Keeyask Generation Project

Terrestrial Effects Monitoring Plan

Mercury in Plants Monitoring Report

TEMP-2020-06

ᑭᓯᔭᐢ
KEEYASK

Manitoba Conservation and Climate Client File 5550.00
Manitoba Environment Act Licence No. 3107

2019 - 2020

KEEYASK GENERATION PROJECT

TERRESTRIAL EFFECTS MONITORING PLAN

REPORT #TEMP-2020-06

MERCURY IN PLANTS MONITORING

Prepared for

Manitoba Hydro

By

ECOSTEM Ltd.

June 2020

This report should be cited as follows:

ECOSTEM Ltd. 2020. Keeyask Generation Project Terrestrial Effects Monitoring Plan Report #TEMP-2020-06: Mercury in Plants Monitoring. A report prepared for Manitoba Hydro by ECOSTEM Ltd., June 2020.

SUMMARY

Background

Construction of the Keeyask Generation Project (the Project) at Gull Rapids began in July 2014. The Keeyask Hydropower Limited Partnership (KHLP) was required to prepare a plan to monitor the effects of construction and operation of the generating station on the terrestrial environment. Monitoring results will help the KHLP, government regulators, members of local First Nation communities, and the general public understand how construction and operation of the generating station will affect the environment, and whether or not more needs to be done to reduce harmful effects.

This report describes the results of mercury in plants monitoring conducted during the sixth summer of Project construction.

Why is the study being done?

Members of partner First Nations are concerned about Project-related changes in mercury levels in traditional foods like fish, beaver, muskrat, moose, and caribou. There is also concern about possible changes in mercury levels in plants that are eaten or have traditional uses. During the Project's environmental assessment, members of the Keeyask Mercury and Human Health Technical Working Group decided that mercury levels should be monitored in Labrador tea, northern Labrador tea, blueberries, and sweet flag (*Wihkis* in Cree).

This study is being conducted to evaluate whether the creation of the Project reservoir increases mercury content in several traditionally used plants. Mercury levels in fish and other country foods are covered under separate monitoring studies.

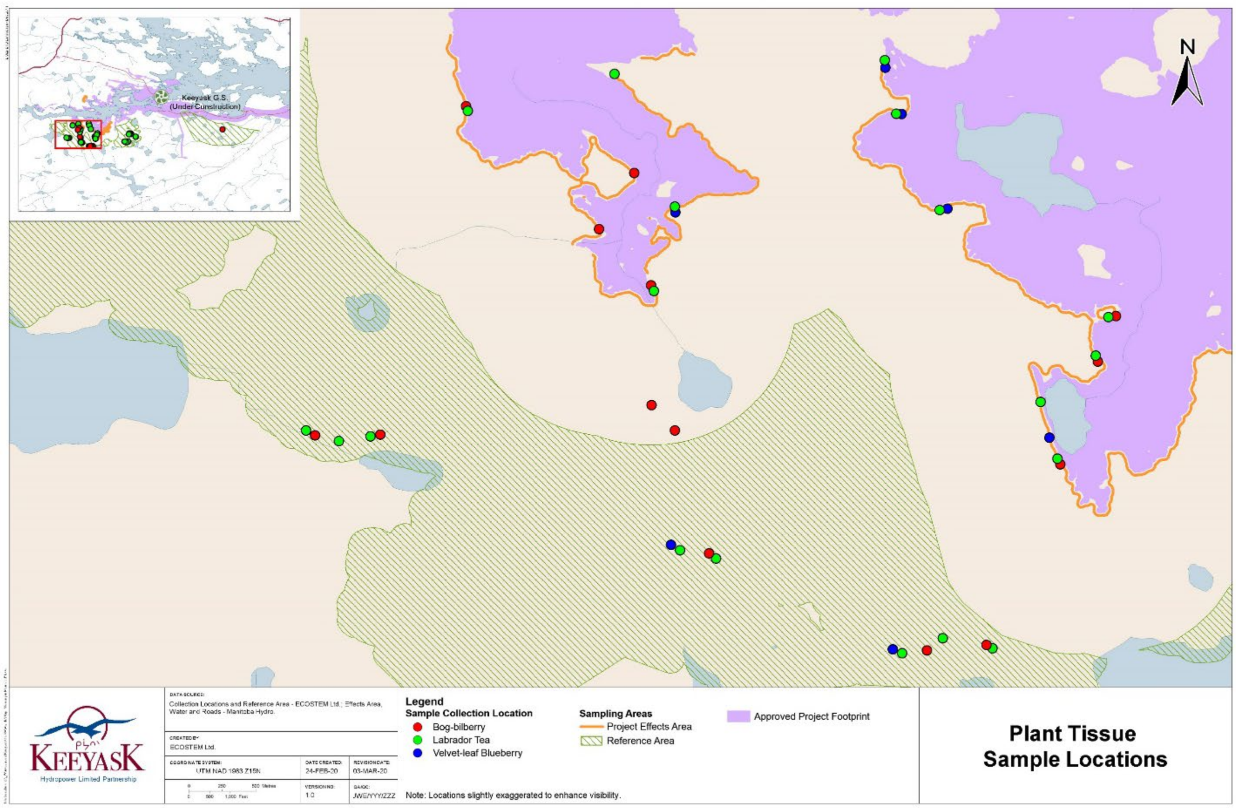
Blueberry plants (left) and Labrador tea plants (right) in the Keeyask area

What was done?

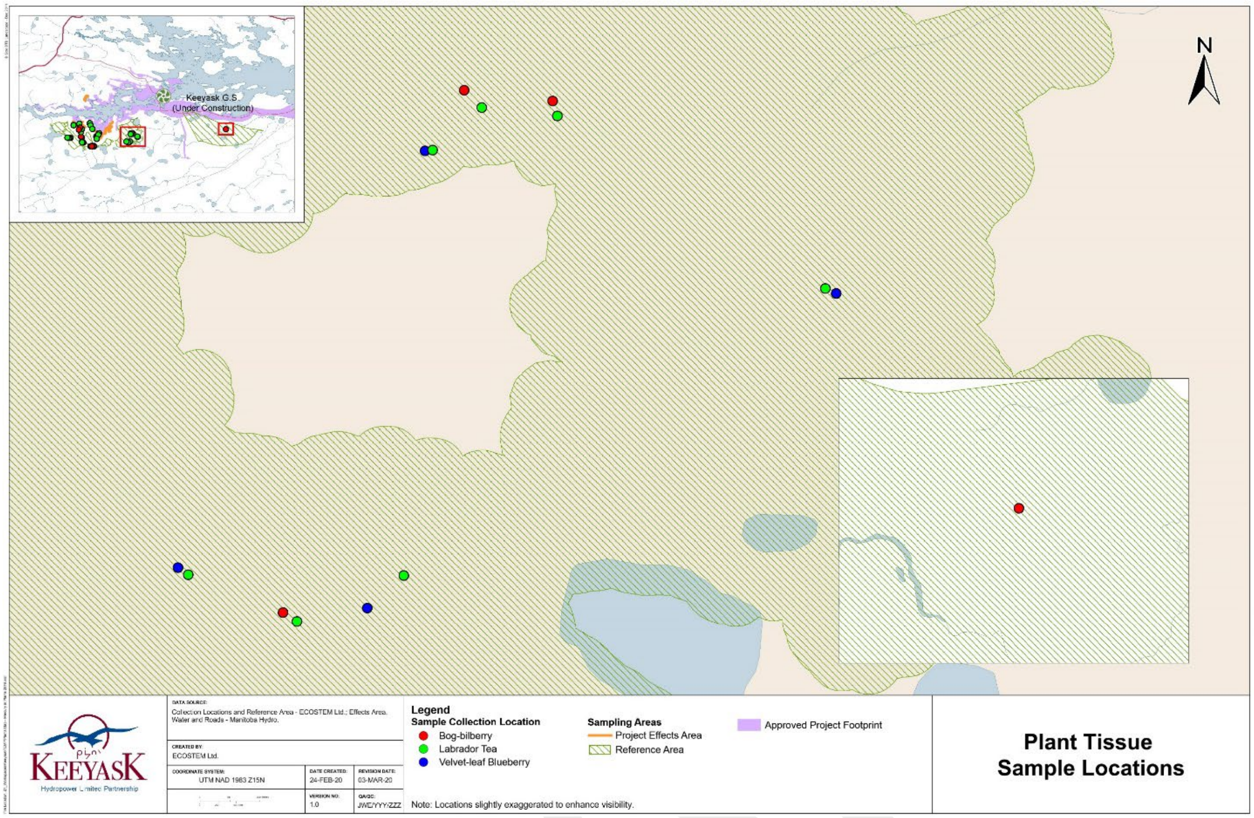
Mercury levels in plants are being monitored as a component of the technical science monitoring, including voluntary submission of plant samples by members of partner First Nations.

To evaluate if there are changes in mercury levels in selected terrestrial plants, mercury levels in plants after the reservoir flooding will be compared with those found in plants that were collected prior to reservoir flooding.

Plant tissue collection to test for mercury levels prior to impoundment began in 2017 and continued in 2018 and 2019. In 2019, blueberries were collected at 29 locations between August 16 and 18. Labrador tea leaves were collected at 26 locations on September 7 and 8. Northern Labrador tea and sweet flag/*Wihkis*, the other two species of interest, were not found in the searched areas.



Plant sample locations in the western part of the study area



Plant sample locations in the eastern part of the study area

What was found?

Laboratory analysis of the blueberries that were collected found that mercury content was below the smallest amount that could be measured (5.0 ng/g) in most (27 of 29) of the samples. The highest measured mercury content in the remaining two samples was 8.0 ng/g.

Mercury content in the Labrador tea leaves was below the smallest amount that could be measured in eight of the 26 (31%) samples. For the remaining five samples, the highest measured mercury content was 7.1 ng/g.

What does it mean?

Mercury occurs naturally in the environment. All of the blueberry and Labrador tea concentrations from the 2019 collections were either below or near the bottom end of the range that has been reported by studies from other places in Canada. In these studies, mean mercury content values for 17 different plant species ranged from 4.9 ng/g up to 39.3 ng/g, with most being higher than 10.0 ng/g. A human health risk assessment, being done as part of the Project's Socio-economic Monitoring Plan, will provide recommendations for safe levels of consumption of blueberries and Labrador tea leaves.

