



**Inuvik Background Soil Arsenic
Review**

FINAL

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INUVIK BACKGROUND SOIL ARSENIC REVIEW

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Introduction

1.0 INTRODUCTION

The Government of the Northwest Territories (GNWT) retained Stantec Architecture Ltd. (Stantec) to compile and review a dataset of soil arsenic concentrations that may be used to characterize soil arsenic concentrations within the municipal boundaries of Inuvik.

The tasks to be completed as part of this report include:

- Compile soil arsenic concentration data collected within the Inuvik municipal boundary from sources approved by GNWT into a table with relevant sample information (e.g., sample year, sample ID, sample coordinates, and soil arsenic concentration);
- Screen dataset for outliers; and
- Calculate key summary statistics (e.g., mean and 95% upper confidence limit of the mean (UCLM)) (with any determined outliers removed).



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Data Compilation and Review

2.0 DATA COMPIRATION AND REVIEW

2.1 DATA COMPIRATION

Based on discussion with GNWT on August 20, 2020, soil arsenic data were compiled from two key sources.

- **Meridian.** In 2011, Tier 3 community-specific soil quality guidelines were developed for arsenic in Inuvik (Meridian 2011). In determining these background concentrations, Meridian compiled and reviewed soil arsenic concentration data collected from samples in 2009, 2010, and 2011 at various locations within the developed area of Inuvik (at sample depths of 15, 60, and 85 cm), as well as from five nearby borrow pits that have supplied fill material used in the construction of the town (Airport Pit, Dempster Highway Pit, Lower Mt. Baldy Pit, Upper Mt. Baldy Pit, and Navy Road Pit). Soil arsenic concentrations in these samples were analyzed using inductively coupled plasma-mass spectroscopy (ICP-MS).
- **Stantec.** In 2017, Stantec collected additional soil samples in areas within the developed area of Inuvik that were not well characterized in the Meridian dataset, as well as in surrounding areas within the municipal boundaries of Inuvik that were considered likely to be representative of regional background. These additional samples were collected at a depth of 15 cm (underneath leaf litter, sod, and ground cover) and soil arsenic concentrations were analyzed using ICP-MS.

The analysis provided by Meridian (2011) indicated that soil arsenic concentrations in the developed area of the town frequently exceed the generic CCME soil quality guideline for arsenic of 12 mg/kg (CCME 1997). These elevated arsenic concentrations were attributed to fill materials, imported from local borrow pits and/or quarries where arsenic concentrations are naturally elevated. Therefore, the soil arsenic concentrations observed in the developed area of Inuvik are representative of 'ambient' background concentrations (i.e., concentrations that represent both natural and regional anthropogenic contributions that are not attributable to a specific point source, see CCME 2016).

Stantec previously completed a summary and review of available soil arsenic data for Inuvik on behalf of the GNWT in 2018 (Stantec 2018). However, the data screening methods and summary statistics calculated in that report are slightly different than in the Yellowknife evaluation completed by Stantec in July 2020 (Stantec 2020). As such, the focus of analysis in the present report is to revisit the available Inuvik dataset and apply the same outlier screening approach and calculate the same overall summary statistics per the report completed for Yellowknife by Stantec in July 2020. The data compiled for analysis in this report include those samples collected at a standardized depth of 15 cm from within the developed area of Inuvik by Meridian and Stantec as well as the regional background samples collected within the municipal boundaries of Inuvik by Stantec. Samples collected by Meridian at depths between 60 and 85 cm were excluded from analysis as these soils are generally not accessible by people. The samples collected from the borrow pits by Meridian were excluded from this statistical analysis because the



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relative contribution of each pit to the overall composition of the town is not known. The remaining soil samples from Meridian and Stantec that were included for further analysis are compiled in **Appendix A**, with final sample locations shown in **Figure 1 (Appendix B)**.

