0.000	0.0015	<LOD
			0.000	0.0004	<LOD
			0.000	0.0037	<LOD
			0.000	0.0206	<LOD
99.5	100		99.995	0.0817	OK
			0.000	0.0105	<LOD
			0.000	0.0110	<LOD
			0.01	0.0091	<LOD
			0.000	0.0150	<LOD
			0.000	0.0211	<LOD
			0.000	0.0318	<LOD
			0.000	0.0582	<LOD
			0.000	0.0000	<LOD
			0.000		

Pure Ni
Pure Ti

	Low	High	Measured	Err	OK
Bi			0.004	0.0021	
Pb			0.000	0.0027	<LOD
Au			0.000	0.0028	<LOD
Re			0.000		OK
W			0.000	0.2372	<LOD
Ta			0.000		OK
Hf			0.000		OK
Te			0.000	0.0000	<LOD
Sb			0.000	0.0047	<LOD
Sn			0.000	0.0051	<LOD
Cd			0.000	0.0039	<LOD
Ag			0.000	0.0047	<LOD
Pd			0.000	0.0057	<LOD
Ru			0.000	0.0013	<LOD
Mo			0.000	0.0008	<LOD
Nb			0.001	0.0005	
Zr			0.000	0.0002	<LOD
Y			0.000	0.0014	<LOD
Se			0.000	0.0061	<LOD
Zn			0.000	0.0253	<LOD
Cu			0.000	0.0283	<LOD
Ni	99.5	100	99.996	0.2889	OK
Co			0.000	0.0102	<LOD
Fe			0.004	0.0099	<LOD
Mn			0.000	0.0138	<LOD
Cr			0.000	0.0166	<LOD
V			0.000	0.0282	<LOD
Ti			0.000	0.0599	<LOD
Al (Bal)			0.000	0.0000	<LOD
LEC			0.000		

	Low	High	Measured	Err	OK
			0.001	0.0005	
			0.001	0.0005	
			0.000	0.0011	<LOD
			0.000		OK
			0.000	0.0000	<LOD
			0.000		OK
			0.000		OK
			0.000	0.0024	<LOD
			0.000	0.0018	<LOD
			0.000	0.0017	<LOD
			0.000	0.0015	<LOD
			0.000	0.0019	<LOD
			0.000	0.0019	<LOD
			0.000	0.0003	<LOD
			0.000	0.0002	<LOD
			0.000	0.0002	<LOD
			0.000	0.0001	<LOD
			0.000	0.0003	<LOD
			0.000	0.0012	<LOD
			0.000	0.0019	<LOD
			0.000	0.0019	<LOD
			0.004	0.0032	<LOD
			0.000	0.0057	<LOD
			0.000	0.0110	<LOD
			0.000	0.0342	<LOD
			0.092	0.0487	
99.5	100		99.942	0.0627	OK
			0.000	0.0000	<LOD
			0.000		

	20Cb3		IARM 25C		180-509	
	Certified	Low	High	Measured	Err	
Bi				0.000	0.0008	<LOD
Pb				0.000	0.0017	<LOD
Au				0.000	0.0000	<LOD
Re				0.000		OK
W	0.08			0.228	0.0940	
Ta	0.004			0.000		OK
Hf				0.000		OK
Te				0.000	0.0000	<LOD
Sb				0.004	0.0037	<LOD
Sn	0.01	0.000	0.020	0.013	0.0030	OK
Cd				0.000	0.0032	<LOD
Ag				0.031	0.0245	<LOD
Pd				0.000	0.0034	<LOD
Ru				0.002	0.0018	<LOD
Mo	2.26	2.034	2.486	2.195	0.0089	OK
Nb	0.58	0.48	0.68	0.569	0.0040	OK
Zr				0.000	0.0005	<LOD
Y				0.000	0.0003	<LOD
Se				0.000	0.0032	<LOD
Zn				0.000	0.0106	<LOD
Cu	3.51	3.264	3.756	3.488	0.0343	OK
Ni	33.30	31.635	34.965	33.012	0.1142	OK
Co	0.091	0.020	0.250	0.168	0.0376	OK
Fe	38.80	36.860	40.740	38.404	0.0720	OK
Mn	0.90	0.400	1.400	0.919	0.0328	OK
Cr	19.97	19.371	20.569	20.260	0.0536	OK
V	0.095	0.035	0.180	0.132	0.0132	OK
Ti	0.003			0.015	0.0165	<LOD
Al (Bal)	0.019			0.000	0.00	<LOD
LEC		0.50	0.50	0.50	#N/A	OK