What will be done next?

The collection of blueberries and Labrador tea leaves under the TEMP monitoring is complete for the construction phase. Collections will resume during operation to find out if creation of the Project reservoir increases mercury concentrations in plants. Any tissue samples submitted by partner First Nations community members will be sent to the lab for processing.

ACKNOWLEDGEMENTS

ECOSTEM Ltd. would like to thank Rachel Boone, Sherrie Mason and the on-site Manitoba Hydro staff, including Rachelle Budge, Megan Anger and Linda Campbell for their support and assistance in planning field activities. Rachel Boone and Sherrie Mason are also gratefully acknowledged for coordinating the terrestrial monitoring studies.

Chiefs and Councils of Tataskweyak Cree Nation (TCN), War Lake First Nation (WLFN), York Factory First Nation (YFFN) and Fox Lake Cree Nation (FLCN) are gratefully acknowledged for their support of this program.

We would also like to thank North/South Consultants Inc., in particular Ron Bretecher and Shari Fournier for their guidance, logistical support and other resources that made these studies possible.

Custom Helicopters is gratefully acknowledged for providing transportation during fieldwork and Nicole Pokornowska and Ben Hofer for coordinating the logistics.

STUDY TEAM

Dr. James Ehnes was the project manager and study designer.

Fieldwork was conducted by Brock Epp and Barry Flett (TCN).

Data analysis and report writing were completed by Brock Epp and James Ehnes. Cartography was completed by Alex Snitowski.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF MAPS

LIST OF PHOTOS

LIST OF APPENDICES

1.0 INTRODUCTION

Construction of the Keeyask Generation Project (the Project), a 695-megawatt hydroelectric generating station (GS) and associated facilities, began in July 2014. The Project is located at Gull Rapids on the lower Nelson River in northern Manitoba where Gull Lake flows into Stephens Lake, 35 km upstream of the existing Kettle GS.

The *Keeyask Generation Project Response to EIS Guidelines* (the EIS; KHLP 2012a), completed in June 2012, provides a summary of predicted effects and planned mitigation for the Project. Technical supporting information for the terrestrial environment, including a description of the environmental setting, effects and mitigation, and a summary of proposed monitoring and follow-up programs is provided in the *Keeyask Generation Project Environmental Impact Statement Terrestrial Supporting Volume* (TE SV; KHLP 2012b). The *Keeyask Generation Project Terrestrial Effects Monitoring Plan* (TEMP; KHLP 2015) was developed as part of the licensing process for the Project. Monitoring activities for various components of the terrestrial environment were described, including the focus of this report, mercury in plants, during the construction and operation phases.

This study addresses concerns that members of the partner First Nations have expressed about mercury levels in traditionally used terrestrial plant species. Mercury levels in these plant species are being monitored via tissue collected as a component of the TEMP, including any plant samples collected and submitted by partner First Nations community members. During Project operation, mercury levels in selected terrestrial plant species will be compared with those in plants that were collected prior to reservoir impoundment. During the Project's environmental assessment, the four plant species/groups selected by members of the Keeyask Mercury and Human Health Technical Working Group for monitoring were Labrador tea (*Rhododendron groenlandicum*), northern Labrador tea (*Rhododendron tomentosum*), blueberries (*Vaccinium* spp.) and sweet flag (*Acorus americanus*), which is called *Wihkis* in Cree.

The objectives of this study are to:

- Evaluate pre-impoundment mercury levels in the selected terrestrial plant species; and,
- Evaluate if there are changes in mercury levels in the selected terrestrial plant species during Project operation.

To date, monitoring during the construction period prior to impoundment was conducted in 2017, 2018 and 2019. This report presents the results from the monitoring conducted in 2019.

2.0 METHODS

Section 7.2.3 of the TEMP and ECOSTEM (2019) detail the methods for this study. The following section summarizes the monitoring activities conducted during 2019.

2.1 SAMPLE COLLECTION

To test for a Project effect on mercury concentrations in plant tissues, permanent sample locations were established within two different zones: the "Project Effects" zone and the "Reference" zone. The Project Effects zone is adjacent to the future reservoir shoreline while the "Reference" zone is an area that has been and will continue to unaffected by the Project or other substantive point or linear sources of mercury.

Mercury concentrations in the collected plant tissue would be representative of areas that have burned in the past approximately 15 to 25 years. These concentrations may also be representative of other age classes, but additional data collection would required to establish this. The Reference zone samples would continue to be representative of unaffected areas after the reservoir is created.

Mercury concentrations in the collected plant tissue provide appropriate data for calculating means and confidence intervals for the before-after and "control-impact" comparisons. It is unlikely that the highest concentration obtained from this study would also be the upper bound for the study area. Confidence intervals calculated from the data could provide an approximation of the upper bound.

Plant tissue samples are collected in each of the zones for three years prior to operation, followed by another three years during operation.

The Project Effects zone was a 50 m wide band adjacent to the future reservoir shoreline. The Reference zone included areas that were at least 1 km away from the future reservoir shoreline or other human features that might influence mercury levels in plant tissue (ECOSTEM 2019).

Permanent sample locations were established within the Project effects and the references zones in 2017. A sample location was an approximately 5 m diameter area that included a homogeneous number of plants to collect tissue samples over six years. A sample location had homogeneous site conditions within its 5 m diameter to control for the potential effects this could otherwise have on mercury uptake.

Based on conditions when the permanent sample locations were established, species for which sufficient tissue could be collected included Labrador tea, velvet-leaf blueberry (*Vaccinium myrtilloides*) and bog-bilberry (*Vaccinium uliginosum*). Tissue samples have not and will not be collected for northern Labrador tea and sweet flag as too few locations were found for northern Labrador tea and none for sweet flag.

Throughout the remainder of this report, all references to “blueberry” are to both velvet-leaf blueberry and bog-bilberry unless otherwise stated.

To maximize seasonal mercury accumulation, the timing for when tissue was collected varied by species group. Blueberry collection was conducted when the berries were ripe. Labrador tea leaf collection was done later in the growing season.

Plant tissue was previously collected by ECOSTEM staff in 2017 and 2018. The volunteer collection program for members of the partner First Nations also began in 2017, with a detailed sampling protocol developed to help achieve consistency across sampling by different individuals.

In 2019, the blueberry permanent sample locations were revisited on August 16 to 18 to collect berries, and the Labrador tea locations were revisited on September 7 and 8 to collect leaves. No new sample locations were added in 2019. The tissue samples were taken from the same plants sampled previously.

The first time that tissue was collected at a sample location, geographic coordinates were recorded from a handheld GPS unit. The location was also marked with a pin flag and flagging tape so it could be relocated.

Information recorded about the location and sampled plants included:

1. Species sampled;
2. Habitat type, including dominant tree species, shrub species and ground cover;
3. Soil type (organic or mineral) and soil moisture regime (water, very wet, moist, dry);
4. Plant condition, including health and size;
5. Growing conditions (full sun, partial shade, shade);
6. Berry condition for blueberries. Condition notes indicated if some of the collected berries were not at optimal ripeness and whether the deviation was towards being unripe or overripe. The size of the berries was also indicated if they appeared smaller or larger than typical;
7. Approximate age of collected tissue; and
8. Photos of plant and location.

When a location was resampled in subsequent years, the information for items 4 to 8 listed above was recorded again. Information pertaining to items 2 and 3 was also collected if there was a noticeable change from the previous sample year.

A sufficient amount of tissue for the lab to conduct mercury analysis was obtained at each location. A minimum of 1/5th of a cup of berries, and 1/3rd of a cup of leaves or roots was gathered. Additional material was collected for blueberries if sufficient berries were available and that could be accomplished within a reasonable length of time. The purpose for the additional blueberry material was for moisture content testing, which was a second test performed on the residual material from the location.

Tissue samples were collected and handled in a manner that minimized potential contamination. This included wearing a new pair of sterile vinyl gloves, using clean tools, placing the tissue in a new sealable freezer bag, sealing it, and then placing the first sealed bag into a second labelled and sealed bag. The samples were kept in a cooler with ice packs, until they could be transferred into a freezer for storage at the end of each day. Plant tissue samples were kept frozen until they were analyzed.

2.2 LABORATORY ANALYSIS

Plant tissue samples collected in 2019 were submitted for mercury analysis to ALS Environmental in Winnipeg, Manitoba on September 27, 2019. Total dry weight mercury content was measured using cold-vapor atomic absorption spectroscopy (CVAAS; method reference: EPA 200.3/EPA 1631E (modified)). Prior to CVAAS analysis, tissue samples underwent hotblock digestion with nitric and hydrochloric acids, in combination with repeated additions of hydrogen peroxide, followed by cold-oxidation using bromine monochloride prior to reduction with stannous chloride. The method detection limit (DL) for mercury with this procedure was 5 ng/g. Appendix 1 presents the full methodology and analysis results provided by ALS Environmental.

The analytical methodology used by ALS Environmental differed slightly in 2017 compared to 2018 in terms of detectors and digestion, however the method differences were not expected to be meaningful when comparing year to year data for mercury concentrations (see ECOSTEM 2019 for details). The analytical methodology was identical in 2018 and 2019.

2.3 DATA ANALYSIS

A statistical comparison of the means for samples from the “Project Effects” zone compared with the “Reference” zone was not performed for the construction annual reports for several reasons. In the case of blueberries, all but two of the concentrations to date were below the DL. For Labrador tea leaves, 15% to 62% of the lab measured concentrations were below the DL in 2017 to 2019. Specialized statistical methods are used for data with values below a laboratory DL. A variety of such methods exist, along with controversy as to which is the most appropriate (Ogden 2010). The choice of a method is deferred to the operation monitoring synthesis report that tests for Project effects as this is when all of the relevant data will be available. Deferring the statistical comparisons of mercury concentrations was not considered to be a limitation for the construction annual reports because all of the measured concentrations during the construction phase were either below or close to the DL, and because these concentrations appear to be well below most of the literature values for comparable areas (see ECOSTEM 2019).