For the data compiled in **Appendix A**, samples have been categorized as either 'Inuvik (Town)' or 'Inuvik (Regional Background)'. Inuvik (Town) samples were collected within the developed areas of Inuvik (i.e., where substantial amounts of fill from the local borrow pits were applied during construction (Meridian 2011)), and Inuvik (Regional Background) samples were collected from background areas within the municipal boundaries of Inuvik that did not appear to be affected by construction fill from the borrow pits.

2.2 PRELIMINARY REVIEW OF DATA DISTRIBUTION

A preliminary evaluation of the underlying data distribution was performed by plotting histograms for the reported available data, as grouped by sample type (Inuvik (Town) and Inuvik (Regional Background)). For each dataset, normality was improved when data were log-transformed (**Figure 2, Appendix B**), suggesting that the underlying data may be lognormally distributed. As such, the exploratory analyses presented in Section 2.3, below, were performed assuming an underlying lognormal distribution. Additional review of the underlying data distribution (e.g., Gamma, Lognormal) will be completed as part of the calculation of summary statistics in Section 3.0, below.

2.3 COMPARISON OF SOIL ARSENIC CONCENTRATIONS IN INUVIK (TOWN) AND INUVIK (REGIONAL BACKGROUND)

To provide an initial review of the distribution of soil arsenic concentrations within the developed area of Inuvik (i.e., Inuvik (Town)) compared to those observed in the regional background samples, boxplots of soil arsenic concentrations were generated.

These boxplots (**Figure 3, Appendix B**) provide a visual representation of the distribution of each dataset, where:

- the centre horizontal line of the box marks the median of the data;
- the lower edge of the box indicates the 25th percentile of the data;
- the upper edge of the box indicates the 75th percentile of the data;
- the whiskers represent the range of observed values that are less than $1.5 \times$ the interquartile range (IQR=75th percentile – 25th percentile) from the upper or lower edges of the box; and
- values that fall more than $1.5 \times$ IQR from the box are labelled as potential outliers, with values between $1.5 \times$ IQR and $3 \times$ IQR from the box labelled as mild outliers (asterisks) and more than $3 \times$ IQR from the box labelled as extreme outliers (open circles).

No potential outliers were identified. However, as can be seen in these boxplots, potential differences in soil arsenic concentrations between the Inuvik (Town) samples and the Regional Background samples are apparent. These potential differences were investigated statistically using a two-sample t-test of log_e-



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transformed soil arsenic concentrations. The results of this statistical analysis indicate that soil arsenic concentrations were significantly higher in the developed areas of Inuvik than in Regional Background samples ($t(65)=-3.807$, $p<0.001$).

The increased soil arsenic concentrations observed in the Inuvik (Town) soils support the hypothesis that soil arsenic concentrations are elevated within the developed area of the Town relative to undisturbed background conditions. However, these represent a regional ambient concentration due to the widespread use of fill from the local borrow pits.



INUVIK BACKGROUND SOIL ARSENIC REVIEW

Calculation of Summary Statistics

3.0 CALCULATION OF SUMMARY STATISTICS

The final task described in the scope of work for this project was to calculate key summary statistics (e.g., mean and 95% upper confidence limit of the mean (UCLM)) for subsets of the available data that may be considered appropriate to characterize soil arsenic concentrations in Inuvik. This analysis was to be based on an appropriate parametric or non-parametric distribution and to exclude any identified outliers.

Based on the results presented above regarding the differences in soil arsenic concentration between the Inuvik (Town) and Inuvik (Regional Background) samples, the underlying data distribution and summary statistics were evaluated for Inuvik (Town) and Inuvik (Regional Background) separately, as well as with all samples combined (representative of concentrations within the municipal boundary of Inuvik).