	Stellite 6B		IARM 95B		180-502	
	Certified	Low	High	Measured	Err	
				0.000	0.0008	<LOD
				0.000		OK
				0.000	0.0000	<LOD
				0.000	0.0105	
	3.42	3.112	3.728	3.433	0.0498	OK
				0.000	0.0231	<LOD
				0.000	0.0485	<LOD
				0.000	0.0000	<LOD
				0.005	0.0029	
				0.011	0.0026	
				0.004	0.0030	<LOD
				0.037	0.0260	<LOD
				0.000	0.0031	<LOD
				0.000	0.0010	<LOD
	0.83	0.697	0.963	0.833	0.0045	OK
	0.002			0.001	0.0005	
	0.002			0.001	0.0004	<LOD
				0.000	0.0004	<LOD
				0.000	0.0034	<LOD
				0.000		OK
	0.01			0.000		OK
	2.25	1.913	2.588	2.259	0.0366	OK
	60.90	58.50	62.50	59.998	0.1053	OK
	1.10	0.990	1.210	1.104	0.0228	OK
	0.99	0.891	1.089	0.994	0.0294	OK
	28.90	28.467	29.334	29.009	0.0597	OK
	0.002			0.031	0.0111	
	0.004			0.043	0.0148	
	0.07			0.000	0.00	<LOD
		2.25	2.25	2.250	#N/A	OK

	CDA 836		IARM 86C		180-510	
	Certified	Low	High	Measured	Err	
Bi	0.01			0.054	0.0099	
Pb	5.03	4.68	5.38	5.019	0.0420	OK

	1.25Cr 0.5 Mo		IARM 35H		195-019	
	Certified	Low	High	Measured	Err	
				0.000	0.0018	<LOD
	0.0009			0.013	0.0082	

Au				0.000	0.0000	<LOD
Re				0.000		OK
W				0.000	0.0378	<LOD
Ta				0.000		OK
Hf				0.000		OK
Te				0.000	0.0083	<LOD
Sb	0.143	0.122	0.164	0.130	0.0073	OK
Sn	4.37	3.452	5.288	4.230	0.0249	OK
Cd				0.000	0.0054	<LOD
Ag	0.02			0.029	0.0056	
Pd				0.000	0.0053	<LOD
Ru				0.000	0.0017	<LOD
Mo				0.000	0.0011	<LOD
Nb				0.000	0.0009	<LOD
Zr				0.000	0.0019	<LOD
Y				0.019	0.0135	<LOD
Se				0.000	0.0051	<LOD
Zn	5.38	4.788	5.972	5.382	0.0349	OK
Cu	84.6	82.49	86.72	84.588	0.0855	OK
Ni	0.27	0.100	0.400	0.269	0.0105	OK
Co				0.006	0.0090	<LOD
Fe	0.24	0.200	0.280	0.247	0.0095	OK
Mn	0.002			0.000	0.0219	<LOD
Cr				0.000	0.0222	<LOD
V				0.017	0.0346	<LOD
Ti				0.051	0.0545	<LOD
Al (Bal)	0.002			0.000	0.00	<LOD
LEC						

				0.005	0.0025	
				0.000		OK
0.004				0.000	0.0028	<LOD
				0.000		OK
				0.000		OK
				0.000	0.0000	<LOD
0.002				0.000	0.0035	<LOD
0.002				0.004	0.0034	<LOD
				0.000	0.0029	<LOD
				0.008	0.0053	<LOD
				0.000	0.0041	<LOD
				0.000	0.0011	<LOD
0.47	0.455	0.525		0.486	0.0037	OK
0.002				0.000	0.0005	<LOD
0.001				0.000	0.0004	<LOD
				0.000	0.0003	<LOD
				0.000	0.0008	<LOD
				0.003	0.0025	<LOD
0.033	0.018	0.048		0.034	0.0053	OK
0.071				0.075	0.0208	
0.004				0.000	0.0452	<LOD
96.96	95.506	98.414		96.961	0.0661	OK
0.56	0.392	0.728		0.569	0.0182	OK
1.11	0.999	1.221		1.092	0.0144	OK
0.004				0.010	0.0134	<LOD
0.0016				0.012	0.0287	<LOD
0.028				0.000	0.00	<LOD
	0.75	0.75		0.750	#N/A	OK