2.4 WET WEIGHT CONCENTRATIONS FOR HUMAN HEALTH RISK ASSESSMENT

In spring 2019, the toxicologist undertaking the Human Health Risk Assessment (HHRA) for the Keeyask Mercury and Human Health Implementation Working Group requested to receive wet weight mercury concentrations for blueberries. Up to that time, blueberry mercury concentrations had only been provided on a dry weight basis for various reasons. Appendix 3 details the reasons as well as providing blueberry wet weight mercury concentrations for all of the construction monitoring years when berry samples were collected.

3.0 RESULTS

In 2019, plant tissue was sampled at 55 locations across both of the Project zones, including 23 in the Project Effects zone and 32 in the Reference zone (Table 3-1; Map 3-1, Map 3-2). One of the permanent bog-bilberry locations in the Project Effects zone was not sampled in 2019 due to a sampled status recording error.

Table 3-1: Number of locations sampled in 2019 for each species found in the sample zones

Species	Project Effects Zone	Reference Zone	Both
Velvet-leaf blueberry	5	6	11
Bog-bilberry	7	11	18
Labrador tea	11	15	26
Total locations	23	32	55

Tissue samples were collected from Labrador tea (Photo 3-1), velvet-leaf blueberry (Photo 3-2) and bog-bilberry (to Photo 3-3). Throughout the remainder of this report, all references to "blueberry" are to both velvet-leaf blueberry and bog-bilberry unless otherwise stated.

Every blueberry sample was either entirely at optimal ripeness or predominantly at optimal ripeness. Four samples had a small proportion of berries that were still unripe, and two samples had berries that were relatively small. For the Labrador tea leaves collected in 2019, the leaves in every sample were in a healthy condition.

Photo 3-1: Labrador tea

Photo 3-2: Velvet-leaf blueberry

Photo 3-3: Bog bilberry

3.1 BLUEBERRY

The laboratory analysis determined that the total dry weight mercury concentration of all but two blueberry samples was below the DL (<5 ng/g; Table 3-2; see Appendix 2 for complete ALS lab report). The two remaining concentrations were slightly above the DL at 7.2 and 8.0 ng/g. Both samples were from bog bilberry, and both were collected in the eference zone.

Table 3-2: Mercury analysis results for blueberry tissue samples collected in 2019

Values	Project Effects Zone	Reference Zone	Both
Number of samples	12	17	29
Number of samples with mercury above DL	0	2	2
Mean dry weight mercury concentration (ng/g)[1]	3.8	4.2	4.0
Standard deviation (ng/g)[1]	0.0	1.3	1.0
Maximum dry weight mercury concentration (ng/g)	3.8	8.0	8.0

[1] Samples with concentrations below DL were set to 75% of the DL.

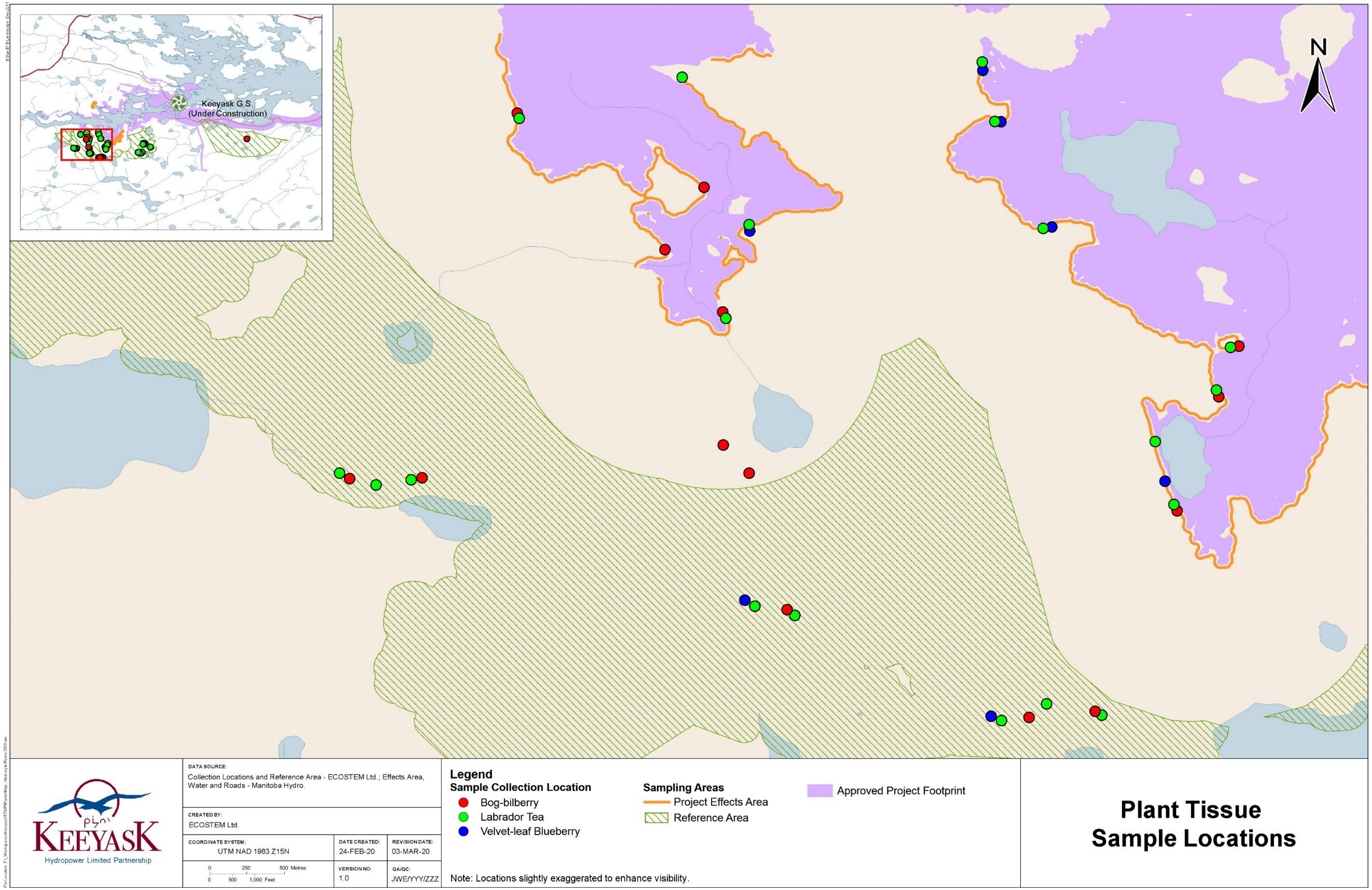
3.2 LABRADOR TEA

Of the 26 Labrador tea tissue samples, 18 had a total mercury dry weight mercury concentration that was slightly above the DL (Appendix 1: Table 6-2). The proportion of samples with concentrations above the DL was similar in both of the effect zones (73% in Project Effects, 67% in Reference (Table 3-3)). The highest measured dry weight concentrations were also similar in both of the zones (7.0 ng/g in Project Effects; 7.1 ng/g in Reference (Table 3-3)).

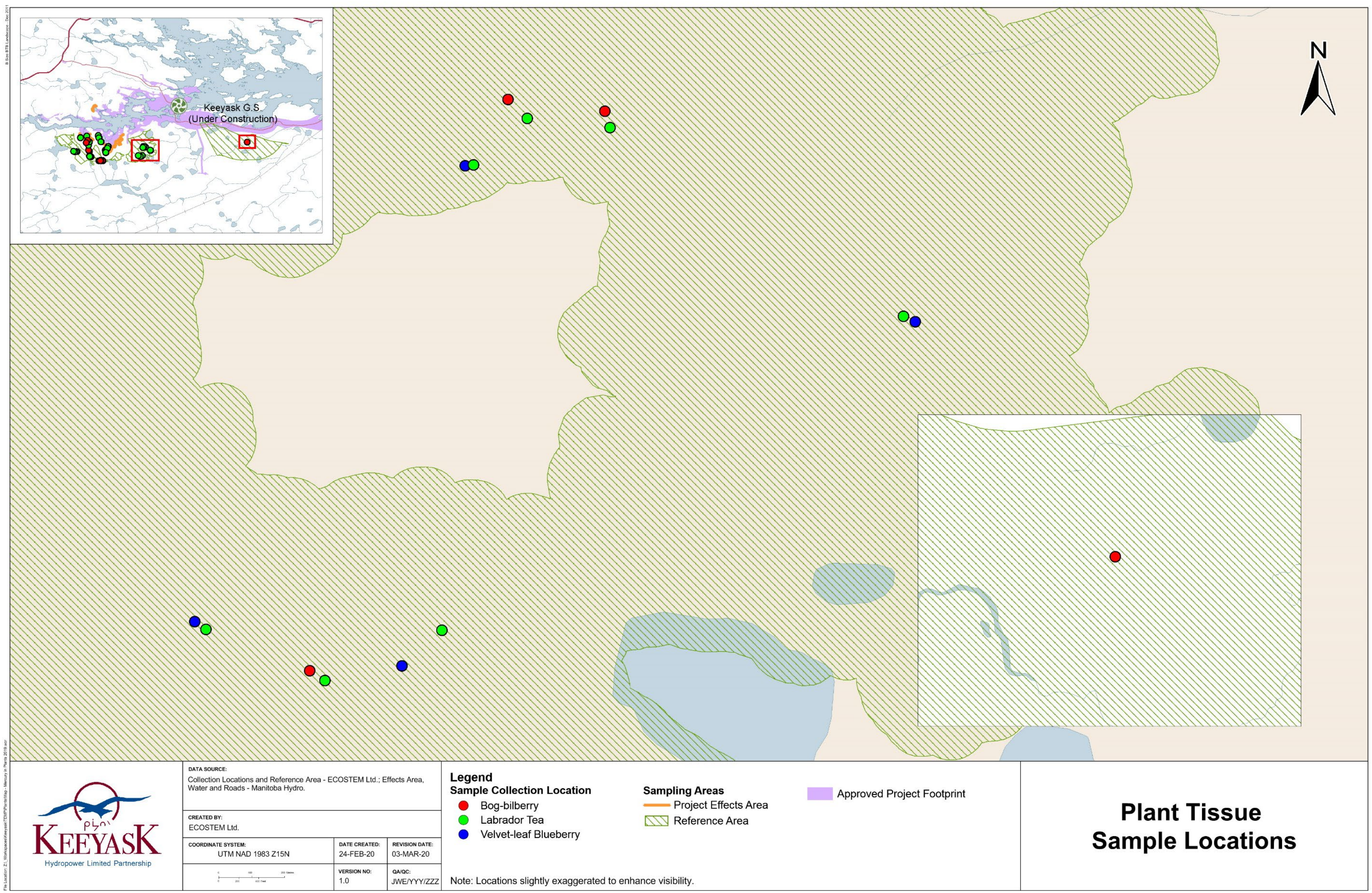
Table 3-3: Mercury analysis results for Labrador tea tissue samples collected in 2019

Values	Project Effects Zone	Reference Zone	Both
Number of samples	11	15	26
Number of samples with mercury above DL	8	10	18
Mean dry weight mercury concentration (ng/g)[1]	5.4	5.4	5.4
Standard deviation (ng/g)[1]	1.2	1.3	1.2
Maximum dry weight mercury concentration (ng/g)	7.0	7.1	7.1

[1] Samples with concentrations below DL were set to 75% of the DL.



