



Noble Energy, Inc.
Metals Statistical Evaluation Summary

July 12, 2024
Former Lilli Unit N-5 Tank Battery
SESW, Section 5, Township 8 North, Range 58 West
Remediation # 20862

This statistical evaluation summary has been prepared by Tasman, Inc. for the former Lilli Uni N-5 Tank Battery.

Metals Evaluation Summary

Background and site data for the following metals of concern (MOC) in soils were compared using the non-parametric Mann-Whitney-Wilcoxon rank-sum test to assess if site concentrations were substantially higher than background concentrations. This method of statistical hypotheses testing is robust, insensitive to outliers, and does not rely on assumptions that site and background data are normally distributed. Site data was pooled together and compared to background values that were offset by a substantial difference, S , defined as $0.25 \times M_b$, where M_b is mean background concentration. This offset is equivalent to ECMC policy of setting the background comparison value to $1.25 \times \text{background}^1$ and is consistent with other guidance for analysis of background conditions².

Mean concentrations for the MOCs on site and offset background soils were compared using a one-sided test using the following null and alternative hypotheses (H_0 and H_A):

Hypothesis	Expression	Narrative Description
Null, H_0	$\mu_{\text{site}} - (\mu_{\text{bkg}} + S) > 0$	Site concentrations exceed $1.25 \times$ background concentrations. <i>i.e.</i> The site has substantially higher metal concentration than background. <i>i.e.</i> Site impacted.
Alternative, H_A	$H_A: \mu_{\text{site}} - (\mu_{\text{bkg}} + S) \leq 0$	Site concentrations are not substantially higher than background concentrations. <i>i.e.</i> Site not impacted.

Where: μ_{site} is the mean site concentration and μ_{bkg} is the mean background concentration.

¹ ECMC. Series 900 Rules – Environmental Impact Prevention (As of January 15, 2021). Table 915-1, Cleanup Concentrations. Footnote 11. <https://cogcc.state.co.us/documents/reg/Rules/LATEST/900%20Series%20-%20Environmental%20Impact%20Prevention.pdf>

² USEPA. September 2002. Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites. EPA 540-R-01-003, OSWER 9285.7-41. See Appendix A.2.1. <https://www.epa.gov/sites/default/files/2015-11/documents/background.pdf> (accessed March 31, 2023).

This form of the hypothesis test establishes an initial presumption that the site is impacted and requires statistically significant evidence before it can be refuted (i.e. rejection of the null hypothesis). The $\alpha = 5\%$ confidence level selected for this statistical test is such that, on average, in 95 out of 100 cases, the test would correctly conclude that site concentrations exceed background concentrations by more than S (i.e. correctly conclude that an impacted site is impacted). In 5 out of 100 cases, the test would incorrectly conclude that elevated site concentrations do not exceed background by more than S (i.e. falsely conclude that an impacted site is clean). Censored data (MOC results less than laboratory reporting limits) were handled by substitution at half of the limit.

Metals Evaluation Results

The results of tests for individual MOCs are summarized in the table below. See Exhibit A for calculations, hypotheses test conditions, and conclusions.

Metal	Sample sizes	Mean/ Median Site Concentrations, mg/kg	Mean/Median Background Concentrations, mg/kg	Substantial Difference ($0.25 * \bar{x}_{bkg}$), mg/kg	Hypothesis Test Result
Arsenic	Site, m = 35 Bkg, n = 23	mean = 5.05 median = 3.02	mean = 5.23 median = 3.62	1.306	Site not impacted

Conclusion

Based on the results summarized above, arsenic concentrations recorded in the site data are indicative of native soil conditions. Consequently, no further metals delineation or assessments are required at this time.