	Hast X			IARM 69C			180-511		
	Certified	Low	High	Measured	Err		Certified	Low	High
Bi				0.000	0.0016	<LOD			
Pb				0.000	0.0025	<LOD			
Au				0.000	0.0000	<LOD			
Re				0.000		OK			
W	0.62	0.320	0.920	0.719	0.1534	OK			
Ta	0.003			0.000		OK			
Hf				0.000		OK			
Te				0.000	0.0000	<LOD			
Sb				0.000	0.0051	<LOD			
Sn	0.002			0.000	0.0044	<LOD			
Cd				0.000	0.0045	<LOD			
Ag				0.026	0.0162				
Pd				0.000	0.0050	<LOD			
Ru				0.004	0.0032	<LOD			
Mo	8.30	7.719	8.881	8.307	0.0316	OK			
Nb	0.09	0.030	0.150	0.074	0.0021	OK			
Zr	0.004			0.002	0.0009				
Y				0.000	0.0005	<LOD			
Se				0.000	0.0057	<LOD			
Zn				0.000	0.0180	<LOD			
Cu				0.055	0.0277				
Ni	48.80	46.85	50.75	48.295	0.1786	OK			
Co	1.11	0.944	1.300	1.184	0.0391	OK			
Fe	18.30	17.39	19.22	18.315	0.0662	OK			
Mn	0.47	0.353	0.588	0.470	0.0366	OK			
Cr	21.60	20.74	22.60	21.984	0.0706	OK			
V	0.03			0.056	0.0163				
Ti	0.02			0.036	0.0368	<LOD			
Al (Bal)	0.12			0.00	0.00	<LOD			
LEC		0.50	0.50	0.50		OK			

	Tool steel M2			BS 32C			180-492		
	Certified	Low	High	Measured	Err		Certified	Low	High
				0.000	0.0007	<LOD			
				0.000	0.0028	<LOD			
				0.000	0.0000	<LOD			
				0.000		OK			
	6.30	6.00	7.00	6.559	0.0705	OK			
				0.000		OK			
				0.000		OK			
				0.000	0.0000	<LOD			
				0.000	0.0042	<LOD			
0.01				0.007	0.0038				
				0.000	0.0037	<LOD			
				0.025	0.0198	<LOD			
				0.000	0.0042	<LOD			
				0.000	0.0027	<LOD			
	4.85	4.61	5.15	4.852	0.0159	OK			
				0.000	0.0010	<LOD			
				0.000	0.0007	<LOD			
				0.000	0.0004	<LOD			
				0.000	0.0057	<LOD			
				0.000	0.0162	<LOD			
	0.13	0.104	0.156	0.124	0.0109	OK			
	0.35	0.250	0.420	0.310	0.0176	OK			
	0.31	0.200	0.403	0.283	0.0464	OK			
	80.59	78.59	82.59	80.176	0.0946	OK			
	0.29	0.24	0.36	0.301	0.0242	OK			
	3.98	3.59	4.42	4.095	0.0329	OK			
	2.03	1.57	2.46	2.010	0.0330	OK			
				0.032	0.0278	<LOD			
0.02				0.00	0.00	<LOD			
	1.24	1.24	1.24			OK			

	SS321			IARM 6D			180-512		
	Certified	Low	High	Measured	Err		Certified	Low	High
Bi				0.000	0.0003	<LOD			
Pb				0.000	0.0013	<LOD			
Au				0.000	0.0000	<LOD			
Re				0.000		OK			

	Ti 6-2-4-2			IARM 177C			180-503		
	Certified	Low	High	Measured	Err		Certified	Low	High
				0.000	0.0013	<LOD			
				0.000	0.0015	<LOD			
				0.000	0.0027	<LOD			
				0.000		OK			

