Terrestrial Environmental Effects Monitoring

Forest Health Monitoring Program

2018 Procedures Manual

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August 2018

PREFACE

Wood Buffalo Environmental Association
Terrestrial Environmental Effects Monitoring
Forest Health Monitoring Program

2018 Procedures Manual

This version of the WBEA TEEM Procedures Manual is intended to provide guidance to personnel tasked with completing the 2018 Forest Health Monitoring program campaign. Personnel must be familiar with all procedures described herein, being sure to be fully prepared to apply the procedures required at each site.

Since the first version of the Procedures Manual (2011), the region has experienced two major forest fires: the 2011 Richardson Fire and the 2016 Horse River Fire. Monitoring plots at sites affected by the Richardson Fire were recovered and included in the 2011-2013 Forest Health Monitoring Program campaign and based on the retention of these sites for that campaign, sites affected by the Horse River Fire have also been retained. All Forest Health Monitoring Program sites, both unaffected and those affected by wildfire, are to be included in the 2018 monitoring campaign.

While TEEM personnel participate in and support the air quality and deposition monitoring programs, the majority are the responsibility of the Ambient Air Technical Committee of WBEA, and the methods associated with such programs are not included in this manual.

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TEEM Forest Health Monitoring Program procedures have been developed to standardize data and sample collection.

Procedures #6, #27, #31, #36, #37 and #39 are not applicable in the 2018 monitoring campaign and have been removed from the 2018 TEEM Procedures Manual (this version). One new procedure (#40) has been added to the program for 2018. The procedures, and the TEEM data forms that are associated with specific procedures, are listed below.

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1.0 INTRODUCTION

The Wood Buffalo Environmental Association's Forest Health Monitoring Program, overseen by the Terrestrial Environmental Effects Monitoring (TEEM) committee, integrates soil, vegetation, air quality and deposition monitoring at locations selected for their sensitivity and/or exposure to anthropogenic air emissions. This program began in the mid-1990s, in response to regulatory requirements associated with Syncrude's 1993 Mildred Lake approval renewal application. While the genesis of the program resulted from a process specific to Syncrude, the TEEM program was constituted as a multi-stakeholder initiative.

Based on the scientific understanding at the time, jack pine forests growing on sandy soils were selected as the ecological receptor most sensitive to acidic deposition in the region. These soils have relatively low acid buffering capacity and were expected to react measurably to acidic deposition. The premise upon which the jack pine monitoring program has been developed is that exposure to air emissions, and the deposition that results, causes a cascade of effects:

1. Changes in the chemical properties of the soil occur first. These changes may be in the availability of nutrients, the mobilization of aluminum, or both;
2. Changes in vegetation in response to altered soil chemistry. This is expected to first be observed in altered distribution of nutrients and other elements in plant tissues, and later in changes in tree growth; and
3. Altered species composition, as changes in soil chemistry and effects on vegetative growth create new competitive advantages and disadvantages among species at the site.

The Forest Health Monitoring Program was developed on the basis of the National Acid Rain Network Early Warning System (ARNEWS), with the majority of the procedures based on the ARNEWS manual (D'Eon et al., 1994). AGRA Earth & Environmental (1999) presented a summary of the ARNEWS protocols as applied to the jack pine monitoring program. Modifications to some of the measurements and sampling procedures have occurred over the years in response to data acquired, and as scientific knowledge and laboratory methods improved.

Jack pine trees at a stand edge facing towards the main emissions sources across an open wetland are expected to be more exposed to air contaminants. Edge monitoring sites are expected to provide an early indication of environmental change relating to exposure to and/or deposition of substances in the air. A number of monitoring sites at these exposed stand edges have been established for sampling and measurement of key parameters relating to air quality, deposition and ecological effects.

Linking soil and vegetation responses to air emissions and deposition requires measurement of air quality and deposition levels. A number of the original monitoring sites were equipped with towers onto which passive monitoring devices for SO_2, NO_x, and O_3 were deployed above the tree canopy. Air quality and deposition monitoring has since expanded to include a greater number of sites, and to incorporate a greater diversity of monitoring instruments and devices.

These complementary programs are operated by WBEA according to procedures that are outside of the Forest Health Monitoring Program.

Personnel must understand the overall program and their part in it, paying particular attention to the interfaces with those executing other program elements. When in doubt about any aspect of the program or the procedures, consultation with the TEEM Program Manager is required.

Because of the longevity of the program (>25 years), and the interval between sampling in program components, it is certain that personnel tasked with field activities, laboratories contracted for sample analyses, and the membership of the TEEM committee itself, will change over the course of the program. Changes in the personnel involved represents a risk to the program, as the potential for errors and omissions increases, and variations in expertise are expected. Adherence to the procedures presented in this manual are required to minimize the errors, omissions, subjectivity, and variability in data such that the integrity of the monitoring program is preserved, and conclusions may be reliably and confidently drawn from the data.

2.0 SAMPLE HANDLING

Preservation of sample integrity is critical, as confidence in the results of laboratory analyses may be significantly decreased if samples are suspected of contamination or degradation. Because of the remote locations at which samples are obtained, and the potential lengthy period required to transport samples from the field to the laboratory, care and attention to proper handling from sampling through to analysis (and archive, if appropriate) is required to maximize integrity of collected samples.

2.1 Selection of Laboratoy(ies)

Because of the number of samples acquired, the need for specific analyses, and the schedule by which the laboratory results will be required, selection of a laboratory (or laboratories) should be made well in advance of the field program. Laboratory selection should include consideration of the capabilities of the laboratory including use of modern equipment and procedures yielding detection limits appropriate for the analyses, and the implementation of quality assurance and quality control programs. The laboratory(ies) selected should be made aware of all analyses required well in advance of the field program, such that when the samples arrive, laboratory staff are prepared to properly receive them and initiate the analyses or place the samples in appropriate storage.

2.2 Chain-of-Custody

The chain-of-custody process ensures that a sample is in possession of, or has been secured by, a responsible person at all times. A sample is under custody of a responsible individual if:

- it is in possession of the individual;
- it is in view of the individual, after being in the individual's possession; or
- the individual placed it in a designated secure area.

The sample transfers custody only when a responsible individual relinquishes custody by signing and dating the chain-of-custody form, and the receiving individual accepts custody by signing and dating the form. This process of custody transfer occurs every time the samples are transferred from one party to the next, as the samples move from acquisition in the field to the laboratory, and if appropriate, from the laboratory to the sample archive facility.

As a part of the transfer of sample custody to the laboratory, laboratory personnel are to examine each sample to ensure that sample integrity has been preserved (e.g., sample temperature is appropriate, sample seals are intact, the proper signatures are present, the holding times are appropriate). Should a sample be compromised, a notation on the chain-of-custody form is to be made, and the TEEM Program Manager is to be notified.

Laboratories may provide a chain-of-custody form, and if so, these are acceptable for use in the TEEM Forest Health Monitoring Program. In some cases, standard forms may not be available, and forms created by WBEA may be used.

Chain-of-custody documentation will be examined in the investigation of an apparently anomalous measurement, laboratory analysis or other result. In the absence of a properly executed chain-of-custody process, the apparently anomalous measurement, analysis or result may be discarded, potentially representing an unrecoverable monetary and data cost to the program.