Map 3-1: Permanent sample locations for plant tissue collection in western area, by species



Map 3-2: Permanent sample locations for plant tissue collection in eastern area, by species

4.0 DISCUSSION

Throughout the remainder of this report, all references to “blueberry” are to both velvet-leaf blueberry and bog-bilberry unless otherwise stated.

The only two blueberry samples with mercury concentrations above the DL (7.2 and 8.0 ng/g) were from bog bilberry, and both were collected in the Reference zone. Both of these locations had concentrations below the DL in the previous years they were sampled. There was no obvious factor to explain this pattern. There are too few blueberry samples above the detection limit to suggest a trend, or a real difference between the two blueberry species (a statistical comparison is complicated by how concentrations below DL are treated (see Section 2.3)). Other possible reasons for this pattern will be examined in the construction synthesis report, which is when the multi-year comparisons will be undertaken. In any event, the two mercury concentrations above the DL were still low relative to most of the relevant literature values (ECOSTEM 2019).

Compared with 2018, the 2019 Labrador tea and blueberry collections had more samples with detectable mercury. Ten more of the Labrador tea samples had detectable mercury than in 2018 (ECOSTEM 2019), but two fewer than in 2017 (ECOSTEM 2018). Two of the blueberry samples had detectable mercury for the first time in 2019 (see above).

The between-year differences in mercury concentrations could be due to natural and/or analytical variability. Natural variability could arise from factors such as year-to-year differences in growing conditions, total plant sequestration, within-plant allocation, or environmental mercury exposure (e.g., atmospheric deposition). Analytical variability arises from the limits imposed by the testing equipment or lab procedure. Natural variability and other potential reasons for year-to-year differences will be examined in the construction synthesis report, which is when the multi-year comparisons will be undertaken.

Having more samples with detectable mercury concentrations in 2019 compared with 2018 was not identified as a potential concern. The increases were small in absolute terms, and all of the 2019 concentrations were still low relative to most of the relevant literature values (ECOSTEM 2019). Also, the mean concentrations for the Project Effects and Reference zones were identical for Labrador tea and similar for blueberry (note that this latter comparison is complicated by how concentrations below DL are treated (see above).

5.0 SUMMARY AND CONCLUSIONS

In 2019, plant tissue was collected for mercury analysis at 23 permanent sample locations within the Project Effects zone and at 32 locations in the Reference zone. Blueberry berries (all references to “blueberry” are for both velvet-leaf blueberry and bog-bilberry) were collected on August 16 to 18, and Labrador tea leaves on September 7 and 8. Samples from the community voluntary collection program were not received in 2019.

For 27 of the 29 blueberry samples, laboratory analysis determined that the dry weight total mercury concentration was below the method’s detection limit (DL) of 5 ng/g. The highest mercury concentration for the remaining two samples was 8.0 ng/g. Both of these locations, which were in the Reference zone, had concentrations below the DL in the previous years they were sampled.

Eight of the 26 Labrador tea leaf tissue samples had a total dry weight mercury concentration that were below the instrument’s DL. The highest mercury concentration in the Labrador tea samples was 7.1 ng/g. Approximately one-half of the samples with detectable mercury levels were from the Project Effects zone.

The toxicologist undertaking the Project’s Human Health Risk Assessment is evaluating the mercury concentrations from this study. In the meantime, studies from elsewhere in Canada provide an indication of what can be expected for mercury concentrations in boreal plants. Results from such studies found mean total dry weight mercury concentration values for 17 different native boreal species ranged from 4.9 ng/g up to 39.3 ng/g, with most being higher than 10.0 ng/g. For the 2019 TEMP samples, all of the blueberry and Labrador tea concentrations were either below or near the bottom end of this range.

Monitoring fieldwork for this study under the TEMP is complete for the construction phase. The construction synthesis report will provide a more detailed examination and evaluation of results to date.

The collection of blueberries and Labrador tea leaves under the TEMP will resume during operation to find out if the Project reservoir increases mercury concentrations in plants. Tissue samples submitted by the partner First Nations community members will be sent to the lab for processing if they have been collected using the protocol.

6.0 LITERATURE CITED

ECOSTEM Ltd. 2018. Keeyask Generation Project Terrestrial Effects Monitoring Plan Report #TEMP-2018-06: Mercury in Plants Monitoring. A report prepared for Manitoba Hydro by ECOSTEM Ltd., June 2018.

ECOSTEM Ltd. 2019. Keeyask Generation Project Terrestrial Effects Monitoring Plan Report #TEMP-2019-06: Mercury in Plants Monitoring. A report prepared for Manitoba Hydro by ECOSTEM Ltd., June 2019.

Keeyask Hydropower Limited Partnership (KHLP). 2012a. Keeyask Generation Project Environmental Impact Statement: Response to EIS Guidelines, Winnipeg, Manitoba. June 2012.

Keeyask Hydropower Limited Partnership (KHLP). 2012b. Keeyask Generation Project Environmental Impact Statement: Terrestrial Environment Supporting Volume, Winnipeg, Manitoba. June 2012.

Keeyask Hydropower Limited Partnership (KHLP). 2015. Keeyask Generation Project Terrestrial Effects Monitoring Plan. Winnipeg, Manitoba. December 2015.

Ogden, T. L. 2010. Handling results below the level of detection. Ann. Occup. Hyg., Vol. 54, No. 3, pp. 255–256, 2010

APPENDIX 1:
ANALYTICAL TEST METHODS AND RESULTS

Table 6-1: ALS Environmental methodology for total mercury

Date Received	27-Sep-2019 12:05				
Report Date	31-Dec-2019 15:28				
ALS Test Code	**ALS Test Description**	**Lab Location**	**Matrix**	**Method Reference**	**Methodology Description**
Total Mercury					
HG-DRY-CVAA-WP	Mercury in Tissue by CVAAS, Dry Weight	Winnipeg	Tissue	EPA 200.3/EPA 1631E (mod)	Tissue samples undergo hotblock digestion with nitric and hydrochloric acids, in combination with repeated additions of hydrogen peroxide, followed by cold-oxidation using bromine monochloride prior to reduction with stannous chloride, and analyzed by CVAAS.
Percent Moisture					
MOISTURE-IN-WP	Percent Moisture	Winnipeg	Tissue	ASTMD2974-87, Method B	Air dry sample at room temperature, and subsequent oven drying at 105°C.

Table 6-2: ALS Environmental test results for percent moisture content, dry weight, and wet weight mercury concentration in the individual 2019 plant samples

Species	Project Zone	Sample Location	Percent Moisture	Mercury Concentration (ng/g[1])	
				Dry Weight	Wet Weight[2]
Rhododendron groenlandicum	Project Effects	LTPE1901	49.4	5.4	2.7
Rhododendron groenlandicum	Project Effects	LTPE1902	50.7	6.4	3.2
Rhododendron groenlandicum	Project Effects	LTPE1903	51.8	<5.0	-
Rhododendron groenlandicum	Project Effects	LTPE1904	50.8	5.5	2.7
Rhododendron groenlandicum	Project Effects	LTPE1905	52.0	6.0	2.9
Rhododendron groenlandicum	Project Effects	LTPE1906	48.9	5.3	2.7
Rhododendron groenlandicum	Project Effects	LTPE1907	51.3	6.9	3.4
Rhododendron groenlandicum	Project Effects	LTPE1908	46.5	5.6	3.0
Rhododendron groenlandicum	Project Effects	LTPE1909	52.1	<5.0	-
Rhododendron groenlandicum	Project Effects	LTPE1910A	50.4	7.0	3.5
Rhododendron groenlandicum	Project Effects	LTPE1910B	50.3	7.4	3.7
Rhododendron groenlandicum	Project Effects	LTPE1911	48.5	<5.0	-
Rhododendron groenlandicum	Reference	LTRE1912	56.1	5.4	2.4
Rhododendron groenlandicum	Reference	LTRE1913	59.2	<5.0	-
Rhododendron groenlandicum	Reference	LTRE1914	58.1	<5.0	-
Rhododendron groenlandicum	Reference	LTRE1915	58.7	<5.0	-
Rhododendron groenlandicum	Reference	LTRE1916	57.3	7.1	3.0
Rhododendron groenlandicum	Reference	LTRE1917A	59.6	6.2	2.5
Rhododendron groenlandicum	Reference	LTRE1917B	60.6	<5.0	-
Rhododendron groenlandicum	Reference	LTRE1918	59.9	6.8	2.7
Rhododendron groenlandicum	Reference	LTRE1919	50.2	<5.0	-
Rhododendron groenlandicum	Reference	LTRE1920	49.9	6.2	3.1
Rhododendron groenlandicum	Reference	LTRE1921	50.3	6.0	3.0
Rhododendron groenlandicum	Reference	LTRE1922	49.2	5.2	2.6
Rhododendron groenlandicum	Reference	LTRE1923	51.8	6.7	3.2
Rhododendron groenlandicum	Reference	LTRE1924	51.2	5.3	2.6
Rhododendron groenlandicum	Reference	LTRE1925	50.6	6.8	3.4
Rhododendron groenlandicum	Reference	LTRE1926	49.8	<5.0	-
Vaccinium myrtilloides	Project Effects	VMPE1903	82.9	<5.0	-
Vaccinium myrtilloides	Project Effects	VMPE1905	80.6	<5.0	-
Vaccinium myrtilloides	Project Effects	VMPE1906	80.3	<5.0	-