W	0.09	0.060	0.200	0.158	0.0400	OK
Ta				0.000		OK
Hf				0.000		OK
Te				0.000	0.0000	<LOD
Sb				0.003	0.0041	<LOD
Sn	0.013	0.010	0.025	0.021	0.0025	OK
Cd				0.003	0.0027	<LOD
Ag				0.032	0.0239	<LOD
Pd				0.000	0.0037	<LOD
Ru				0.001	0.0008	<LOD
Mo	0.358	0.29	0.44	0.358	0.0026	OK
Nb	0.039	0.01	0.06	0.039	0.0009	OK
Zr	0.002			0.000	0.0004	<LOD
Y				0.000	0.0003	<LOD
Se				0.000	0.0014	<LOD
Zn				0.000	0.0046	<LOD
Cu	0.302	0.15	0.5	0.332	0.0141	OK
Ni	9.42	9	9.8	9.293	0.0536	OK
Co	0.182	0.140	0.300	0.231	0.0412	OK
Fe	69.40	68	70	68.921	0.0832	OK
Mn	1.52	1.25	1.85	1.580	0.0339	OK
Cr	17.45	17.1	18	17.721	0.0443	OK
V	0.128	0.100	0.200	0.168	0.0120	OK
Ti	0.63	0.43	0.83	0.644	0.0213	OK
Al (Bal)	0.11			0.00	0.00	<LOD
LEC				0.50	#N/A	OK

			0.000	0.0000	<LOD
			0.000		OK
			0.000		OK
			0.000	0.0042	<LOD
			0.000	0.0034	<LOD
2.02	1.919	2.121	2.023	0.0121	OK
			0.000	0.0030	<LOD
			0.007	0.0059	<LOD
			0.000	0.0034	<LOD
			0.000	0.0014	<LOD
1.96	1.764	2.156	1.960	0.0088	OK
			0.001	0.0009	<LOD
3.99	3.75	4.23	3.990	0.0157	OK
			0.000	0.0007	<LOD
			0.000	0.0008	<LOD
			0.000	0.0022	<LOD
0.003			0.000	0.0038	<LOD
0.011			0.008	0.0057	<LOD
			0.000	0.0070	<LOD
0.033	0.010	0.040	0.018	0.0118	
0.0015			0.000	0.0206	<LOD
			0.000	0.0616	<LOD
0.02			0.000	0.1016	<LOD
85.72	84.01	87.43	85.996	0.1163	OK
6.02			0.00	0.00	<LOD
			6.0	#N/A	OK

	AA7075		ALC 7075 AF		180-505	
	Certified	Low	High	Measured	Err	
Bi	0.007	0.001	0.020	0.007	0.0005	OK
Pb	0.0073	0.001	0.020	0.007	0.0005	OK
Au				0.000	0.0000	<LOD
Re				0.000		OK
W				0.034	0.0248	<LOD
Ta				0.000		OK
Hf				0.000		OK
Te				0.000	0.0013	<LOD
Sb				0.002	0.0017	<LOD
Sn	0.014	0.007	0.024	0.015	0.0009	OK
Cd				0.002	0.0012	<LOD
Ag				0.007	0.0052	<LOD
Pd				0.000	0.0014	<LOD
Ru				0.000	0.0003	<LOD
Mo				0.000	0.0001	<LOD
Nb				0.000	0.0001	<LOD
Zr	0.0024	0.0014	0.0034	0.0025	0.0002	OK
Y				0.000	0.0001	<LOD
Se				0.000	0.0002	<LOD
Zn	5.75	5.578	5.923	5.772	0.0115	OK
Cu	1.750	1.663	1.838	1.757	0.0080	OK
Ni	0.027	0.0070	0.0470	0.026	0.0015	OK
Co				0.000	0.0026	<LOD
Fe	0.17	0.136	0.204	0.169	0.0050	OK
Mn	0.031	0.015	0.050	0.037	0.0053	OK
Cr	0.22	0.187	0.253	0.224	0.0105	OK
V	0.020			0.050	0.0148	
Ti	0.092	0.000	0.250	0.143	0.0296	OK
Al (Bal)	91.7	89.8268	93.4932	91.75	0.08	OK
LEC						