2.3 Sample Labelling

The chain-of-custody form is to be filled out in the field at the time of sample collection, or during the process of storing samples at the end of the field day. Each sample taken is to be labelled according to the requirements for the sample, according to the **SAMPLE LABELLING PROCEDURE (#1)**. Sample names entered into the chain-of-custody form must match the labels applied to the samples.

2.4 Sample Inspection

At the end of each field day, each sample is to be inspected to confirm that:

- the samples are properly and clearly labelled, per **SAMPLE LABELLING PROCEDURE (#1)**;
- that sample containers are properly sealed;
- that sample numbers and information are properly recorded on the relevant TEEM Data Form, if required; and
- that the chain-of-custody form is fully and properly completed for each sample,

Corrective actions, such as transferring a sample from a compromised sample container to a new, clean and properly labelled container, or transferring information from a torn, stained and potentially illegible chain-of-custody form to a new form, are to be taken as necessary at the end of each field day. Proper tools must be used to transfer samples, and transfers must be conducted in an environment that will not lead to sample contamination.

2.5 Sample Storage & Shipping

A storage and shipping plan is to be prepared in advance of the initiation of sample collection. This plan is to be based on the shipping services available in Fort McMurray, and the timetables associated with each service. Consideration of the delivery time at the laboratory(ies) is required, as is coordination with personnel at the laboratory(ies) receiving the samples, to ensure that samples do not sit in a receiving dock or warehouse for an unacceptable period of time.

It may be necessary to store samples for short periods (a few hours, overnight, a few days) before they can be shipped to the appropriate laboratory(ies). Proper storage is required to preserve sample integrity, from initial sample acquisition in the field through to ultimate storage in the TEEM sample archive facility.

Packaging is dependent on the type of shipping service used, particularly in the instance of shipping by air. Advance knowledge of shipping requirements and restrictions is necessary to properly plan, schedule, package and deliver sample containers to the shipping depot.

The **SAMPLE STORAGE & SHIPPING PROCEDURE (#2)** describes the storage requirements for the samples collected within the Forest Health Monitoring Program, from the time of field collection through to sample archival. Samples are generally held in an interim storage facility for a few days, after which they are packaged and shipped to the laboratory(ies). The receiving laboratory(ies) are to be notified upon shipment so that they are properly prepared to receive the samples. Each laboratory is to be instructed to contact the shipper if the samples do not arrive on the expected date. In this event, the shipper is to immediately notify the TEEM Program Manager, and contact with the shipping company made to initiate a trace on the samples. Lengthy delays in shipment may compromise the entire sample set.

3.0 JACK PINE MONITORING SITE SELECTION & ESTABLISHMENT

3.1 Jack Pine Monitoring Site Selection Criteria

From the inception of the Forest Health Monitoring Program in 1996 to the present, an increasing focus has been applied to the criteria used in the selection of monitoring sites. The initial set of stand interior monitoring sites was selected from a pool of candidate sites, with each site in the pool being having met the criteria in place at the time (BOVAR Environmental et al., 1997). The location of the stand within a larger forest landscape and away from the influence of natural and anthropogenic edges, and the size of the stand itself, were criteria adopted from the ARNEWS program (D'Eon et al., 1994). Based on these criteria, the first 10 jack pine stand interior monitoring sites were selected, and monitoring plots were established at each of these sites. The selection of stand interior sites in 2001 (AMEC Earth & Environmental Limited, 2001) and in 2004 (CE Jones and Associates et al., 2006) was guided by these criteria, leading to additional sites being incorporated into the Forest Health Monitoring Program.

The emphasis on the selection of ecologically analogous sites was increased in the site evaluation process leading up to the 2011 monitoring program. The selection of sites that are as analogous as the environment in the region allows reduces variability within the measured parameters, increasing the ability to detect responses to deposition and exposure to air emissions. The vegetation community is very sensitive to water and nutrient availability and therefore, it is the vegetation community that defines the ecological analogue types (Table 1). The Type 3 jack pine ecological analogue has been selected as the primary jack pine stand type in which the long-term monitoring plots (stand interior and stand edge) will be established and monitored. Type 3 characteristics are highlighted in green shading. Blue shading in the Characteristic and Common Species sections of Table 1 indicate a much lower or higher presence of characteristic and common species than are present in Type 3 analogue types. Rose-shaded cells highlight the presence, and in some cases an abundance, of species that indicate elevated water availability and/or nutrient availability, relative to the xeric, nutrient poor Type 3 jack pine stand type desired for the program. It is recognized that there will be variability around the values associated with species cover in Type 3 sites, but that in order to be considered for inclusion in the program the variability is to be minimal, not extending into the ranges defined by the values shaded in blue and red (i.e., not so large as to cause the site to be reclassified into another ecological analogue type).

Trees growing at an exposed stand edge facing an emissions source may be exposed to substances in the ambient air to a greater extent than are trees growing the interior of a stand (Beier, 1991; Draaijers et al., 1988; Hasselrot and Grennfelt, 1987; Lester et al., 1986; Weathers et al., 2001). The measurement of selected tree morphological characteristics and the sampling of plant tissues at the exposed edge of a forest stand provides an opportunity to detect forest responses to changes in air quality earlier than would be observed in vegetation at the stand interior. Monitoring at stand edges was initially examined in the early 2000's (AMEC Earth & Environmental Limited, 2000), with a network of stand edge monitoring sites being established in the 2011 to 2013 period.

Table 1: Vegetation Characteristics of Jack Pine Ecological Analogue Types

Species	Ecological Analogue Type									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Characteristic Species										
Pinus banksiana (overstory)	38.0	34.0	32.2	49.0	38.0	31.5	32.0	31.0	22.0	35.0
Pinus banksiana (seedlings)	2.1	0.1	0.1	0.5	1.5	0.1	0.5	0.5	0.5	0.1
Arctostaphylos uva-ursi	10.8	9.0	3.5	9.5	1.7	2.7	0.7	3.2	1.0	14.0
Vaccinium myrtilloides	6.0	6.1	3.4	4.3	4.3	11.8	2.9	16.0	19.0	7.0
Cladina mitis	39.0	14.5	52.5	24.7	37.4	28.5	61.6	49.0	29.0	4.7
Total Characteristic Species	*95.9*	*63.7*	*91.7*	*88.0*	*82.9*	*74.6*	*97.7*	*99.7*	*71.5*	*60.8*
Differential Species										
Alnus crispa		0.1	0.1	7.0		3.8			3.0	
Amelanchier alnifolia	0.6				0.1					0.1
Anemone mulifida	0.4									
Betula papyrifera				0.5						
Cornus canadensis	0.5	2.7	0.1	0.5				0.5		3.2
Elymus innovatus	0.1		0.1	0.3	2.4		0.2	0.8	2.0	1.3
Ledum groenlandicum		1.0				3.0		0.1		
Linnaea borealis	1.2	2.2		0.4		0.5		0.5	8.0	2.4
Lycopodium complanatum	0.5	1.8		3.5		6.0				
Oryzopsis asperifolium				0.2	0.3					
Oryzopsis pungens	0.2	0.1	0.2	0.5	0.3	0.1	0.3	2.2	0.5	0.1
Picea glauca									0.5	
Picea mariana		1.2						0.1		
Poulus tremuloides	0.1			0.3					2.0	
Salix spp.						0.1				
Shepherdia canadensis		0.1	0.3							3.0
Vaccinium vitis-idaea	2.7	8.0	2.3	2.5	0.1	7.2	1.1	3.0	7.0	5.0
Pleurozium schreberia	11.6	18.9	9.4	3.4	37.2		0.1	2.8	9.0	11.0
Cladonia gracilis				0.2	1.5	13.5		1.8	0.5	
Dicranum polysetum	1.5	2.7	2.0	4.1	5.3	0.1			0.5	
Total Differential Species	*19.3*	*38.8*	*14.7*	*23.4*	*47.2*	*34.3*	*1.7*	*12.0*	*33.1*	*26.1*
Common Species										
Maianthemum canadense	0.5	2.8	2.5	2.0	4.0	0.5	1.9	3.3	0.5	
Rosa acicularis	0.7	0.3	0.5	0.1	0.1	0.2	0.1	0.5	0.5	0.1
Polytrichum junbiperinum			0.4	0.6	0.1	0.4	0.1			
Cladina stellaris	1.3	0.1	5.2	7.0	2.0	0.1	1.1	0.5	0.5	0.8
Total Common Species	*2.5*	*3.2*	*8.6*	*9.7*	*6.2*	*1.2*	*3.3*	*4.3*	*1.5*	*0.9*
Total Species Cover	**117.7**	**105.7**	**115.0**	**121.1**	**136.3**	**110.1**	**102.7**	**116.0**	**106.1**	**87.8**