Species	Project Zone	Sample Location	Percent Moisture	Mercury Concentration (ng/g[1])	
				Dry Weight	Wet Weight[2]
Vaccinium myrtilloides	Project Effects	VMPE1908	83.7	<5.0	-
Vaccinium myrtilloides	Project Effects	VMPE1910	80.9	<5.0	-
Vaccinium myrtilloides	Reference	VMRE1914	84.9	<5.0	-
Vaccinium myrtilloides	Reference	VMRE1915	80.5	<5.0	-
Vaccinium myrtilloides	Reference	VMRE1917	80.9	<5.0	-
Vaccinium myrtilloides	Reference	VMRE1918	84.4	<5.0	-
Vaccinium myrtilloides	Reference	VMRE1922	82.1	<5.0	-
Vaccinium myrtilloides	Reference	VMRE1925	83.2	<5.0	-
Vaccinium uliginosum	Project Effects	VUPE1901	85.6	<5.0	-
Vaccinium uliginosum	Project Effects	VUPE1902	86.4	<5.0	-
Vaccinium uliginosum	Project Effects	VUPE1907	83.9	<5.0	-
Vaccinium uliginosum	Project Effects	VUPE1909A	85.2	<5.0	-
Vaccinium uliginosum	Project Effects	VUPE1909B	85.4	<5.0	-
Vaccinium uliginosum	Project Effects	VUPE1911	86.2	<5.0	-
Vaccinium uliginosum	Project Effects	VUPE1960	82.9	<5.0	-
Vaccinium uliginosum	Project Effects	VUPE1961	86.6	<5.0	-
Vaccinium uliginosum	Reference	VURE1901	83.0	<5.0	-
Vaccinium uliginosum	Reference	VURE1912	85.0	<5.0	-
Vaccinium uliginosum	Reference	VURE1913	85.9	<5.0	-
Vaccinium uliginosum	Reference	VURE1916A	85.2	<5.0	-
Vaccinium uliginosum	Reference	VURE1916B	82.7	<5.0	-
Vaccinium uliginosum	Reference	VURE1919	84.9	<5.0	-
Vaccinium uliginosum	Reference	VURE1920	84.4	<5.0	-
Vaccinium uliginosum	Reference	VURE1921	84.8	<5.0	-
Vaccinium uliginosum	Reference	VURE1923	85.2	<5.0	-
Vaccinium uliginosum	Reference	VURE1924	86.0	7.2	1.0
Vaccinium uliginosum	Reference	VURE1926	71.4	<5.0	-
Vaccinium uliginosum	Reference	VURE1962	84.5	8.0	1.2

Notes: [1] Values are converted from mg/kg (the units used in the ALS report) to ng/g. Detection limit is 5 ng/g. [2] Values are calculated for samples with concentrations above the detection limit by ECOSTEM Ltd.. A value of "-" indicates it is not provided because the dry weight concentration is below the detection limit.

APPENDIX 2: ALS ENVIRONMENTAL- CERTIFICATE OF ANALYSIS

Ecostem Ltd.
ATTN: BROCK EPP
495 - A Madison Street
Winnipeg MB R3J 1J2

Date Received: 27-SEP-19
Report Date: 31-DEC-19 15:28 (MT)
Version: FINAL

Client Phone: 204-772-7204

Certificate of Analysis

Lab Work Order #: L2355763
Project P.O. #: NOT SUBMITTED
Job Reference:
C of C Numbers:
Legal Site Desc:

Hua Wo
Chemistry Laboratory Manager

[This report shall not be reproduced except in full without the written authority of the Laboratory.]

ADDRESS: 1329 Niakwa Road East, Unit 12, Winnipeg, MB R2J 3T4 Canada | Phone: +1 204 255 9720 | Fax: +1 204 255 9721
ALS CANADA LTD Part of the ALS Group An ALS Limited Company

L2355763 CONTD....
PAGE 2 of 14
31-DEC-19 15:28 (MT)
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2355763-1	L2355763-2	L2355763-3	L2355763-4	L2355763-5
	Description	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE
	Sampled Date	16-AUG-19	16-AUG-19	16-AUG-19	16-AUG-19	16-AUG-19
	Sampled Time					
	Client ID	VUPE1901	VUPE1902	VMPE1903	VMPE1905	VMPE1906
Grouping	**Analyte**					
TISSUE						
Physical Tests	% Moisture (%)	85.6	86.4	82.9	80.6	80.3
Metals	Mercury (Hg) (mg/kg)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

L2355763 CONTD....
PAGE 3 of 14
31-DEC-19 15:28 (MT)
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L2355763-6 TISSUE 16-AUG-19 VUPE1907	L2355763-7 TISSUE 16-AUG-19 VMPE1908	L2355763-8 TISSUE 16-AUG-19 VUPE1909A	L2355763-9 TISSUE 16-AUG-19 VUPE1909B	L2355763-10 TISSUE 16-AUG-19 VMPE1910
Grouping	**Analyte**					
TISSUE						
Physical Tests	% Moisture (%)	83.9	83.7	85.2	85.4	80.9
Metals	Mercury (Hg) (mg/kg)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

L2355763 CONTD....
PAGE 4 of 14
31-DEC-19 15:28 (MT)
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L2355763-11 TISSUE 16-AUG-19 VUPE1911	L2355763-12 TISSUE 16-AUG-19 VUPE1960	L2355763-13 TISSUE 16-AUG-19 VUPE1961	L2355763-14 TISSUE 18-AUG-19 VURE1901	L2355763-15 TISSUE 18-AUG-19 VURE1912
Grouping	**Analyte**					
TISSUE						
Physical Tests	% Moisture (%)	86.2	82.9	86.6	83.0	85.0
Metals	Mercury (Hg) (mg/kg)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

L2355763 CONTD....
PAGE 5 of 14
31-DEC-19 15:28 (MT)
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample ID / Description / Sampled Date / Sampled Time / Client ID		L2355763-16 TISSUE 18-AUG-19 VURE1913	L2355763-17 TISSUE 18-AUG-19 VMRE1914	L2355763-18 TISSUE 17-AUG-19 VMRE1915	L2355763-19 TISSUE 17-AUG-19 VURE1916A	L2355763-20 TISSUE 17-AUG-19 VURE1916B
Grouping	**Analyte**					
TISSUE						
Physical Tests	% Moisture (%)	85.9	84.9	80.5	85.2	82.7
Metals	Mercury (Hg) (mg/kg)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

L2355763 CONTD....
PAGE 6 of 14
31-DEC-19 15:28 (MT)
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2355763-21	L2355763-22	L2355763-23	L2355763-24	L2355763-25
	Description	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE
	Sampled Date	17-AUG-19	16-AUG-19	17-AUG-19	17-AUG-19	17-AUG-19
	Sampled Time					
	Client ID	VMRE1917	VMRE1918	VURE1919	VURE1920	VURE1921
Grouping	**Analyte**					
TISSUE						
Physical Tests	% Moisture (%)	80.9	84.4	84.9	84.4	84.8
Metals	Mercury (Hg) (mg/kg)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

L2355763 CONTD....
PAGE 7 of 14
31-DEC-19 15:28 (MT)
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2355763-26	L2355763-27	L2355763-28	L2355763-29	L2355763-30
	Description	TISSUE	TISSUE	TISSUE	TISSUE	TISSUE
	Sampled Date	17-AUG-19	17-AUG-19	17-AUG-19	17-AUG-19	17-AUG-19
	Sampled Time					
	Client ID	VMRE1922	VURE1923	VURE1924	VMRE1925	VURE1926
Grouping	**Analyte**					
TISSUE						
Physical Tests	% Moisture (%)	82.1	85.2	86.0	83.2	71.4
Metals	Mercury (Hg) (mg/kg)	<0.0050	<0.0050	0.0072	<0.0050	<0.0050

L2355763 CONTD....
PAGE 8 of 14
31-DEC-19 15:28 (MT)
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample ID		L2355763-31	L2355763-32	L2355763-33	L2355763-34	L2355763-35
Description		TISSUE	TISSUE	TISSUE	TISSUE	TISSUE
Sampled Date		17-AUG-19	07-SEP-19	07-SEP-19	07-SEP-19	07-SEP-19
Sampled Time						
Client ID		VURE1962	LTPE1901	LTPE1902	LTPE1903	LTPE1904
Grouping	**Analyte**					
TISSUE						
Physical Tests	% Moisture (%)	84.5	49.4	50.7	51.8	50.8
Metals	Mercury (Hg) (mg/kg)	0.0080	0.0054	0.0064	<0.0050	0.0055

L2355763 CONTD....
PAGE 9 of 14
31-DEC-19 15:28 (MT)
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L2355763-36 TISSUE 07-SEP-19 LTPE1905	L2355763-37 TISSUE 07-SEP-19 LTPE1906	L2355763-38 TISSUE 07-SEP-19 LTPE1907	L2355763-39 TISSUE 07-SEP-19 LTPE1908	L2355763-40 TISSUE 07-SEP-19 LTPE1909
Grouping	**Analyte**					
TISSUE						
Physical Tests	% Moisture (%)	52.0	48.9	51.3	46.5	52.1
Metals	Mercury (Hg) (mg/kg)	0.0060	0.0053	0.0069	0.0056	<0.0050

L2355763 CONTD....
PAGE 10 of 14
31-DEC-19 15:28 (MT)
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L2355763-41 TISSUE 07-SEP-19 LTPE1910A	L2355763-42 TISSUE 07-SEP-19 LTPE1910B	L2355763-43 TISSUE 07-SEP-19 LTPE1911	L2355763-44 TISSUE 08-SEP-19 LTRE1912	L2355763-45 TISSUE 08-SEP-19 LTRE1913
Grouping	**Analyte**					
TISSUE						
Physical Tests	% Moisture (%)	50.4	50.3	48.5	56.1	59.2
Metals	Mercury (Hg) (mg/kg)	0.0070	0.0074	<0.0050	0.0054	<0.0050