EXHIBIT A

Large Sample Wilcoxon Rank Sum Test

LILLI UNIT N-5 - Arsenic (As)

From Box 3-34 of EPA QA/G-9S, but reformulated to match Test Form 2 in CERCLA Background Guidance



Concentrations									
Sample ID (Site)	As milligrams per kilogram (mg/kg)	Intermediate	Substituted As (mg/kg)		Sample ID (Background)	As (mg/kg)		Source	As (mg/kg)
SEP01-DL02@4'	2.850		2.850		BG01@3.5'	3.26		bkg + substantial difference (S)	4.566
BH01@4.5'	3.130		3.130		BG02@3.5'	2.49		bkg + S	3.796
BH01@7.5-8.5'	3.060		3.060		BG02@5'	3.84		bkg + S	5.146
BH01@15-17.5'	4.890		4.890		BG03@3.5'	3.14		bkg + S	4.446
BH01@23-24'	0.514		0.514		BG03@5'	3.38		bkg + S	4.686
BH02@4.5'	2.130		2.130		BG04@3.5'	2.95		bkg + S	4.256
BH02@7.5-8.5'	3.820		3.820		BG04@5'	3.36		bkg + S	4.666
BH02@22-24'	3.020		3.020		BG05@3.5'	3.62		bkg + S	4.926
BH03@4.5'	2.720		2.720		BG05@5'	3.08		bkg + S	4.386
BH03@7.5-8.5'	3.610		3.610		BG06@3.5'	3.02		bkg + S	4.326
BH03@15-17.5'	8.050		8.050		BG06@5'	2.80		bkg + S	4.106
BH03@17.5-19'	2.700		2.700		BG07@6'	5.34		bkg + S	6.646
BH04@4.5'	3.010		3.010		BG07@15'	3.9		bkg + S	5.206
BH04@7.5-8.5'	3.070		3.070		BG07@18'	3.07		bkg + S	4.376
BH04@15-17.5'	9.010		9.010		BG08@6'	8.23		bkg + S	9.536
BH04@20-22'	5.920		5.920		BG08@15'	10.40		bkg + S	11.706
BH04@23-24'	8.040		8.040		BG08@18'	3.52		bkg + S	4.826
BH05@4.5'	2.970		2.970		BG09@6'	5.21		bkg + S	6.516
BH05@7.5-8.5'	2.910		2.910		BG09@15'	7.00		bkg + S	8.306
BH05@15-17.5'	3.480		3.480		BG09@18'	4.46		bkg + S	5.766
BH05@23-24'	16.300		16.300		BG11@6'	11.5		bkg + S	12.806
BH06@14-16.5'	2.380		2.380		BG11@15'	7.92		bkg + S	9.226
BH06@29-31'	0.492		0.492		BG11@18'	14.70		bkg + S	16.006
BH07@19-21.5'	1.850		1.850					bkg + S	1.306
BH07@24-27'	<0.259	0.259	0.130					bkg + S	1.306
BH07@29-31'	0.307		0.307					bkg + S	1.306
BH08@17-17.5'	8.580		8.580					bkg + S	1.306
BH08@24-26.5'	1.960		1.960					bkg + S	1.306
BH08@29-31'	2.260		2.260					bkg + S	1.306
BH09@21.5-24'	33.400		33.400						
BH09@30-31'	2.940		2.940						
BH10@24-26.5'	6.850		6.850						
BH10@30-31'	2.090		2.090						
BH11@19-21.5'	7.600		7.600						
BH11@21.5-24'	10.800		10.800						

Site concentrations (m):	35		
bkg concentrations (n):	23		
mean-Site:	5.05	mean-bkg:	5.23
S, based on mean:	1.263	S, based on mean:	1.306
median-Site:	3.02	median-bkg:	3.62
S, based on median:	0.755	S, based on median:	0.905

Computations				
Source	Value	Rank	Site Rank	Bkg Rank
Site	0.130	1	1	
Site	0.307	2	2	
Site	0.492	3	3	
Site	0.514	4	4	
bkg + S	1.306	7		7
bkg + S	1.306	7		7
bkg + S	1.31	7		7
bkg + S	1.306	7		7
bkg + S	1.31	7		7
Site	1.850	10	10	
Site	1.960	11	11	
Site	2.09	12	12	
Site	2.130	13	13	
Site	2.26	14	14	
Site	2.380	15	15	
Site	2.700	16	16	
Site	2.720	17	17	
Site	2.850	18	18	
Site	2.910	19	19	
Site	2.94	20	20	