For each subset of analyzed data, the suitability of combining data as described was evaluated by testing the combined data for goodness of fit to a parametric data distribution in USEPA's ProUCL Version 5.1 statistical software at a significance level of 0.05. Data grouping was supported when the combined data were found to meet a parametric data distribution. Standard summary statistics (i.e., sample size (n), minimum, maximum, and the arithmetic mean) for each dataset were calculated in Systat (Version 13.2). The 95% UCLMs were calculated using ProUCL Version 5.1, which provides recommended UCLMs based upon data size, data distribution, and skewness. In addition, the 90th percentile of each selected data subset was calculated in Systat (Version 13.2) to provide a direct comparison to the 'reasonable upper limit' 90th percentile soil arsenic concentrations reported in the previous evaluation of soil arsenic concentrations in Inuvik (Meridian 2011).

The resulting distributions and summary statistics are presented in **Table 1**, below.

Table 1 Summary Statistics

Sample Type	Distribution	Sample size (n)	Minimum	Maximum	Mean	95% UCLM	90 th Percentile
Inuvik Town	Gamma	53	1.7	141	48	60	101
Inuvik Regional Background	Normal, Gamma, or Lognormal	14	2	37	12	16	22
Combined	Gamma	67	1.67	141	40	50	100



4.0 CONCLUSION

This report presents a compilation and review of available soil arsenic concentration data that may be used to characterize soil arsenic concentrations within the municipal boundaries of Inuvik. Soil arsenic concentrations are significantly higher within the developed area of Inuvik compared to undeveloped areas within the municipal boundaries of Inuvik. This is consistent with the hypothesis that soil arsenic concentrations are elevated within the developed area of the town due to the widespread use of imported fill from local borrow pits and/or quarries where elevated soil arsenic concentrations are naturally occurring. However, given the considerable overlap in soil arsenic concentrations between these two areas, it is also possible to create a combined dataset that may be considered representative of both areas within the municipal boundaries of Inuvik. These factors should be taken into consideration by the GNWT when determining which data should be relied on as representative of soil arsenic concentrations in the Inuvik area.



5.0 REFERENCES

- CCME. 1997. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Arsenic (Inorganic). <http://ceqg-rcqe.ccme.ca/download/en/257>
- CCME. 2016. Guidance Manual for Environmental Site Characterization in Support of Environmental and Human Health Risk Assessment: Volume 1 Guidance Manual. ISBN 978-1-77202-026-7
- Meridian Environmental. 2011. Derivation of local soil quality guidelines for arsenic in Inuvik, NT.
- Stantec. 2020. Yellowknife background soil arsenic data review.
- Stantec. 2018. Update of soil arsenic background concentrations for Yellowknife, Inuvik, and surrounding areas.