15s Main Filter and 30s Low Filter

	1.25Cr 0.5Mo		IARM35H		195-019	
	Provisional	Low	High	Measured	Err	
Bi				0.000	0.0018	<LOD
Pb	0.001			0.013	0.0082	
Au				0.005	0.0026	
Re				0.000		OK

	Tool steel T-1		IARM 48C		195-152	
	Certified	Low	High	Measured	Err	
				0.000	0.0005	<LOD
				0.000	0.0030	<LOD
				0.000	0.0000	<LOD
				0.000		OK

W	0.004			0.000	0.0028	<LOD
Ta				0.000		OK
Hf				0.000		OK
Te				0.000	0.0000	<LOD
Sb	0.002			0.000	0.0035	<LOD
Sn	0.002			0.004	0.0034	<LOD
Cd				0.000	0.0029	<LOD
Ag				0.008	0.0053	<LOD
Pd				0.000	0.0041	<LOD
Ru				0.000	0.0011	<LOD
Mo	0.47	0.430	0.530	0.488	0.0037	OK
Nb	0.002			0.000	0.0005	<LOD
Zr	0.001			0.000	0.0004	<LOD
Y				0.000	0.0003	<LOD
Se				0.000	0.0008	<LOD
Zn				0.003	0.0025	<LOD
Cu	0.032	0.012	0.052	0.034	0.0053	OK
Ni	0.071			0.075	0.0209	
Co	0.004			0.000	0.0452	<LOD
Fe	96.96	95.990	97.930	96.951	0.0540	OK
Mn	0.56	0.48	0.64	0.571	0.0183	OK
Cr	1.11	1.00	1.22	1.109	0.0053	OK
V	0.004			0.000	0.0014	<LOD
Ti	0.002			0.000	0.0015	<LOD
Al (Bal)	0.028			0.00	0.00	<LOD
LEC	0.75			0.750		OK

17.50	16.63	18.38	17.348	0.0783	OK
			0.000		OK
			0.000		OK
			0.000	0.0000	<LOD
			0.010	0.0033	
0.012			0.029	0.0032	
			0.004	0.0034	<LOD
			0.060	0.0034	
			0.000	0.0041	<LOD
			0.003	0.0016	
0.17	0.140	0.190	0.160	0.0020	OK
0.005	0.001	0.010	0.004	0.0005	OK
			0.002	0.0005	
			0.000	0.0001	<LOD
			0.000	0.0080	<LOD
			0.000	0.0212	<LOD
0.13	0.09	0.180	0.102	0.0116	OK
0.204	0.1	0.24	0.164	0.0157	
0.22	0.12	0.32	0.200	0.0401	
74.5	73.383	75.618	74.758	0.0928	OK
0.39	0.30	0.500	0.431	0.0228	OK
4.24	3.90	4.75	4.444	0.0312	OK
1.27	1.14	1.40	1.259	0.0076	OK
0.006			0.002	0.0025	<LOD
0.017			0.00	0.00	<LOD
1.025			1.025		OK

	Custom 455		IARM16B		195-142	
	Certified	Low	High	Measured	Err	
Bi				0.000	0.0007	<LOD
Pb				0.002	0.0020	<LOD
Au				0.000	0.0000	<LOD
Re				0.000		OK
W	0.011			0.077	0.0392	
Ta				0.000		OK
Hf				0.000		OK
Te				0.000	0.0000	<LOD
Sb				0.006	0.0039	<LOD
Sn	0.004			0.010	0.0025	
Cd				0.003	0.0025	<LOD
Ag				0.034	0.0227	<LOD
Pd				0.000	0.0037	<LOD
Ru				0.002	0.0012	<LOD
Mo	0.016	0.010	0.022	0.015	0.0007	OK
Nb	0.25	0.225	0.275	0.257	0.0024	OK
Zr				0.001	0.0005	<LOD
Y				0.000	0.0003	<LOD
Se				0.000	0.0014	<LOD
Zn				0.000	0.0054	<LOD
Cu	2.23	2.119	2.342	2.223	0.0260	OK
Ni	8.28	7.866	8.694	8.236	0.0527	OK
Co	0.027			0.091	0.0405	
Fe	76.4	72.580	80.220	76.299	0.0366	OK
Mn	0.026			0.094	0.0254	
Cr	11.44	10.868	12.012	11.476	0.0366	OK
V	0.067			0.057	0.0038	
Ti	1.11	1.055	1.166	1.105	0.0081	OK
Al (Bal)	0.062			0.000	0.00	<LOD