L2355763 CONTD....
PAGE 11 of 14
31-DEC-19 15:28 (MT)
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample ID / Description / Sampled Date / Sampled Time / Client ID		L2355763-46 TISSUE 08-SEP-19 LTRE1914	L2355763-47 TISSUE 08-SEP-19 LTRE1915	L2355763-48 TISSUE 08-SEP-19 LTRE1916	L2355763-49 TISSUE 08-SEP-19 LTRE1917A	L2355763-50 TISSUE 08-SEP-19 LTRE1917B
Grouping	**Analyte**					
TISSUE						
Physical Tests	% Moisture (%)	58.1	58.7	57.3	59.6	60.6
Metals	Mercury (Hg) (mg/kg)	<0.0050	<0.0050	0.0071	0.0062	<0.0050

L2355763 CONTD....
PAGE 12 of 14
31-DEC-19 15:28 (MT)
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L2355763-51 TISSUE 08-SEP-19 LTRE1918	L2355763-52 TISSUE 07-SEP-19 LTRE1919	L2355763-53 TISSUE 07-SEP-19 LTRE1920	L2355763-54 TISSUE 07-SEP-19 LTRE1921	L2355763-55 TISSUE 07-SEP-19 LTRE1922
Grouping	**Analyte**					
TISSUE						
Physical Tests	% Moisture (%)	59.9	50.2	49.9	50.3	49.2
Metals	Mercury (Hg) (mg/kg)	0.0068	<0.0050	0.0062	0.0060	0.0052

L2355763 CONTD....
PAGE 13 of 14
31-DEC-19 15:28 (MT)
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L2355763-56 TISSUE 07-SEP-19 LTRE1923	L2355763-57 TISSUE 07-SEP-19 LTRE1924	L2355763-58 TISSUE 07-SEP-19 LTRE1925	L2355763-59 TISSUE 07-SEP-19 LTRE1926	
Grouping	**Analyte**					
TISSUE						
Physical Tests	% Moisture (%)	51.8	51.2	50.6	49.8	
Metals	Mercury (Hg) (mg/kg)	0.0067	0.0053	0.0068	<0.0050	

L2355763 CONTD....
PAGE 14 of 14
31-DEC-19 15:28 (MT)
Version: FINAL

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
HG-DRY-CVAA-WP	Tissue	Mercury in Tissue	EPA 200.3/1631E (mod)
Tissue samples undergo hotblock digestion with nitric and hydrochloric acids, in combination with repeated additons of hydrogen peroxide, followed by cold-oxidation using bromine monochloride prior to reduction with stannous chloride, and analysis by CVAAS.			
MOISTURE-IN-WP	Tissue	Percent Moisture	ASTMD2974-87, Method B

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
WP	ALS ENVIRONMENTAL - WINNIPEG, MANITOBA, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

ALS Environmental

Quality Control Report

Workorder: L2355763 Report Date: 31-DEC-19 Page 1 of 2

Client: Ecostem Ltd.
495 - A Madison Street
Winnipeg MB R3J 1J2
Contact: BROCK EPP

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
HG-DRY-CVAA-WP	Tissue							
Batch R4946472								
WG3239326-3 CRM		**DORM-4N**						
Mercury (Hg)			97.4		%		70-130	12-DEC-19
WG3239326-4 DUP		**L2355763-7**						
Mercury (Hg)		<0.0050	<0.0050	RPD-NA	mg/kg	N/A	40	12-DEC-19
WG3239326-2 LCS								
Mercury (Hg)			99.0		%		80-120	12-DEC-19
WG3239326-1 MB								
Mercury (Hg)			<0.0050		mg/kg		0.005	12-DEC-19
Batch R4958096								
WG3240348-3 CRM		**DORM-4N**						
Mercury (Hg)			108.8		%		70-130	31-DEC-19
WG3243681-3 CRM		**DORM-4N**						
Mercury (Hg)			101.4		%		70-130	31-DEC-19
WG3240348-4 DUP		**L2355763-20**						
Mercury (Hg)		<0.0050	<0.0050	RPD-NA	mg/kg	N/A	40	31-DEC-19
WG3243681-4 DUP		**L2355763-22**						
Mercury (Hg)		<0.0050	<0.0050	RPD-NA	mg/kg	N/A	40	31-DEC-19
WG3240348-2 LCS								
Mercury (Hg)			107.0		%		80-120	31-DEC-19
WG3243681-2 LCS								
Mercury (Hg)			91.5		%		80-120	31-DEC-19
WG3240348-1 MB								
Mercury (Hg)			<0.0050		mg/kg		0.005	31-DEC-19
WG3243681-1 MB								
Mercury (Hg)			<0.0050		mg/kg		0.005	31-DEC-19
MOISTURE-IN-WP	Tissue							
Batch R4940625								
WG3240036-1 DUP		**L2355763-3**						
% Moisture		82.9	83.1		%	0.3	20	11-DEC-19
Batch R4942713								
WG3241955-1 DUP		**L2355763-40**						
% Moisture		52.1	51.2		%	1.7	20	12-DEC-19
Batch R4942723								
WG3241966-1 DUP		**L2355763-59**						
% Moisture		49.8	51.2		%	2.7	20	13-DEC-19

Quality Control Report

Workorder: L2355763 Report Date: 31-DEC-19 Page 2 of 2

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

All test results reported with this submission were conducted within ALS recommended hold times.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

APPENDIX 3:
WET WEIGHT MERCURY CONCENTRATIONS IN BLUEBERRY

6.1 Introduction

In spring 2019, the toxicologist conducting the Human Health Risk Assessment (HHRA) for the Keeyask Mercury and Human Implementation Working Group requested to receive weight wet mercury concentrations for blueberries. Up to that time, blueberry mercury concentrations had only been provided on a dry weight basis for the following reasons:

1. Based on this study's objectives, the mercury concentrations relevant for comparison purposes reported in the literature are all provided on a dry weight basis (see ECOSTEM 2019).
2. Wet weight concentrations create standardization challenges for interpretation as the water content of blueberries can vary considerably (see below).
3. Dry weight concentrations maintain consistency with the approach that has been in place since 2011 (which included lab-measured dry weight concentrations obtained from samples collected in 2012 and 2013).
4. There is a field limitation to collecting sufficient tissue for the lab to provide both wet and dry weight mercury concentrations (see below).

Mercury concentrations in blueberries are standardized by dry weight lab-measurements. This study requires standardized concentrations for comparability between samples, sample years and the results from other relevant studies. It is particularly important for this study since its goal is to test for Project effects on mercury concentrations. Wet weight concentrations create standardization challenges for interpretation as the water content of blueberries can vary considerably. Examples of factors contributing to this variability include when they are picked during the fruiting period, or the proportion of the berries that are not at optimal ripeness. Also, people may consume the plant tissues after they lose a portion of their water content (e.g., blueberries dry out on the counter or in a freezer).

An additional reason for using standardized (i.e., dry weight) concentrations is that it is extremely unlikely that people from the communities will consume berries from the exact locations where this study has collected samples, due to their remote locations. Reporting standardized concentrations facilitates more reliable generalizations regarding concentrations throughout the Project area.

There are two reasons why the laboratory cannot measure both dry weight and wet weight mercury concentrations for every blueberry sample: two separate lab analyses are required; and, the quantity of berries within a sample location is limited.

The lab analysis limitation arises because the minimum sample weight for the two separate lab tests is approximately double that required for the dry weight test. In other words, the minimum amount of plant tissue to be collected in the field at each location is doubled.

There are field limitations to gathering sufficient tissue to perform two separate tests. First, in some years, the total quantity of berries is low due to growing conditions. Second, since the tissue samples are collected while staff are in the area conducting other terrestrial monitoring, the quantity of berries remaining on plants can be limited (due to animal browsing or berries falling on the ground). Finally, because tissue is collected from the same plants in successive years, it is preferable to minimize the amount of tissue removed from the site to avoid introducing a confounding factor when testing for Project effects on mercury concentrations (e.g., a proportion of the nutrients from berries that are not removed by animals are recycled back into the plants).

6.2 METHODS

6.2.1 APPROACH

To support the HHRA data request, this report provides both wet dry weight and wet weight mercury concentrations for blueberries.

For samples that have a sufficient quantity of blueberries to complete two lab tests, there are two possible approaches to providing both the dry weight concentrations needed for this study and the wet weight concentrations requested for the HHRA. These approaches are:

1. The lab measures dry weight concentration in one portion of the sample and the wet weight concentration in another portion.
2. The lab measures dry weight concentration in a portion of the sample. A standard equation then uses percent moisture content to convert dry weight concentrations into wet weight concentrations.

This report adopted the second approach for several reasons. First, it was feasible to collect sufficient blueberry material for two lab tests at some, but not all, of the sample locations (see above). Second, it is an acceptable practice for a HHRA to convert lab-measured dry weight concentrations into wet weight concentrations using a standard equation (e.g., U.S. EPA 2018: Section 9.4). Finally, this approach maintains consistency with the approach from previous sample years.

This appendix converts dry weight concentrations to wet weight using Equation 1, which was recommended by the US EPA Exposure Factors Handbook (2018; Equation 9-2) and the HHRA toxicilogist (R. Wilson, pers. comm 2019):

Equation 1:

$$C_{ww} = C_{dw}\left[\frac{100 - W}{100}\right]$$

where: C_{ww} = wet-weight concentration, C_{dw} = dry-weight concentration, and, W = percent moisture content.

The two variables in Equation 1 are dry weight concentration and percent moisture content. Lab-measured dry weight concentrations were available for every sample. Examples of potential sources for percent moisture content values are a lab-measured percent moisture content on another portion of the same sample used for the mercury extraction, a value obtained from other data from the Project area, or a value obtained from other sources such as the literature value or the value provided by the US EPA HHRA Exposure Factors Handbook (U.S. EPA 2018). Depending on the sample year, percent moisture content was either measured or estimated from values obtained by this study and by Project environmental assessment studies.

6.2.2 PERCENT MOISTURE CONTENT

Blueberry samples were collected for mercury analysis in 2012, 2013, 2017, 2018 and 2019. The 2012 and 2013 samples were opportunistically collected in the Project area while conducting other unrelated monitoring fieldwork. The 2017, 2018 and 2019 samples were collected by this study to test for Project effects on mercury concentrations. Results from the 2012 and 2013 samples were included because they provide additional relevant data.