A jack pine stand edge monitoring site is to meet the following criteria:

1. The edge monitoring site is to generally consistent with the Ecological Analogue Type 3 forest type, across an area large enough to permit establishment of a 5 m x 20 m monitoring plot containing 15 or more jack pine trees having a DBH of 10 cm or more (indicative of trees 40 to 70 years of age[1]), and selection of 10 off-plot trees that are similar to those in the vegetation plot;
2. The forest edge is to face towards the core of the oil sands emissions source area, receiving unobstructed airflow from across an open wetland that provides sufficient fetch such that the air impinging on the edge trees represents ambient air;
3. The top half of each tree, and the entire crown, is to receive unobstructed airflow; and
4. The understory must indicate the absence of a near-surface water table, in the area where the edge trees are rooted.

Depth to the water table is indicated by the presence and abundance of Labrador tea (*Ledum groenlandicum*), a species that requires relatively high soil moisture levels. Typical suitable jack pine edge monitoring sites are located on sand deposits that abut open wetlands, where the edge of the sand deposit rises abruptly from the wetland edge. A suitable jack pine edge monitoring site is indicated when the jack pine trees to be included in the edge monitoring plot are situated above the line of transition from a Labrador tea-dominated understory to a bearberry (*Arctostaphlos uva-ursi*) understory, and in the absence of substantive cover by other shrub and tree species (e.g., willow, alder, aspen, spruce).

The stand interior site establishment process is illustrated in Figure 1, and that for stand edge sites in Figure 2.

3.2 Site Selection Timing

Site selection and establishment activities are to be conducted in the summer. If conducted in the period from August 1 to mid-September, site establishment and the sampling and measurement activities associated with the monitoring program may be conducted concurrently.

3.3 Jack Pine Monitoring Site Layout & Staking

3.3.1 Vegetation Plot

3.3.1.1 Stand Interior Monitoring Site

A vegetation plot measuring 10 m x 40 m is to be established in the approximate centre of the jack pine stand. The plot is to be a minimum of three tree heights (approximately 50 m) away from the stand edge, seismic lines, roads, and other disturbances. The plot must be representative of the overall stand, including trees of similar age and structure as are present in the stand as a whole, at a density that is representative of the stand.

[1] New stand edge monitoring sites are not to be established in jack pine stand edges affected by wildfire in 2011 or 2016, however, stand edge monitoring sites established prior to++ the wildfires are to remain in the program.