AA7075	ALC 7075 AF			180-505	
Certified	Low	High	Measured	Err	
0.007	0.000	0.150	0.007	0.0005	OK
0.0073	0.001	0.020	0.007	0.0005	OK
			0.000	0.0000	<LOD
			0.000		OK
			0.034	0.0247	<LOD
			0.000		OK
			0.000		OK
			0.000	0.0013	<LOD
			0.002	0.0017	<LOD
0.014	0.007	0.025	0.015	0.0009	OK
			0.002	0.0012	<LOD
			0.007	0.0052	<LOD
			0.000	0.0014	<LOD
			0.000	0.0003	<LOD
			0.000	0.0001	<LOD
			0.000	0.0001	<LOD
0.0024	0.0004	0.0044	0.002	0.0002	OK
			0.000	0.0001	<LOD
			0.000	0.0002	<LOD
5.75	5.578	5.923	5.773	0.0113	OK
1.750	1.663	1.838	1.758	0.0080	OK
0.027	0.0070	0.0470	0.026	0.0015	OK
			0.000	0.0431	<LOD
0.17	0.136	0.204	0.169	0.0050	OK
0.031	0.016	0.050	0.037	0.0053	OK
0.22	0.1	0.4	0.221	0.0028	OK
0.020			0.044	0.0015	
0.092	0.072	0.112	0.092	0.0020	OK
91.7	89.8268	93.4932	91.804	0.01	OK

This certificate is issued in accordance with Thermo Fisher Scientific factory specifications.
 The measurements were found to be within specification limits at the time of manufacture and calibration.

Samples used for factory calibrations are either certified reference standards (CRM) or reference samples (RM), when available.
 Certificates of Analysis (CoA) are available on request

Signed:



Deven Erickson

ATTACHMENT C-2: CERTIFIED REFERENCE MATERIAL

Soil

Art. ID NCS DC73319a
Unit 70 g
Deliverydetails No Dangerous Good /not restricted

Text/Information	Analyte/Parameter	CAS number	Concentration/Value	Unit	Method	Source
	Silver (Ag)	[7440-22-4]	0,81 ± 0,04	µg/g		
	Arsenic (As)	[7440-38-2]	33 ± 3	µg/g		
	Boron (B)	[7440-42-8]	69 ± 4	µg/g		
	Barium (Ba)	[7440-39-3]	700 ± 40	µg/g		
	Beryllium (Be)	[7440-41-7]	3,3 ± 0,3	µg/g		
	Bismuth (Bi)	[7440-69-9]	1,4 ± 0,2	µg/g		
	Bromine (Br)	[7726-95-6]	4,1 ± 0,6	µg/g		
	Cadmium (Cd)	[7440-43-9]	2,5 ± 0,2	µg/g		
	Cerium (Ce)	[7440-45-1]	71 ± 5	µg/g		
	Chlorine (Cl)	[7782-50-5]	~87	µg/g		
	Cobalt (Co)	[7440-48-4]	10,3 ± 0,6	µg/g		
	Chromium (Cr)	[7440-47-3]	44 ± 3	µg/g		
	Caesium (Cs)	[7440-46-2]	7,2 ± 0,5	µg/g		
	Copper (Cu)	[7440-50-8]	42 ± 5	µg/g		
	Dysprosium (Dy)	[7429-91-6]	6,0 ± 0,5	µg/g		
	Erbium (Er)	[7440-52-0]	3,8 ± 0,4	µg/g		
	Europium (Eu)	[7440-53-1]	0,89 ± 0,08	µg/g		
	Fluorine (F)	[7782-41-4]	513 ± 21	µg/g		
	Gallium (Ga)	[7440-55-3]	18,1 ± 1,4	µg/g		
	Gadolinium (Gd)	[7440-54-2]	5,5 ± 0,4	µg/g		
	Germanium (Ge)	[7440-56-4]	1,3 ± 0,2	µg/g		
	Hafnium (Hf)	[7440-58-6]	6,5 ± 0,5	µg/g		
	Mercury (Hg)	[7439-97-6]	0,31 ± 0,03	µg/g		
	Holmium (Ho)	[7440-60-0]	1,3 ± 0,2	µg/g		
	Iodine (I)	[7553-56-2]	2,0 ± 0,2	µg/g		
	Indium (In)	[7440-74-6]	0,12 ± 0,02	µg/g		
	Lanthanum (La)	[7439-91-0]	39 ± 2	µg/g		
	Lithium (Li)	[7439-93-2]	28 ± 2	µg/g		
	Lutetium (Lu)	[7439-94-3]	0,57 ± 0,06	µg/g		
	Manganese (Mn)	[7439-96-5]	0,131 ± 0,006	%		
	Molybdenum (Mo)	[7439-98-7]	2,0 ± 0,2	µg/g		