Percent moisture content values for use in Equation 1 were either lab-measured or estimated for all of the blueberry samples collected in each of the sample years. Percent moisture content values for use in Equation 1 were obtained for each of the years as follows:

- 2012, 2013 and 2019: Lab-measured using an accredited method;
- 2017: Estimated by adjusting the percent moisture content obtained during the drying of the sample for the mercury concentration test by a correction constant; and,
- 2018: A constant estimated from the results from the other years. Several versions of the constant were produced to reflect various degrees of caution, and for sensitivity analysis.

In 2012, 2013 and 2019, it was possible to gather sufficient blueberries from each location to obtain both a lab-measured dry weight mercury concentration, and percent moisture content using an accredited method (ASTM D 2974-87, Method B).

In 2017, it was not feasible to collect sufficient material at all locations to perform two separate lab tests. In the event that there was a future desire to compare mean percent moisture content values from this study with literature reported values, percent moisture content was lab-measured during the mercury extraction procedure using a non-accredited method.

In 2018 there was no attempt to gather sufficient blueberry tissue for two lab tests for several reasons. First, it was clear that there were both field limitations on collecting enough material to do this and study design concerns (i.e., introducing a confounding factor). Second, it appeared that sufficient data were already available to estimate percent moisture content or for comparative purposes. Third, up to this time, there had been no indication that moisture contents or wet weight concentrations would be needed for other Project studies.

Following the HHRA request in spring 2019 for blueberry wet weight concentrations, attempts were made to collect a quantity of blueberries that would be sufficient to lab-measure both dry weight mercury concentration and percent moisture content for each sample. Fortunately, sufficient tissue was obtained in 2019 as growing conditions were the best since 2017.

Lab-measured percent moisture contents ranged from 79.6% to 86.0% in 2012, and from 80.2% to 85.4% in the 2013 samples.

Lab-measured percent moisture contents in the 2019 samples ranged from 71.4% to 86.6%. The 71.4% minimum was deemed to be a lab handling or analytical error because, in relative terms, it was: (i) more than 10% below the lowest values obtained in the two other years when moisture content was measured using an accredited method (see previous paragraph); and, (ii) 11% lower than the second lowest value in 2019. For this reason, the lab reported value of 71.4% outlier value was replaced with the minimum value obtained from the other three years (i.e., 79.6%; Table 6-3).

Mean (arithmetic mean) lab-measured percent moisture contents for the 2012, 2013 and 2019 samples ranged from 83.1% to 83.9% (Table 6-3). All of these values were very close to the 84.21% value provided for blueberries in the US EPA Exposure Factors Handbook (U.S. EPA 2018; Table 9-53).

Table 6-3: Lab-measured percentage water content for blueberry samples collected in 2012, 2013 and 2019

Year	Number of Samples	Measured Moisture Content (%)	
		Minimum	Mean
2012	11	79.6	83.1
2013	5	80.2	83.2
2019	29	80.3[1]	83.9[1]
All	**67**	**79.6**	**83.4[2]**
2017 Adjustment			
2017	27		80.6
2017	Difference from multi-year mean		-2.8

Notes: [1] Excludes one outlier thought to be the result of a lab error in sample handling or processing.
[2] Mean of year means.

For 2017, the lab-measured percent moisture content values were adjusted upward by a constant to correct for the bias created by using a lower drying temperature. The accredited procedure used to extract total mercury from the blueberry samples began by drying the sample at 60° C. The accredited method for measuring percent moisture content dries the sample at 105° C. While the difference in drying temperatures is relatively large, studies that have examined the degree of bias (Kelly 2005; Matthews 2010) suggest that the percent moisture content obtained from drying at 60° C is expected to be close to that obtained at 105° C.

The constant that was added to the 2017 percent moisture values was the estimated degree of downward bias produced by drying the sample at 60° C rather than 105° C. The degree of bias was estimated as the difference between the mean percent moisture content in the 2017 samples compared with the mean percent moisture content across the 2012, 2013 and 2019 sample years.

The mean percent moisture content in the 2017 samples was 2.8% lower than in the other years for which the lab used the accredited percent moisture content method (Table 6-3). This compared favorably with the ranges reported by others (Matthews 2010; Kelly 2005).

For the 2018 samples, the following three versions of estimated moisture content were produced to reflect various degrees of caution, and for sensitivity analysis:

1. A very cautious version, which used the minimum value from all of the 2012, 2013, 2017 and 2019 samples (i.e., 79.6%). Although unlikely, it was possible that one to a few of the 2018 samples had a lower moisture than this. It was thought to be extremely unlikely that more than 10% of the 2018 samples had a lower content since 96% of the 45 samples had contents higher than 80%. Even if 10% of the samples had moisture contents lower than 79.6%, mean moisture content for the year would still be higher than the minimum;
2. The 25^{th} percentile value from the 2012, 2013, 2017 and 2019 samples. This approach was analogous to using 0.75 DL for mercury concentrations that were below the DL; and,
3. The multi-year mean obtained from the 2012, 2013 and 2019 samples (i.e., 83.4%; Table 6-3). The mean is the statistic typically reported in the general scientific literature (this may not be the case for HHRA studies). This approach was less cautious than the preceding version.

6.2.3 OTHER ASSUMPTIONS FOR WET WEIGHT CONCENTRATIONS

Six versions of wet weight concentrations were calculated for the 2017 to 2019 samples. The purpose of the versions was to reflect various degrees of caution, and to facilitate sensitivity analysis. Table 6-3 provides the assumptions used for each version. Version 1 was the most cautious while Version 6 was the least cautious.

Appendix 3 provides dry and wet weight concentrations for all blueberry samples collected to date using the methods described in this section.

Table 6-4: Assumptions used to calculate the six versions of wet weight concentrations

Version	Mercury Concentration for Samples Below the DL	Percent Moisture Content for Samples with No Lab Measurement
1	Equal to DL	Minimum from all of the years with lab-measured contents
2	0.75 DL	Minimum from all of the years with lab-measured contents
3	Equal to DL	25th percentile from all of the years with lab-measured contents
4	0.75 DL	25th percentile from all of the years with lab-measured contents
5	Equal to DL	Multi-year mean from Table 6-3
6	0.75 DL	Multi-year mean from Table 6-3

6.3 RESULTS

The maximum dry weight mercury concentration in 2017 and in 2018 was 5.00 ng/g (i.e., all samples below the DL), and 8.00 ng/g 2019 (Table 6-5). Maximum dry weight mercury concentrations in each of 2012 and 2013 was 10.00, which was the DL for those years.

Table 6-5 provides mean annual dry weight mercury concentrations for the 2017 to 2019 sample years. Mean concentrations were the same for 2017 and 2018 but 2019 was higher (Table 6-5) because 2019 was the only year with at least one concentration above the DL. The table also shows two variations of the mean dry weight concentration to reflect different assumptions for concentrations below the DL: either the DL or 0.75 DL. These illustrate the average effect on the versions of the wet weight concentration estimates (Table 6-4).

Table 6-5: Dry weight mercury concentration results

Parameter	Mercury Concentration (ng/g)		
	2017	2018	2019
Number of samples	27	31	29
Maximum concentration	5.00	5.00	8.00[1]
Mean concentration[2]. For samples with concentration below the DL, based on using:			
DL	5.00	5.00	5.18
0.75 DL	3.75	3.75	4.02

Notes: [1] Only one other sample had a Mercury concentration above the DL. Mean equals the maximum for 2017 and 2018 because all concentrations were below the DL of 5.00 ng/g). [2] Two samples in 2019 were above the DL.

Maximum wet weight concentrations in the 2017 to 2019 samples ranged from 1.18 ng/g to 1.24 ng/g using the DL for samples with mercury concentrations below the DL (Table 6-6). Using 0.75 DL reduced the bottom of this range from 1.18 ng/g to 0.89 ng/g.

Maximum wet weight concentrations in the 2017 to 2019 samples ranged from 0.83 ng/g to 1.18 ng/g using the DL for samples with mercury concentrations below the DL (Table 6-6). Using 0.75 DL reduced the range of concentrations to 0.63 ng/g to 0.89 ng/g.

The mean and the maximum wet weight concentrations for the 2018 samples were identical because all dry weight concentrations were below the DL and the same percent moisture content was assumed for every sample.

Table 6-7 provides data for a sensitivity analysis of the various moisture content assumptions as well as using either the DL or 0.75 DL for samples with concentration below the DL (which was all of the 2018 samples). On this basis, both the maximum and mean estimated wet weight mercury concentration ranged from 0.623 ng/g to 1.180 ng/g for the 2018 samples.

Appendix 3: Table 6-8 provides wet weight concentrations for each sample by degree of caution (i.e., Version number).

Table 6-6: Maximum and mean wet weight mercury concentrations for blueberry samples collected in 2017, 2018 and 2019

Calculation Approach[1]	Mercury Concentration (ng/g)		
	2017	2018[2]	2019
Maximum concentration. For samples with concentration below the DL, based on using:			
DL	1.18	1.18	1.24
0.75 DL	0.89	0.89	1.24
Mean concentration. For samples with concentration below the DL, based on using:			
DL	0.83	1.18	0.84
0.75 DL	0.63	0.89	0.65

Notes: [1] See Section **Error! Reference source not found.** for approaches. [2] Calculation uses minimum percent moisture content.

Table 6-7: Maximum and mean[1] wet weight mercury concentrations for the 2018 blueberry samples using the six calculation versions provided for sensitivity analysis

Version[1]	Mercury Concentration (ng/g)
Version 1	1.180
Version 2	0.885
Version 3	0.895
Version 4	0.671
Version 5	0.830
Version 6	0.623

Notes: [1] Maximum and mean are identical as a single moisture content used for every sample.
[2] See Section 6.2.3 for methods.