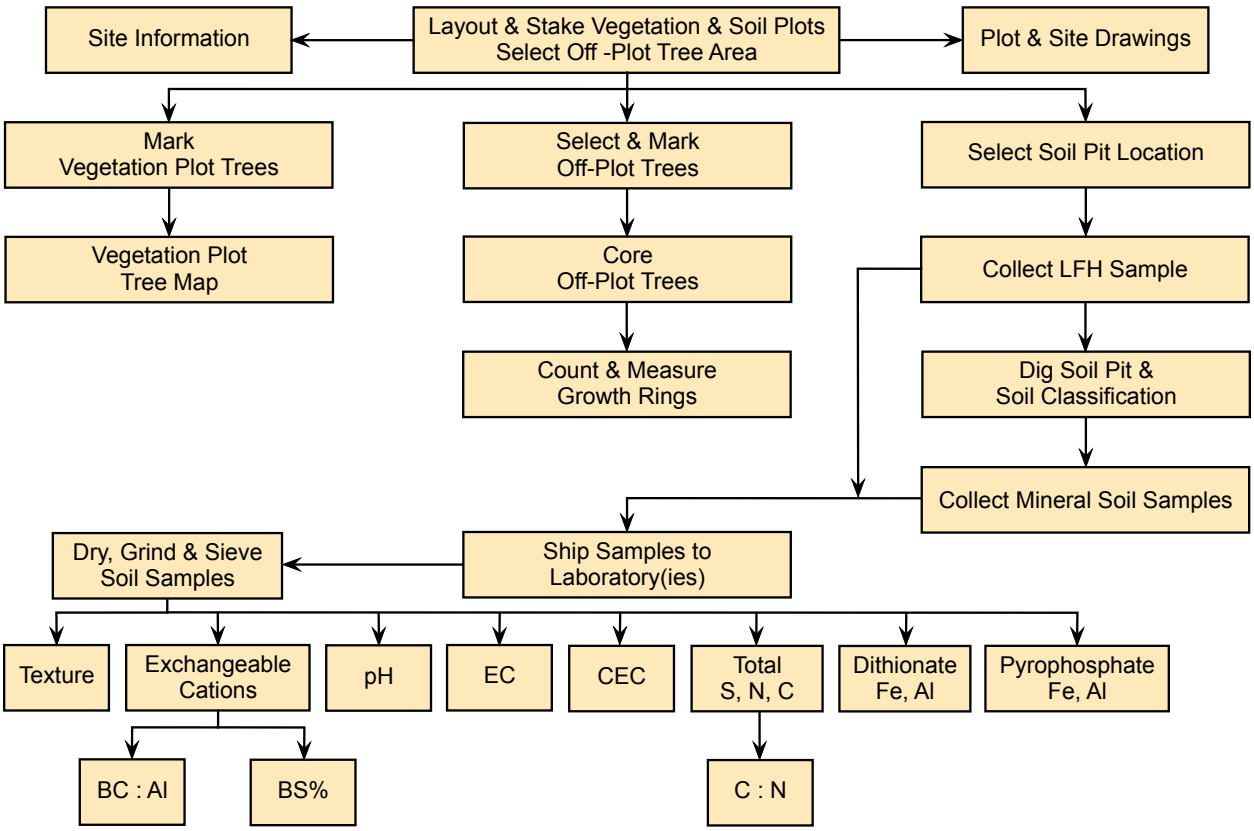

Figure 1: Stand Interior Site Establishment

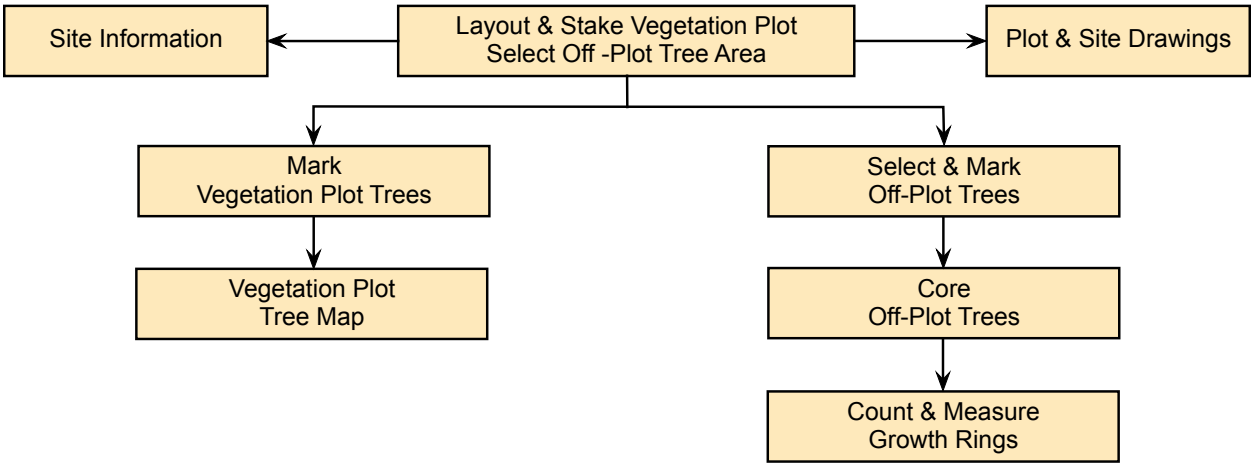

Figure 2: Stand Edge Site Establishment

The corners of this plot, the plot centre, and the midpoints along each axis, are to be marked with a wood stake over which a hollow, white plastic stake is installed. This provides for visual reference points (white stakes), and for detection of the plot corners in the event that the wooden markers are broken or destroyed. The plot is to be divided into four, 20 m x 5 m quadrants. The quadrant that represents best the southwest quadrant is assigned coordinates in "-x, -y" format, and in clockwise rotation, the northwest quadrant is assigned coordinates in "+x, -y" format, the northeast quadrant in "+x, +y" format and the southeast quadrant in "-x, +y" format (Figure 3). Each tree within the plot is to be numbered and labelled according to the **TREE NUMBERING & LABELLING PROCEDURE (#5)**.

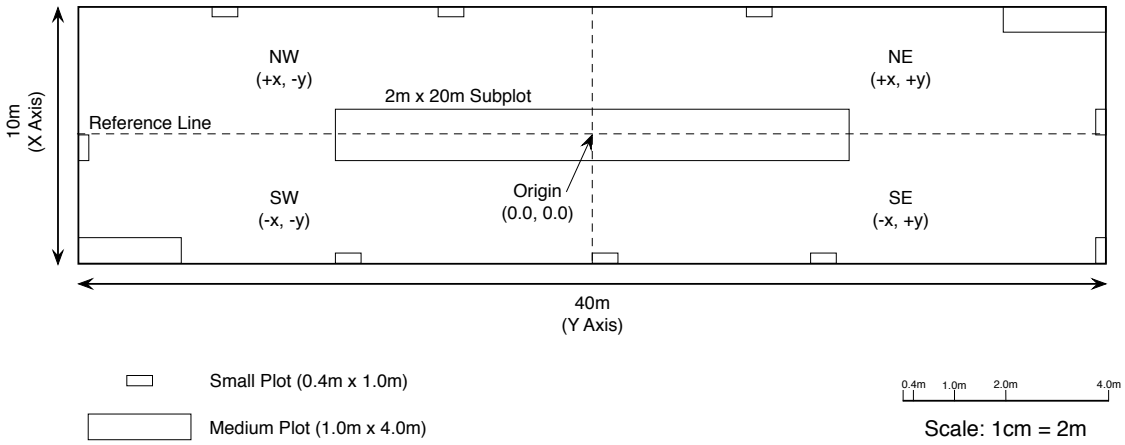

Figure 3: Stand Interior Vegetation Plot Layout

In 2004, an understory plant community component was added to the jack pine monitoring component of the program. Understory plant community assessments are to continue in the 6-year monitoring cycle of the Forest Health Assessment Program. Assessments of plant community composition are to be made using a series of subplots delineated within the vegetation plot. Ten small (1 m x 0.4 m), two medium (4 m x 1 m), and one large (20 m x 2 m) subplots are to be arranged as shown in Figure 3. The corners of the subplots are to be staked using pigtail stakes, with short lengths of flagging tape tied to the top to facilitate visual identification of the subplots.

3.3.1.2 Vegetation Plot Tree Labelling & Marking and Tree Map

Within the vegetation plot, all standing trees (living and dead) of 10 cm DBH and larger, except for dead standing trees whose tops do not reach into the canopy, are to be numbered and labelled according to the **TREE NUMBERING & LABELLING PROCEDURE (#5)**.

A tree is deemed to be within the vegetation plot if its point of germination occurred in the plot. Thus, trees that germinated within the plot but which lean outside the plot are considered to be in the plot. Conversely, trees that germinated outside of, but which are leaning into, the plot, are to be excluded. Trees that fork at a height of 1.3 m or lower are considered to be two trees, and

each stem is to be separately numbered and tagged. Trees that grow in clumps (rare for jack pine) having germinated from the same location are deemed to be plot trees if the germination point is in the plot – all stems in the clump having reached 10 cm DBH are to be separately numbered and tagged.

Trees (≥10 cm DBH) are to be mapped within the four quadrants of the vegetation plot, according to the **VEGETATION PLOT TREE MAP PROCEDURE (#24)**, which includes completion of TEEM Form 02. An example stand interior vegetation plot map is shown in Figure 5.