Appendix A SOIL ARSENIC CONCENTRATIONS

INUVIK BACKGROUND SOIL ARSENIC REVIEW

Sample Year	Sample ID	Source	Type	Sample Description	Latitude ^A	Longitude ^A	Sample Depth (cm)	As (mg/kg)
2010	1-A	Meridian (2011)	Town	Brown native fill	68.3549	-133.7000	15	141
2010	1-B	Meridian (2011)	Town	Brown native fill	68.3549	-133.7000	15	81.9
2010	2-A	Meridian (2011)	Town	Brown fill	68.3540	-133.7086	15	81
2010	2-B	Meridian (2011)	Town	Brown fill	68.3540	-133.7086	15	72.9
2010	3-A	Meridian (2011)	Town	Brown fill	68.3555	-133.7127	15	80
2010	3-B	Meridian (2011)	Town	Brown fill	68.3555	-133.7127	15	73.8
2010	4-A	Meridian (2011)	Town	Brown fill	68.3553	-133.7194	15	46.8
2010	4-B	Meridian (2011)	Town	Brown fill	68.3553	-133.7194	15	50.5
2010	5-A	Meridian (2011)	Town	Brown fill	68.3550	-133.7221	15	14.1
2010	5-B	Meridian (2011)	Town	Brown fill	68.3550	-133.7221	15	46.3
2010	6-A	Meridian (2011)	Town	Brown fill	68.3581	-133.7117	15	25.1
2010	6-B	Meridian (2011)	Town	Brown fill	68.3581	-133.7117	15	15.2
2010	7-A	Meridian (2011)	Town	Native soil	68.3590	-133.7152	15	47.5
2010	7-B	Meridian (2011)	Town	Native soil	68.3590	-133.7152	15	25.7
2010	8-A	Meridian (2011)	Town	Brown fill	68.3610	-133.7175	15	78.3
2010	8-B	Meridian (2011)	Town	Brown fill	68.3610	-133.7175	15	100
2010	9-A	Meridian (2011)	Town	Brown fill	68.3623	-133.7195	15	11
2010	9-B	Meridian (2011)	Town	Brown fill	68.3623	-133.7195	15	15.3
2010	10-A	Meridian (2011)	Town	Brown fill	68.3638	-133.7241	15	62.7
2010	10-B	Meridian (2011)	Town	Brown fill	68.3638	-133.7241	15	72.6
2010	11-A	Meridian (2011)	Town	Brown fill	68.3641	-133.7206	15	7.18
2010	11-B	Meridian (2011)	Town	Brown fill	68.3641	-133.7206	15	6.39
2010	12-A	Meridian (2011)	Town	Brown fill	68.3633	-133.7253	15	57
2010	12-B	Meridian (2011)	Town	Brown fill	68.3633	-133.7253	15	66.4
2010	13-A	Meridian (2011)	Town	Brown fill	68.3616	-133.7281	15	107
2010	13-B	Meridian (2011)	Town	Brown fill	68.3616	-133.7281	15	131
2010	14-A	Meridian (2011)	Town	Brown fill	68.3616	-133.7304	15	5.13
2010	14-B	Meridian (2011)	Town	Brown fill	68.3616	-133.7304	15	14.4
2010	15-A	Meridian (2011)	Town	Brown fill	68.3579	-133.7219	15	101
2010	15-B	Meridian (2011)	Town	Brown fill	68.3579	-133.7219	15	105
2010	16-A	Meridian (2011)	Town	Brown fill	68.3576	-133.7221	15	81.5
2010	16-B	Meridian (2011)	Town	Brown fill	68.3576	-133.7221	15	86.9