NOTES:

EPA = Environmental Protection Agency

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act

yellow highlight = tied values

Large Sample Wilcoxon Rank Sum Test

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Site	2.970	21	21	
Site	3.010	22	22	
Site	3.020	23	23	
Site	3.060	24	24	
Site	3.070	25	25	
Site	3.130	26	26	
Site	3.480	27	27	
Site	3.610	28	28	
bkg + S	3.80	29		29
Site	3.820	30	30	
bkg + S	4.11	31		31
bkg + S	4.26	32		32
bkg + S	4.33	33		33
bkg + S	4.38	34		34
bkg + S	4.39	35		35
bkg + S	4.45	36		36
bkg + S	4.57	37		37
bkg + S	4.67	38		38
bkg + S	4.69	39		39
bkg + S	4.83	40		40
Site	4.890	41	41	
bkg + S	4.93	42		42
bkg + S	5.15	43		43
bkg + S	5.21	44		44
bkg + S	5.77	45		45
Site	5.920	46	46	
bkg + S	6.52	47		47
bkg + S	6.65	48		48
Site	6.85	49	49	
Site	7.60	50	50	
Site	8.040	51	51	
Site	8.050	52	52	
bkg + S	8.306	53		53
Site	8.580	54	54	
Site	9.010	55	55	
bkg + S	9.23	56		56
bkg + S	9.54	57		57
Site	10.80	58	58	
bkg + S	11.71	59		59
bkg + S	12.81	60		60
bkg + S	16.006	61		61
Site	16.300	62	62	
Site	33.400	63	63	

Raw Rank Sum (R):	982	1034
Minimum possible value for Rank Sum:	630	276
Adjusted Rank Sum (W_0):	352	758

Sum of all ranks:	1711
n * m:	805

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yellow highlight = tied values

Step 1. Null Hypothesis (H₀)

$H_0: \mu_{\text{site}} - (1.25 * \mu_{\text{bkg}}) > 0$
 Site concentrations exceed 1.25 * background concentrations. (one-sided test)

Step 2. Alternative Hypothesis (H_A)

$H_A: \mu_{\text{site}} - (1.25 * \mu_{\text{bkg}}) \leq 0$
 There is no difference between site and 1.25*background concentrations.

Step 3. Test Statistic

m and n > 20, so test statistic is:

$$z_0 = \frac{W_{bkg} - mn/2}{\sqrt{\text{var}(W_{bkg})}}$$

Where:

$$\text{var}(W_0) = \frac{mn(m+n+1)}{12} - \left\{ \frac{mn}{12(m+n)(m+n-1)} \sum_{j=1}^g t_j(t_j^2 - 1) \right\}$$

$$\text{var}(W_{bkg}) = \text{Term1} - (\text{Term2} \times \text{SumTerm})$$

m is the sample size for Site data
 n is the sample size for bkg data
 g is number of tied groups

W _{bkg} :	758
m:	35
n:	23
most likely W:	402.5
var(W₀)	
tied groups (g):	2
var(W ₀) Term 1:	3958
var(W ₀) Term 2:	0.0203
var(W ₀) Sum Term:	12
var(W ₀)	3958

each group has only two tied values

Z_{bkg}	
z _{bkg} numerator:	355.5
z _{bkg} denominator:	62.9
z _{bkg} :	5.65

Step 4a. Critical Value

False rejection error rate (α):	0.05	falsely conclude that Site ≤ background
False acceptance error rate (β):	0.2	falsely conclude that Site > background

Critical value (z _{0.95}):	1.645
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Step 4b. p-value

p-value:	8.0E-09
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Step 5a. Test Stat compared against Critical Value

Test Statistic (z _{bkg}):	5.65	
Critical Value (z _{0.95}):	1.645	
z _{bkg} > z _{0.95} :	TRUE	reject null hypothesis at 95% confidence level - Site clean

Step 5b. p-value compared against significance level

p-value:	8.0E-09	
significance level:	0.05	
p-value < significance level:	TRUE	reject null hypothesis at 95% confidence level - Site clean

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