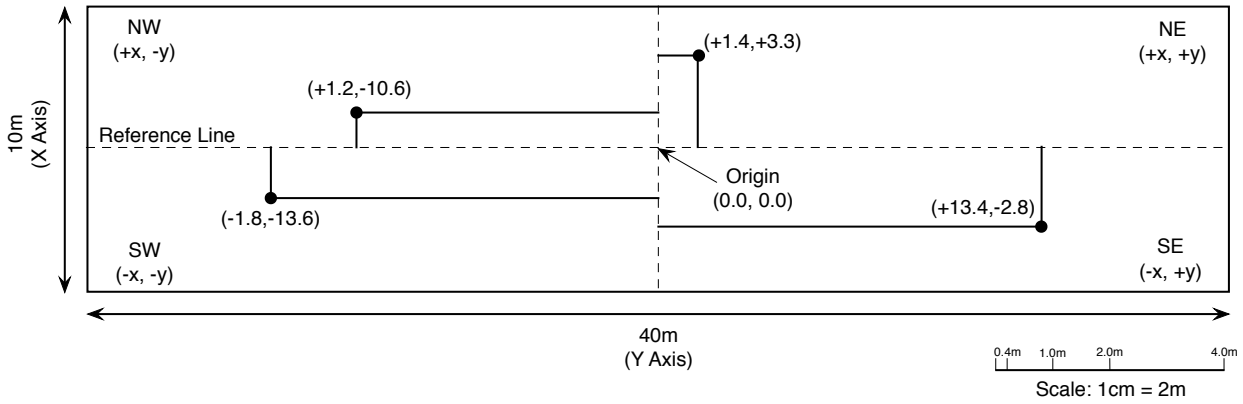

Figure 5: Example Stand Interior Vegetation Plot Tree Map

3.3.1.3 Stand Edge Monitoring Site

A 5 m x 20 m plot, oriented parallel to the stand edge (perpendicular to the direction of air flow from the oil sands processing facilities) is to be established. The corners of this plot are to be staked with a wood stake over which a hollow, white plastic stake is installed. This provides for visual reference points (white stakes), and for detection of the plot corners in the event that the wooden markers are broken or destroyed.

Trees (≥10 cm DBH) are to be mapped within the stand edge vegetation plot, according to the **VEGETATION PLOT TREE MAP PROCEDURE (#24)**, which includes completion of TEEM Form E02. For stand edge vegetation plots, the origin is defined as the plot corner closest to the reference stake. From these measurements, a scale map of the plot is to be generated. A plot map for stand edge vegetation plots is also to be generated, similar to that for the stand interior vegetation plot.

Four small (1 m x 0.4 m) and two medium (4 m x 1 m) subplots are to be staked around the perimeter of the stand edge vegetation plot, generally following the pattern of subplots arranged within the stand interior vegetation plot.

3.3.2 Soil Plots

Soil plots are to be established only at stand interior monitoring sites; they are not required at stand edge monitoring sites. Soil plots are to be a minimum of 10 m from the vegetation plot.

A standard 40 m x 10 m (400 m^2) plot is preferred. In those instances where site characteristics do not permit the establishment of the preferred plot configuration, alternate configurations are permitted (Figure 4).

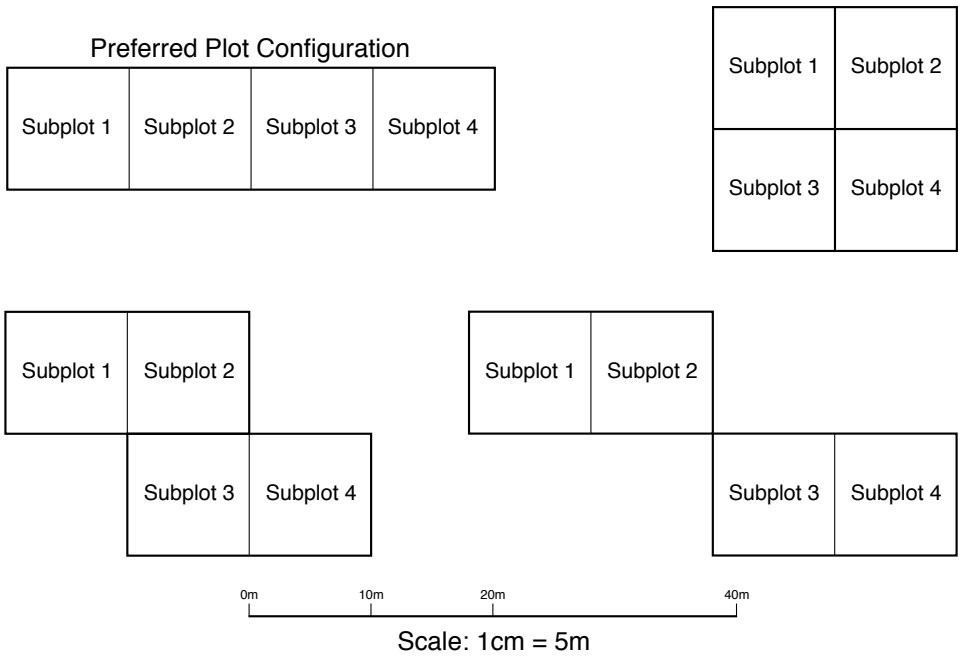

Figure 4: Stand Interior Soil Plot Configurations

At sites where one or more 400 m^2 plot(s) cannot be established, any or all of the soil plots at the site may be reduced to 300 m^2 or 225 m^2, by reducing the long dimension from 40 m to 30 m, and the short dimension from 10 m to 7.5 m. The configurations illustrated in Figure 4 may be applied to the smaller plots.

Each soil plot is to be divided into four subplots. The corners of the plot and each subplot are to be staked with a wood stake over which a hollow, white plastic stake is installed. This provides for visual reference points (white stakes), and for detection of the plot corners in the event that the wooden markers are broken or destroyed. Use of any kind of metal stake for marking the soil plots is not permitted.

Soil plots are to be numbered from “1” to “4” (i.e., “S1” to “S4”), and the four subplots within each soil plot are to be numbered from “1” to “4” (e.g., “S1-1” to “S1-4” for subplots in soil plot “S1”).

In the case where a previously established soil plot becomes unsuitable for continued use, a replacement plot is to be established according to the guidance above. The new soil plot will be numbered “5”, with subplots numbered “S5-1” to “S5-4”. Plot numbers are not to be reused.

3.3.3 Soil Pit Location

A soil pit is required during site establishment, and only at stand interior monitoring locations. An area of about 3 m x 3 m is to be allowed for the soil pit. The pit is to be a minimum of 10 m from the vegetation plot, and 5 m from any of the soil plots. The soil pit location must be recorded and marked on all site drawings.

A soil pit is not required at stand edge monitoring sites.

3.3.4 Off-Plot Tree Area

Trees of the same growth form and in an area of similar density as those in the vegetation plot are to be used for sampling involving destructive techniques (e.g., coring, branch excision). Use of trees outside of the vegetation plot preserves the plot trees, ensuring that the effects of branch harvest do not influence the health of trees that are the core of the jack pine monitoring program.

At stand interior sites, an area within the stand and outside of the boundaries of the soil and vegetation plots by a minimum of 5 m, is to be identified. The area is to contain 20 or more trees that are similar in height, morphological structure and insect/disease infestation as those that occur within the vegetation plot. Two off-plot tree areas may be identified if site characteristics do not provide for a single off-plot tree area having 20 or more representative trees.

At stand edge sites, an area that includes about 20 trees in proximity to the vegetation plot and which are generally exposed to the same air flow and environmental conditions as are the trees in the vegetation plot is to be identified as the off-plot tree area.

From the pool of trees in the off-plot area(s), 10 trees that are representative of the trees at the stand interior and stand edge monitoring sites are to be selected. These trees are to be numbered and labelled according to **TREE NUMBERING & LABELLING PROCEDURE (#5)**.

3.3.5 Off-Plot Tree Age

Tree age is to be determined for each of the 10 off-plot trees, at each of the stand interior and stand edge monitoring sites. Tree cores are to be obtained using **TREE CORING PROCEDURE (#25)**. Tree cores are to be processed and analysed according to the **TREE CORE PREPARATION & ANALYSIS PROCEDURE (#26)**, which includes completion of TEEM Form X05 (stand interior) or TEEM Form EX05 (stand edge).