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Sample Year	Sample ID	Source	Type	Sample Description	Latitude ^A	Longitude ^A	Sample Depth (cm)	As (mg/kg)
2010	17-A	Meridian (2011)	Town	Brown fill	68.3574	-133.7251	15	29.8
2010	17-B	Meridian (2011)	Town	Brown fill	68.3574	-133.7251	15	24.3
2010	18-A	Meridian (2011)	Town	Grey crush	68.3574	-133.7255	15	1.67
2010	18-B	Meridian (2011)	Town	Grey crush	68.3574	-133.7255	15	3.34
2009	119157-H1-1	Meridian (2011)	Town	NA	68.3563	-133.7223	15	2.1
2009	119157-H4-S1-6	Meridian (2011)	Town	NA	68.3549	-133.7201	15	124
2017	TI-SS-01	Stantec (2017)	Town	NA	68.3568	-133.7032	15	23
2017	TI-SS-02	Stantec (2017)	Town	NA	68.3569	-133.7146	15	62
2017	TI-SS-03	Stantec (2017)	Town	NA	68.3576	-133.7190	15	100
2017	TI-SS-04	Stantec (2017)	Town	NA	68.3562	-133.7326	15	20
2017	TI-SS-05	Stantec (2017)	Town	NA	68.3637	-133.7177	15	25
2017	TI-SS-06	Stantec (2017)	Town	NA	68.3660	-133.7227	15	22
2017	TI-SS-07	Stantec (2017)	Town	NA	68.3640	-133.7296	15	17
2017	TI-SS-08	Stantec (2017)	Town	NA	68.3624	-133.7343	15	3.1
2017	TI-SS-09	Stantec (2017)	Town	NA	68.3622	-133.7403	15	17
2017	TI-SS-10	Stantec (2017)	Town	NA	68.3673	-133.7324	15	5.8
2017	TI-SS-11	Stantec (2017)	Town	NA	68.3667	-133.7382	15	5.8
2017	TI-SS-12	Stantec (2017)	Town	NA	68.3631	-133.7434	15	35
2017	TI-SS-13	Stantec (2017)	Town	NA	68.3683	-133.7431	15	11
2017	TI-SS-14	Stantec (2017)	Town	NA	68.3731	-133.7484	15	39
2017	TI-SS-15	Stantec (2017)	Town	NA	68.3783	-133.7531	15	59
2017	RB-SS-01	Stantec (2017)	Regional Background	NA	68.4105	-133.7688	15	12
2017	RB-SS-02	Stantec (2017)	Regional Background	NA	68.4010	-133.7628	15	16
2017	RB-SS-03	Stantec (2017)	Regional Background	NA	68.3707	-133.7211	15	5.4
2017	RB-SS-04	Stantec (2017)	Regional Background	NA	68.3633	-133.7066	15	24
2017	RB-SS-05	Stantec (2017)	Regional Background	NA	68.3471	-133.6987	15	2.1
2017	RB-SS-06	Stantec (2017)	Regional Background	NA	68.3401	-133.6797	15	37
2017	RB-SS-07	Stantec (2017)	Regional Background	NA	68.3303	-133.6478	15	14
2017	RB-SS-08	Stantec (2017)	Regional Background	NA	68.3239	-133.6088	15	4.2
2017	RB-SS-09	Stantec (2017)	Regional Background	NA	68.3328	-133.5691	15	3.4
2017	RB-SS-10	Stantec (2017)	Regional Background	NA	68.3358	-133.5471	15	9.1
2017	RB-SS-11	Stantec (2017)	Regional Background	NA	68.3293	-133.5427	15	9.9

INUVIK BACKGROUND SOIL ARSENIC REVIEW

Sample Year	Sample ID	Source	Type	Sample Description	Latitude ^A	Longitude ^A	Sample Depth (cm)	As (mg/kg)
2017	RB-SS-12	Stantec (2017)	Regional Background	NA	68.3136	-133.5085	15	11
2017	RB-SS-13	Stantec (2017)	Regional Background	NA	68.3174	-133.4429	15	< 2
2017	RB-SS-14	Stantec (2017)	Regional Background	NA	68.3130	-133.3884	15	11

Notes

- A. For Meridian (2011) samples, sample locations have been estimated based on maps provided in Meridian (2011). Note, in the sampling program described in Meridian (2011), it is specified that two samples were collected at each location, with an approximate horizontal spacing of 2 m between each sample. Therefore, samples marked as '-A' and '-B' with the same prefacing digit have been provided the same latitude and longitude in this table but were collected 2 m apart.