6.4 DETAILED TABLES

Table 6-8: Dry and wet weight mercury concentrations for blueberry samples collected in 2012, 2013, 2017, 2018 and 2019

Year	Percent Moisture		Mercury Concentration (ng/g unless otherwise stated)								
			Dry Weight			Estimated Wet Weight by Version					
	Measured	Adjusted or Assumed	Lab Result (mg/kg)	Result or DL if Below DL	Result or 0.75 DL if Below DL	1	2	3	4	5	6
2019	71.4	79.6	<0.0050	5.0	3.8	1.02	0.77	1.02	0.77	1.02	0.77
2019	80.3	80.3	<0.0050	5.0	3.8	0.99	0.74	0.99	0.74	0.99	0.74
2019	80.5	80.5	<0.0050	5.0	3.8	0.98	0.73	0.98	0.73	0.98	0.73
2019	80.6	80.6	<0.0050	5.0	3.8	0.97	0.73	0.97	0.73	0.97	0.73
2019	80.9	80.9	<0.0050	5.0	3.8	0.96	0.72	0.96	0.72	0.96	0.72
2019	80.9	80.9	<0.0050	5.0	3.8	0.96	0.72	0.96	0.72	0.96	0.72
2019	82.1	82.1	<0.0050	5.0	3.8	0.90	0.67	0.90	0.67	0.90	0.67
2019	82.9	82.9	<0.0050	5.0	3.8	0.86	0.64	0.86	0.64	0.86	0.64
2019	82.9	82.9	<0.0050	5.0	3.8	0.86	0.64	0.86	0.64	0.86	0.64
2019	83.0	83.0	<0.0050	5.0	3.8	0.85	0.64	0.85	0.64	0.85	0.64
2019	83.2	83.2	<0.0050	5.0	3.8	0.84	0.63	0.84	0.63	0.84	0.63
2019	83.7	83.7	<0.0050	5.0	3.8	0.82	0.61	0.82	0.61	0.82	0.61
2019	83.9	83.9	<0.0050	5.0	3.8	0.81	0.60	0.81	0.60	0.81	0.60
2019	84.4	84.4	<0.0050	5.0	3.8	0.78	0.59	0.78	0.59	0.78	0.59
2019	84.4	84.4	<0.0050	5.0	3.8	0.78	0.59	0.78	0.59	0.78	0.59
2019	84.8	84.8	<0.0050	5.0	3.8	0.76	0.57	0.76	0.57	0.76	0.57
2019	84.9	84.9	<0.0050	5.0	3.8	0.76	0.57	0.76	0.57	0.76	0.57
2019	84.9	84.9	<0.0050	5.0	3.8	0.76	0.57	0.76	0.57	0.76	0.57
2019	85.0	85.0	<0.0050	5.0	3.8	0.75	0.56	0.75	0.56	0.75	0.56
2019	85.2	85.2	<0.0050	5.0	3.8	0.74	0.56	0.74	0.56	0.74	0.56
2019	85.2	85.2	<0.0050	5.0	3.8	0.74	0.56	0.74	0.56	0.74	0.56
2019	85.2	85.2	<0.0050	5.0	3.8	0.74	0.56	0.74	0.56	0.74	0.56
2019	85.6	85.6	<0.0050	5.0	3.8	0.72	0.54	0.72	0.54	0.72	0.54
2019	85.9	85.9	<0.0050	5.0	3.8	0.71	0.53	0.71	0.53	0.71	0.53
2019	86.2	86.2	<0.0050	5.0	3.8	0.69	0.52	0.69	0.52	0.69	0.52
2019	86.4	86.4	<0.0050	5.0	3.8	0.68	0.51	0.68	0.51	0.68	0.51
2019	86.6	86.6	<0.0050	5.0	3.8	0.67	0.50	0.67	0.50	0.67	0.50
2019	86.0	86.0	0.0072	7.2	7.2	1.01	1.01	1.01	1.01	1.01	1.01
2019	84.5	84.5	0.0080	8.0	8.0	1.24	1.24	1.24	1.24	1.24	1.24
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62

Year	Percent Moisture		Mercury Concentration (ng/g unless otherwise stated)								
			Dry Weight			Estimated Wet Weight by Version					
	Measured	Adjusted or Assumed	Lab Result (mg/kg)	Result or DL if Below DL	Result or 0.75 DL if Below DL	1	2	3	4	5	6
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2018	-	76.4	<0.0050	5.0	3.8	1.18	0.89	0.90	0.67	0.83	0.62
2017	73.6	76.4	<0.0050	5.0	3.8	1.18	0.89	1.18	0.89	1.18	0.89
2017	74.5	77.3	<0.0050	5.0	3.8	1.14	0.85	1.14	0.85	1.14	0.85
2017	75.8	78.6	<0.0050	5.0	3.8	1.07	0.80	1.07	0.80	1.07	0.80
2017	75.9	78.7	<0.0050	5.0	3.8	1.07	0.80	1.07	0.80	1.07	0.80
2017	76.2	79.0	<0.0050	5.0	3.8	1.05	0.79	1.05	0.79	1.05	0.79
2017	76.2	79.0	<0.0050	5.0	3.8	1.05	0.79	1.05	0.79	1.05	0.79
2017	76.4	79.2	<0.0050	5.0	3.8	1.04	0.78	1.04	0.78	1.04	0.78
2017	77.4	80.2	<0.0050	5.0	3.8	0.99	0.74	0.99	0.74	0.99	0.74
2017	77.8	80.6	<0.0050	5.0	3.8	0.97	0.73	0.97	0.73	0.97	0.73
2017	78.3	81.1	<0.0050	5.0	3.8	0.95	0.71	0.95	0.71	0.95	0.71
2017	78.5	81.3	<0.0050	5.0	3.8	0.94	0.70	0.94	0.70	0.94	0.70
2017	79.1	81.9	<0.0050	5.0	3.8	0.91	0.68	0.91	0.68	0.91	0.68
2017	79.7	82.5	<0.0050	5.0	3.8	0.88	0.66	0.88	0.66	0.88	0.66
2017	79.9	82.7	<0.0050	5.0	3.8	0.87	0.65	0.87	0.65	0.87	0.65
2017	80.3	83.1	<0.0050	5.0	3.8	0.85	0.63	0.85	0.63	0.85	0.63
2017	80.4	83.2	<0.0050	5.0	3.8	0.84	0.63	0.84	0.63	0.84	0.63
2017	81.4	84.2	<0.0050	5.0	3.8	0.79	0.59	0.79	0.59	0.79	0.59
2017	81.6	84.4	<0.0050	5.0	3.8	0.78	0.59	0.78	0.59	0.78	0.59
2017	81.8	84.6	<0.0050	5.0	3.8	0.77	0.58	0.77	0.58	0.77	0.58
2017	81.9	84.7	<0.0050	5.0	3.8	0.77	0.57	0.77	0.57	0.77	0.57
2017	82.4	85.2	<0.0050	5.0	3.8	0.74	0.56	0.74	0.56	0.74	0.56
2017	82.5	85.3	<0.0050	5.0	3.8	0.74	0.55	0.74	0.55	0.74	0.55
2017	82.8	85.6	<0.0050	5.0	3.8	0.72	0.54	0.72	0.54	0.72	0.54
2017	85.6	88.4	<0.0050	5.0	3.8	0.58	0.44	0.58	0.44	0.58	0.44
2017	88.4	91.2	<0.0050	5.0	3.8	0.44	0.33	0.44	0.33	0.44	0.33
2017	90.4	93.2	<0.0050	5.0	3.8	0.34	0.26	0.34	0.26	0.34	0.26
2017	97.4	97.6	<0.0050	5.0	3.8	0.12	0.09	0.12	0.09	0.12	0.09
2013	80.2	80.2	<0.0100	10.0	7.5	1.98	1.49	1.98	1.49	1.98	1.49
2013	82.1	82.1	<0.0100	10.0	7.5	1.79	1.34	1.79	1.34	1.79	1.34
2013	84.0	84.0	<0.0100	10.0	7.5	1.60	1.20	1.60	1.20	1.60	1.20
2013	84.3	84.3	<0.0100	10.0	7.5	1.57	1.18	1.57	1.18	1.57	1.18
2013	85.4	85.4	<0.0100	10.0	7.5	1.46	1.10	1.46	1.10	1.46	1.10
2012	79.6	79.6	<0.0100	10.0	7.5	2.04	1.53	2.04	1.53	2.04	1.53
2012	80.7	80.7	<0.0100	10.0	7.5	1.93	1.45	1.93	1.45	1.93	1.45
2012	82.4	82.4	<0.0100	10.0	7.5	1.76	1.32	1.76	1.32	1.76	1.32
2012	83.1	83.1	<0.0100	10.0	7.5	1.69	1.27	1.69	1.27	1.69	1.27
2012	83.2	83.2	<0.0100	10.0	7.5	1.68	1.26	1.68	1.26	1.68	1.26
2012	83.3	83.3	<0.0100	10.0	7.5	1.67	1.25	1.67	1.25	1.67	1.25
2012	83.4	83.4	<0.0100	10.0	7.5	1.66	1.25	1.66	1.25	1.66	1.25
2012	83.5	83.5	<0.0100	10.0	7.5	1.65	1.24	1.65	1.24	1.65	1.24
2012	83.9	83.9	<0.0100	10.0	7.5	1.61	1.21	1.61	1.21	1.61	1.21
2012	85.5	85.5	<0.0100	10.0	7.5	1.45	1.09	1.45	1.09	1.45	1.09
2012	86.0	86.0	<0.0100	10.0	7.5	1.40	1.05	1.40	1.05	1.40	1.05

6.5 LITERATURE CITED

American Society for Testing and Materials (ASTM). 1993. ASTM D 2974-87. Standard test methods for moisture, ash, and organic matter of peat and other organic soils. Re-printed from the Annual Book of ASTM Standards, Copyright ASTM. p. 31 – 33.

Kelly, B. 2005. Oven-Drying Characteristics of Soils of Different Origins. Drying Tech. 23:1141-1149.

R. Wilson, pers. comm. 2019. Email on May 24, 2019.

Matthews, S. 2010. Effect of drying temperature on fuel moisture content measurements. International Journal of Wildland Fire 19: 800–802.

U.S. EPA. 2018. Update for Chapter 9 of the Exposure Factors Handbook: Intake of Fruits and Vegetables. U.S. Environmental Protection Agency, National Center for Environmental Assessment, Office of Research and Development, Washington, DC 20460.