3.3.6 Reference Stake and Site Georeferencing

At the completion of plot layout and staking, the reference point is to be selected, and a reference stake installed according to the **REFERENCE STAKE INSTALLATION & GEO-**

REFERENCING PROCEDURE (#4). Where stand interior and edge sites are in close proximity, a single reference stake may be used to georeferenced both sites.

Coordinates, in UTM (NAD83) format, are to be obtained for the reference stake, plot, off-plot tree areas, all other equipment, and significant site features. Distances and bearings between the reference stake and each of these monitoring elements and site features are to be obtained, as are bearings along the long axis of monitoring plots. Georeferencing is to follow the **REFERENCE STAKE INSTALLATION & GEO-REFERENCING PROCEDURE (#4)**.

3.4 Monitoring Site Information

Site information for a new monitoring site is to be recorded according to the **SITE INFORMATION PROCEDURE (#3)**, which includes completion of TEEM Form 01 (stand interior) or TEEM Form E01 (stand edge). Practitioners should complete this form in detail, ensuring that a person who had not visited the site is able to visualize the location of the plot on the terrain. Site information and observations should be from the perspective of the vegetation plot.

3.5 Soil Classification and Characterization (Stand Interior Sites Only)

Soil classification and characterization is required only for stand interior monitoring sites.

3.5.1 Soil Pit

In the year that the site is established, the soil at the site is to be classified on the basis of the soil exposed in, and samples taken from, a pit dug at least 1 m deep, preferably into the C horizon. Coordinates for the pit location (UTM, NAD83) is to be recorded.

The pit is to be a minimum of 10 m from the vegetation plot, and no closer to any of the soil plots by at least 5 m. The location for the soil pit is to be determined during plot layout and staking. The pit location should avoid obvious hummocks, depressions or other unique site characteristics. A soil pit approximately 1 m x 1 m is to be dug into the C horizon (or to 1 m deep if the C horizon is not encountered), placing excavated material on a plastic sheet or tarp on one side of the pit; this avoids contaminating the area around the pit. A larger pit is acceptable if the instability of sandy soils so requires.

At the completion of soil characterization and sampling, the soil pit is to be filled, with the upper horizon materials being replaced nearer the surface.

3.5.2 Soil Classification

The soil exposed in the pit is to be described in sufficient detail that, together with the results of the laboratory analysis of pit samples, the soil can be classified into the appropriate subgroup of the Canadian System of Soil Classification (Soil Classification Working Group, 1998), and to the appropriate soil map unit. The soil pit information is acquired according to the **SOIL DESCRIPTION PROCEDURE (#7)**, which includes completion of TEEM Form 10.

3.5.3 Soil Pit Sample Collection

For soil classification, each **soil horizon** is to be measured, characterized, and samples taken for laboratory analysis. Sampling and measurement of soil horizons in the soil pit differs from the sampling required during the 6-year monitoring cycle, and practitioners must be fully aware of this critical difference.

3.5.3.1 LFH Sample Collection

A sample of the LFH horizon is to be taken from an area of about 2,500 cm^2 (larger area if material is sparse) at the location of the soil pit, prior to beginning the excavation of the pit. A stainless steel knife, scraper or spoon is used to carefully loosen all litter material from the mineral soil, and to add this loosened material to the sample. Mineral soil is to be excluded from the sample as much as possible.

A field duplicate sample of LFH material is to be obtained from 10% of the sites being established in a single year, rounded up to the next whole number (e.g., 1 field duplicate for up to 10 sites, 2 field duplicate samples for 11 to 20 sites; 3 for 21 to 30 sites, etc.). To collect a field duplicate, approximately twice the amount of LFH material (over an area of up to 5,000 cm^2) is to be collected. This material, once cleaned, is to be thoroughly mixed. The mixed sample is to be divided into two equal portions, one representing the subplot sample, the other the field duplicate.

The LFH sample is to be placed into a labelled plastic storage bag and sealed, which itself is to be placed into a second, labelled plastic storage bag. Samples are to be labelled and handled according to the **SAMPLE LABELLING PROCEDURE (#1)** and the **SAMPLE STORAGE & SHIPPING PROCEDURE (#2)**.

3.5.3.2 Mineral Soil Sample Collection

Preparation of the pit sides for sampling, and the sampling itself, must be conducted with stainless steel hand tools. At least one side of the soil pit should be prepared for photography and sampling. If roots or other materials interfere with proper sampling, or the horizon is thin, material may be taken from the same horizon on the other pit side(s).

Prior to sampling, the pit wall is to be photographed. Photograph numbers are to be recorded in field notes.

Samples should be taken from the entire depth of each horizon. A volume of soil sufficient to provide approximately 500 cm^3 of material for laboratory analyses (after removing coarse fragments) is to be taken. This will ensure that sufficient material is available for the suite of laboratory analyses required, and to archive sufficient remaining material to repeat laboratory analyses if required at a future date. Sampling is to begin at the bottom of the pit (C horizon) and proceed upwards to avoid contamination of lower soils during the sampling process. In the case of deep horizons, sample collection may be facilitated by scraping a larger than required amount of soil (ensuring that the entire depth of the horizon is equally sampled) onto a flat, clean surface, mixing completely and taking the 500 cm^3 sample.

A field duplicate sample of each mineral horizon is to be obtained from 10% of the sites (pits) being established in a single year, rounded up to the next whole number (1 field duplicate set for up to 10 sites, 2 field duplicate sets for 11 to 20 sites; 3 for 21 to 30 sites, etc.). To obtain a field duplicate sample from a soil pit, twice the amount of soil from a horizon is to be obtained from the pit and placed onto a clean surface. This sample is to be completely mixed and divided into two equal portions, one as the soil pit sample; the other as the soil pit duplicate sample.

Each mineral soil sample is to be placed into a labelled plastic storage bag and sealed, which itself is to be placed into a second, labelled plastic storage bag and sealed. Samples are to be labelled and handled according to the **SAMPLE LABELLING PROCEDURE (#1)** and the **SAMPLE STORAGE & SHIPPING PROCEDURE (#2)**.

3.5.4 Soil Pit Sample Laboratory Analyses

3.5.4.1 Sample Preparation

Upon receipt at the laboratory, soil samples are to be split into two subsamples in an approximate 3:1 ratio. The larger of the subsamples is to be dried, while the smaller is to be returned to the fridge or freezer in field-moist condition. The field moist subsamples are to be reserved for analysis of soluble nutrients. Drying and preparation of soil samples is to be conducted according to the **SOIL SAMPLE PREPARATION & WEIGHING PROCEDURE (#9)**.

3.5.4.2 Texture

Soil texture (proportion of sand, silt and clay) is a measurement of the size distribution of the individual mineral particles in a soil sample. Soil texture data are used in soil classification, evaluation of field texture, determination of the relationship of parent material to the soil, chemical adsorption properties, base exchange capacity, water retention, unsaturated hydraulic conductivity, permeability, aeration, and soil plasticity (Schumacher et al., 1995). Each mineral soil horizon sampled from the soil pit is to be analysed for soil texture according to the **SOIL TEXTURE ANALYSIS PROCEDURE (#10)**, which is based on Kalra and Maynard (1991) and Carter and Gregorich (2008).