Appendix B FIGURES

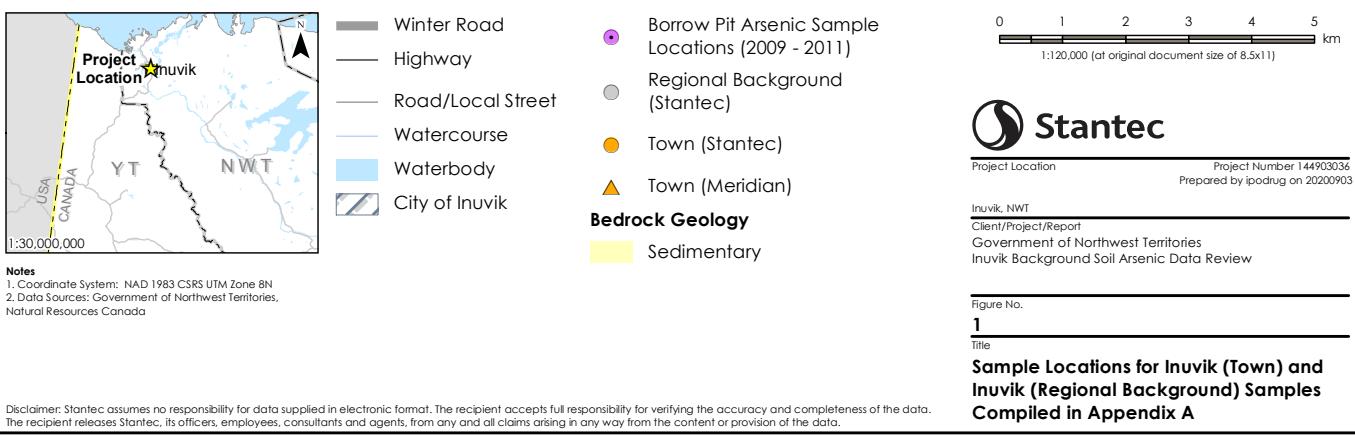
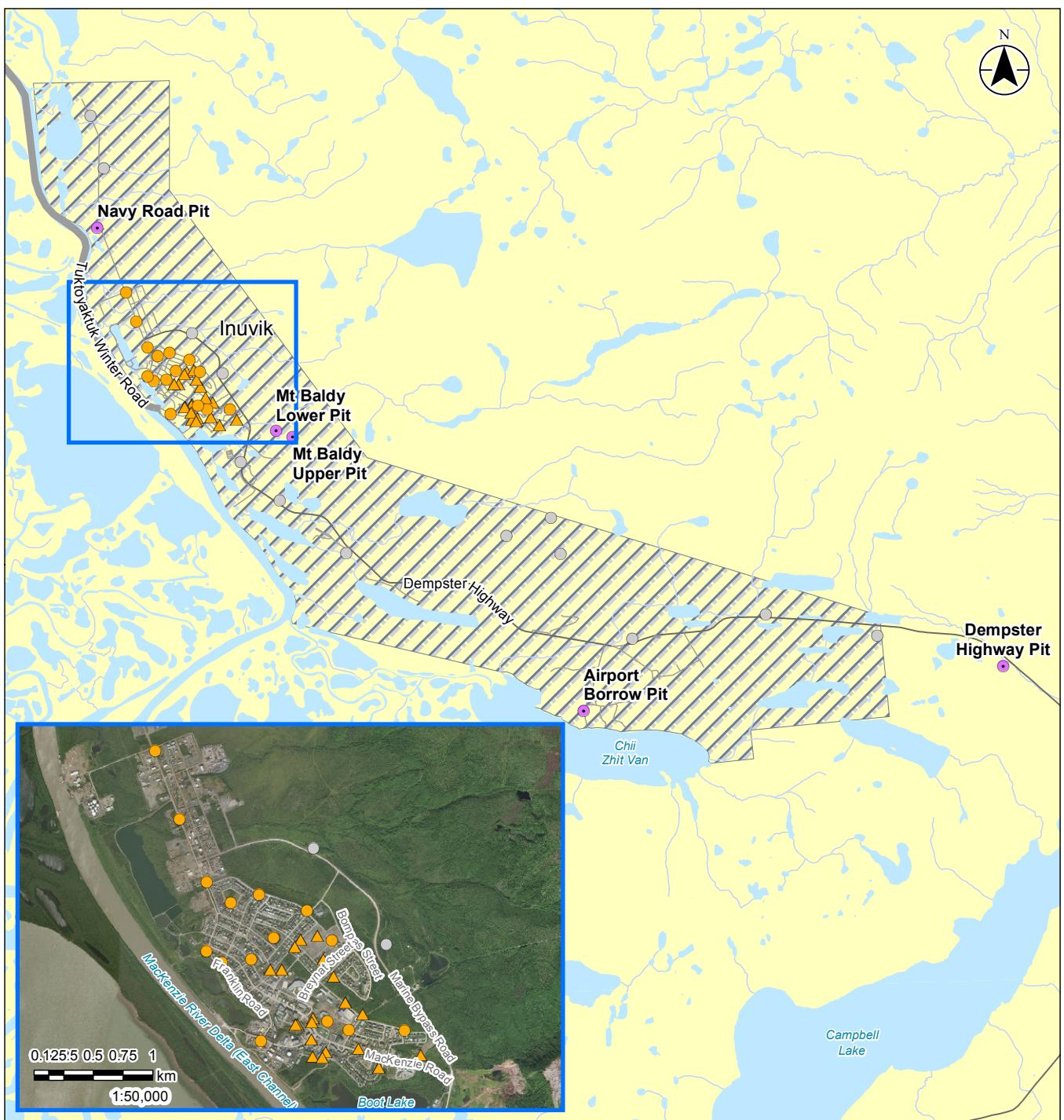