Nitrogen (N)	[7727-37-9]	0,32 ± 0,03	%
Niobium (Nb)	[7440-03-1]	15,3 ± 1,4	µg/g
Neodymium (Nd)	[7440-00-8]	30,8 ± 1,3	µg/g
Nickel (Ni)	[7440-02-0]	16,9 ± 1,5	µg/g
Phosphorus (P)	[7723-14-0]	0,23 ± 0,02	%
Lead (Pb)	[7439-92-1]	339 ± 12	µg/g
Praseodymium (Pr)	[7440-10-0]	8,5 ± 0,7	µg/g
Rubidium (Rb)	[7440-17-7]	137 ± 9	µg/g
Sulfur (S)	[7704-34-9]	726 ± 94	µg/g
Antimony (Sb)	[7440-36-0]	2,4 ± 0,3	µg/g
Scandium (Sc)	[7440-20-2]	8,3 ± 0,3	µg/g
Selenium (Se)	[7782-49-2]	~0,22	µg/g
Samarium (Sm)	[7440-19-9]	5,9 ± 0,4	µg/g
Tin (Sn)	[7440-31-5]	9,8 ± 1,1	µg/g
Strontium (Sr)	[7440-24-6]	192 ± 9	µg/g
Tantalum (Ta)	[7440-25-7]	1,3 ± 0,1	µg/g
Terbium (Tb)	[7440-27-9]	0,98 ± 0,09	µg/g
Tellurium (Te)	[13494-80-9]	~0,06	µg/g
Thorium (Th)	[7440-29-1]	13,1 ± 0,9	µg/g
Titanium (Ti)	[7440-32-6]	0,326 ± 0,009	%
Thallium (Tl)	[7440-28-0]	1,2 ± 0,1	µg/g
Thulium (Tm)	[7440-30-4]	0,61 ± 0,06	µg/g
Uranium (U)	[7440-61-1]	6,0 ± 0,3	µg/g
Vanadium (V)	[7440-62-2]	61 ± 4	µg/g
Tungsten (W)	[7440-33-7]	3,5 ± 0,5	µg/g
Yttrium (Y)	[7440-65-5]	38 ± 3	µg/g
Ytterbium (Yb)	[7440-64-4]	3,8 ± 0,4	µg/g
Zinc (Zn)	[7440-66-6]	475 ± 30	µg/g
Zirconium (Zr)	[7440-67-7]	218 ± 10	µg/g
SiO ₂		56,60 ± 0,46	%
Al ₂ O ₃		12,92 ± 0,21	%
TFe ₂ O ₃		4,41 ± 0,20	%
FeO		~2,25	%
CaO		2,78 ± 0,11	%
MgO	[1309-48-4]	1,17 ± 0,04	%
Na ₂ O		1,65 ± 0,07	%
K ₂ O		2,85 ± 0,08	%
H ₂ O+		~4,3	%

Corg	~6,8	%
TC	7,87 ± 0,26	%
Loss on Ignition (LOI)	15,82 ± 0,64	%

ATTACHMENT C-3: XRF (ELECTRONIC)

- XRF Raw Data Output
- Excluded XRF Measurements
- Final XRF Dataset