3.5.4.3 pH

Soil pH is one of the most indicative chemical measurements in soil (Schumacher et al., 1995). Soil pH affects the solubility of compounds, the availability of plant nutrients, the relative bonding of ions to exchange sites, and the activity of soil microorganisms. Decreases in soil pH resulting from soil acidification may reflect an overall decline in base saturation and an increase in the exchangeable acidity (Bach, 1980).

A calcium chloride ($CaCl_2$) solution is to be used in the analysis of pH in soil samples from the Forest Health Monitoring Program (Kalra and Maynard, 1991). Data generated from analyses conducted using other solutions cannot be directly compared to data generated from the analysis of pH in $CaCl_2$ solutions. Samples taken from the LFH horizon and each mineral soil horizon are to be analysed for soil pH according to the **SOIL PH ANALYSIS PROCEDURE (#11)**.

3.5.4.4 Electrical Conductivity

The main ions comprising soluble salts are cations (Na^+, Ca^{2+}, Mg^{2+}) and anions (SO_4^{2-} and Cl^-), with typically lower amounts of K^+, HCO_3^-, CO_3^-, and NO_3^-. Analysis of electrical conductivity in soil samples is to be conducted according to the **SOIL ELECTRICAL CONDUCTIVITY ANALYSIS PROCEDURE (#12)**, which is based on Miller and Curtin (2008).

3.5.4.5 Cation Exchange Capacity (CEC)

Cation exchange capacity (CEC) is a bulk surrogate for the presence and availability of plant nutrients (Schumacher et al., 1995). CEC, usually expressed in $cmol^+/kg$ of soil, is a measurement of the quantity of readily exchangeable cations in the soil (Rhoades, 1982). These cations include Ca^{2+}, Mg^{2+}, Na^+, and K^+, critical nutrients for plant health. Decreases in soil pH will produce a related decrease in CEC. Analysis of soil cation exchange capacity is to be conducted according to the **SOIL CATION EXCHANGE CAPACITY ANALYSIS PROCEDURE (#13)**, which is based on Kalra and Maynard (1991) and Skinner et al. (2001).

3.5.4.6 Exchangeable Cations

The analysis of exchangeable cation concentrations provides the data necessary for the calculation of the BC:Al ratio and the base saturation percentage (BS%). This analysis is to be conducted according to the **SOIL EXCHANGEABLE CATIONS ANALYSIS PROCEDURE (#14)**.

3.5.4.7 BC:Al Ratio

The ratio of base cation and aluminum ion concentrations in the soil is an important indicator of soil health. Soil base cations, Ca^{2+}, Mg^{2+}, and K^+, are important nutrients for plant growth, while Al^{3+} may be toxic to vegetation. Soil acidification and leaching process can lead to depletion of base cations and the release of adsorbed Al^{3+} into the soil water solution (Belyazid, 2005). This leads to a larger fraction of exchange sites being occupied by aluminum at the expense of Ca^{2+}, Mg^{2+}, and K^+, and ultimately to a decrease in the BC:Al ratio (Cronan and Grigal, 1995). The BC:Al ratio is a calculated value, derived according to the **BC:AL CALCULATION PROCEDURE (#15)**.

3.5.4.8 Base Saturation

Base saturation (Ross et al., 2008) is the proportion of cation exchange sites in the soil occupied by plant nutrient cations (Ca^{2+}, Mg^{2+}, K^+, Na^+). Non-nutrient cations (H^+, Fe^{2+}, Mn^{2+}, Cu^{2+}, Zn^{2+}, Al^{3+}, and others) can also occupy cation exchange sites. Some of these cations, including Al^{3+}, are toxic to plants. A relationship between pH and base saturation has been postulated in models used to predict soil changes caused by acid deposition (Reuss, 1983; Reuss and Johnson, 1985; Robarge and Johnson, 1992). Base saturation is also often referenced in the forest soil literature as an indicator of the effects of acidic deposition or the recovery from these effects (Reuss, 1983). The BS% is calculated according to the **SOIL BASE SATURATION PERCENTAGE CALCULATION PROCEDURE (#16)**.

3.5.4.9 Total Sulphur, Nitrogen & Carbon

Quantification of total carbon, in conjunction with total nitrogen and total sulphur, provides insight about the potential for uptake or release of nitrogen and/or sulphur by the soil organic matter due to microbial activity (Blume et al., 1980). Carbon, nitrogen, and sulphur cycle between organic and inorganic forms in the soil, soil microbes, and plant systems.

Carbon, nitrogen and sulphur dynamics may be altered in trees exposed to air emissions. Nitrogen and sulphur may accumulate in needles exposed to sulphur and nitrogen oxides, and ammonia. Carbon distribution in the soil may be altered in response to plant stress, including that caused by air contaminants. These changes may become apparent in soils as shed needles with altered carbon and/or nutrient content are deposited to the soil surface. Total carbon, nitrogen, and sulphur are measured using dry combustion (Skjemstad and Baldock, 2008), described in the **TOTAL SULPHUR, NITROGEN & CARBON ANALYSIS PROCEDURE (#17)**.

3.5.4.10 Carbon to Nitrogen Ratio (C:N)

Nitrogen deposition can lead to a variety of effects that vary by ecosystem type (Brady and Weil, 2008; Galloway et al., 2008; Millennium Ecosystem Assessment, 2005; Rockström et al, 2009) or export of nitrogen from forest ecosystems to streams, rivers, and lakes (Pregitzer et al., 2004). If the balance between carbon and nitrogen in the soil is heavily weighted towards carbon, the decomposition of organic material in the soil by fungi and bacteria will deplete soil nitrogen. If the balance is heavily weighted towards nitrogen, the decomposition of organic material in the soil by fungi and bacteria will be unable to consume all available nitrogen leading to nitrogen excess. The carbon to nitrogen ratio (C:N) is calculated according to the **SOIL C:N CALCULATION PROCEDURE (#18)**.

3.5.4.11 Complexed Aluminum & Iron

Micronutrient chemistry in the terrestrial environment largely involves complexation reactions with organic substances (Schumacher et al., 1995). Organic Fe and Al complexes accumulate in the mineral horizons of certain types of soils and can be used to distinguish podzolic (spodic) B horizons. Micronutrient cations in displaced soil solutions have been found to occur partly in organically bound forms (Geering et al., 1969). With mounting evidence to demonstrate higher aluminum solubility with watershed acidification, the proportion of Fe and Al bound by organics may be important information in terrestrial monitoring programs assessing the impacts of atmospheric pollutants.

Using specific extraction procedures, an approximate differentiation can be made between organic Fe and Al and other secondary accumulation products, such as Fe and Al oxides. The pyrophosphate extraction procedure assesses organically bound iron and aluminum in soil. The dithionate extraction procedure provides a bulk assessment of both the organically bound and inorganic (oxide) forms of iron and aluminum in soil. The Forest Health Monitoring Program assesses both organically bound iron and aluminum (through pyrophosphate extraction) and oxide forms of iron and aluminum (through dithionate extraction and comparison with the results of the extraction using pyrophosphate) in the soil classification process. Since these are expected to be relatively stable parameters, these analyses need only be conducted as a

component of the soil characterization program during interior stand monitoring site establishment. The results of these analyses are used in the classification of soils, predominantly the differentiation between Podzols and Brunisols.