Figure 2 **Histograms for untransformed log-transformed soil arsenic concentrations for Inuvik (Regional Background) and Inuvik (Town) samples compiled in Appendix A.**

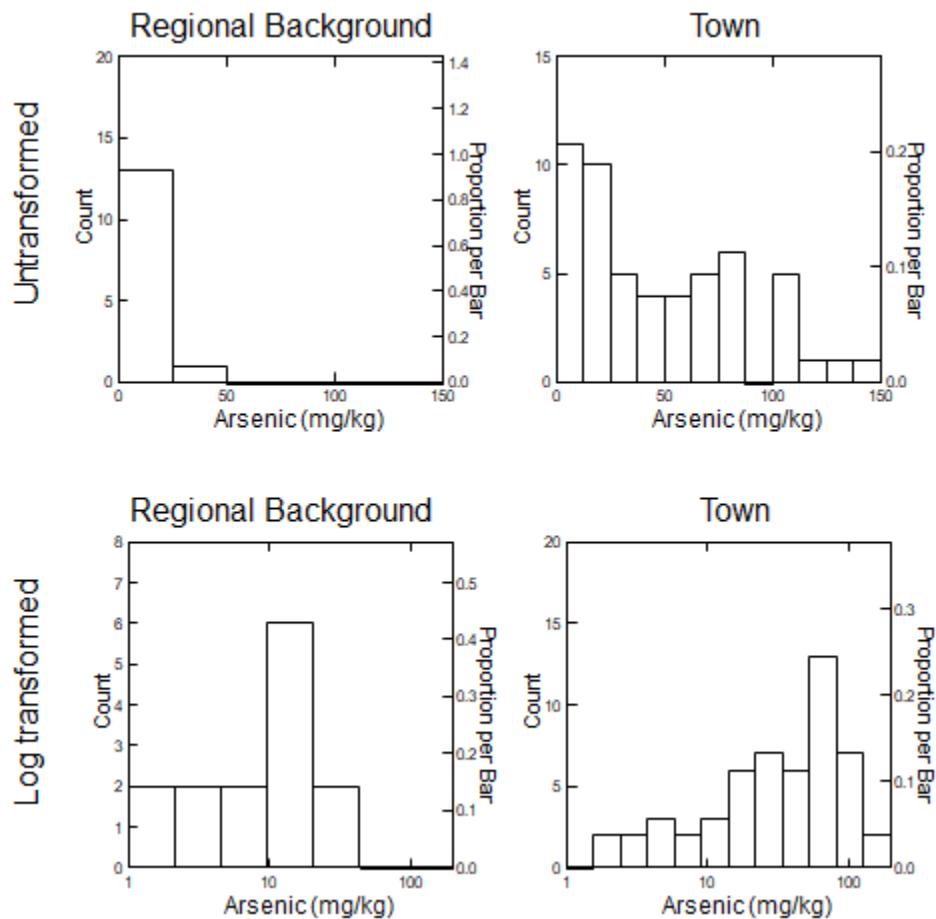


Figure 3 Boxplots summarizing soil arsenic concentrations for Inuvik (Regional Background) and Inuvik (Town) as summarized in Appendix A