This extraction and analysis is based on Courchesne and Tunnel (2008), and is to be conducted according to the **SOIL COMPLEXED ALUMINUM & IRON ANALYSIS PROCEDURE (#19)**.

3.6 Plot Layout & Site Drawings

The plot layout and site drawings provide critical information for field personnel. A pair of scale drawings, a plot layout drawing showing plot layout details and a site drawing illustrating the position of the site on the landscape, is required for each stand interior and stand edge monitoring site.

3.6.1 Plot Layout Drawing

The plot layout drawing is to be prepared at a scale that permits presentation of all plots, the off-plot tree area, the location of the soil pit, and the location of the reference stake on a single letter-sized page. Distances and bearings from the reference stake to the nearest corner of each of the vegetation and soil plots are to be shown. Soil plot and subplot numbers are required. The bearing of the long axis of each of the vegetation and soil plots relative to true North is to be presented; this bearing is to be taken from the corner of the plot that is georeferenced with respect to the reference stake. The boundary of the off-plot tree area is to be delineated. The scale and a scale bar, an arrow showing true North, and an arrow showing the bearing (relative to true North) to the each of the oil sands upgrading facilities (Syncrude, Suncor, Canadian Natural Horizon, Nexen). Figure 6 illustrates an example plot layout drawing for a stand interior monitoring site.

A plot layout drawing is also required for each stand edge monitoring site.

3.6.2 Site Drawing

A site drawing showing the location of the plots in a wider context is also required. This drawing is to indicate the location of the helicopter landing site, nearby cutlines, forest stand edges, the jack pine edge monitoring site (if present), and any other landscape feature in the vicinity of the site. The site drawing is to fit on a single letter-sized page. The scale of this drawing will be dependent on the distance from the plot to other landscape features; the scale and scale bar are to be included. An arrow to true North, and arrows and bearings (relative to true North) to the each of the oil sands upgrading facilities (Syncrude, Suncor, Canadian Natural Horizon, Nexen) are to be included. An example site drawing for a stand edge monitoring site is illustrated in Figure 7. An example of a site drawing that includes both stand interior and stand edge monitoring sites is presented in Figure 8.

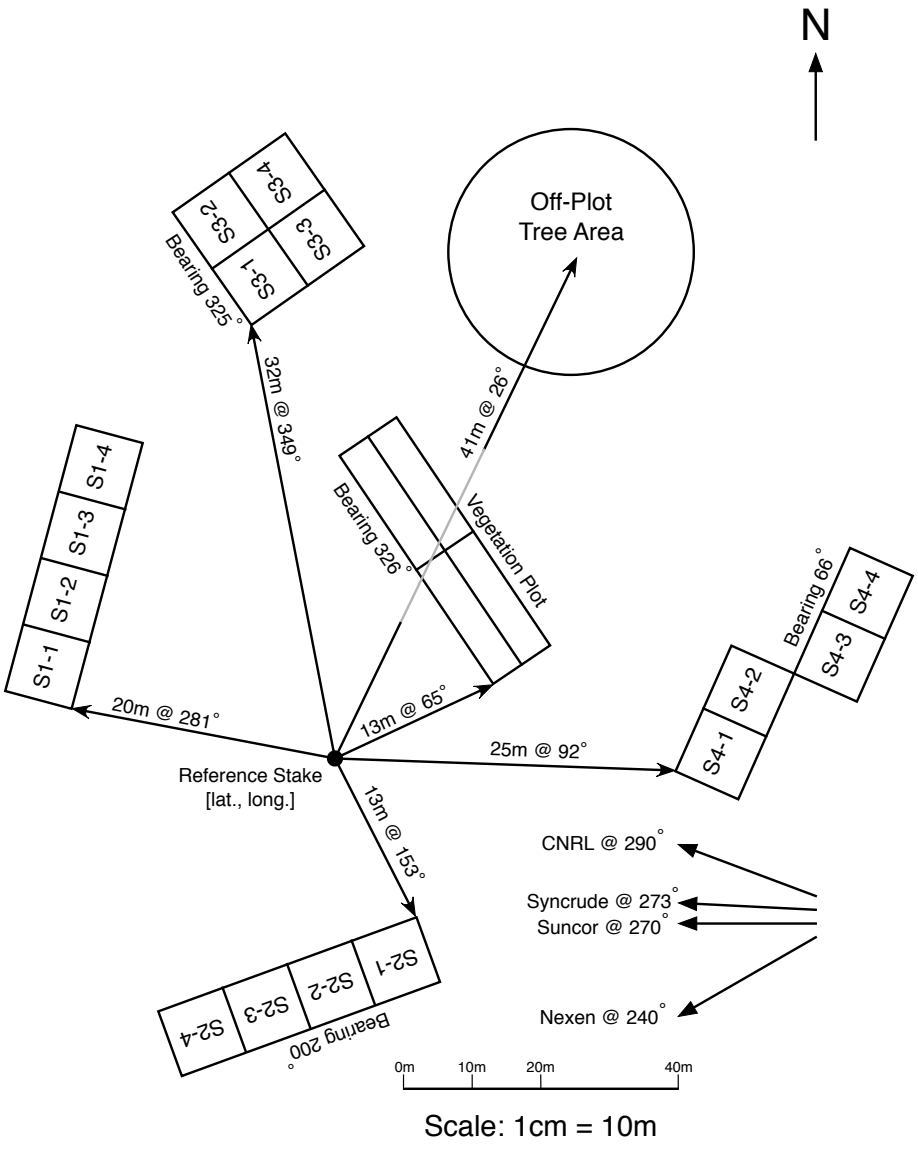

Figure 6: Example Stand Interior Plot Layout Drawing

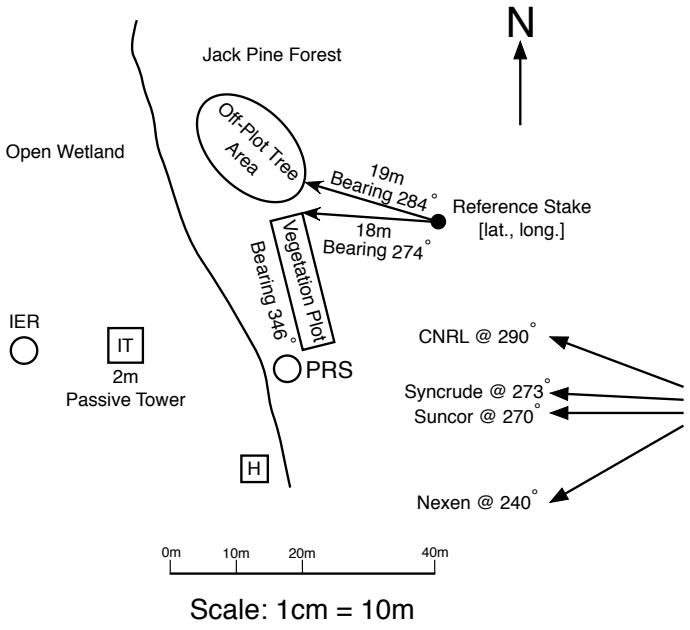

Figure 7: Example Stand Edge Site Drawing

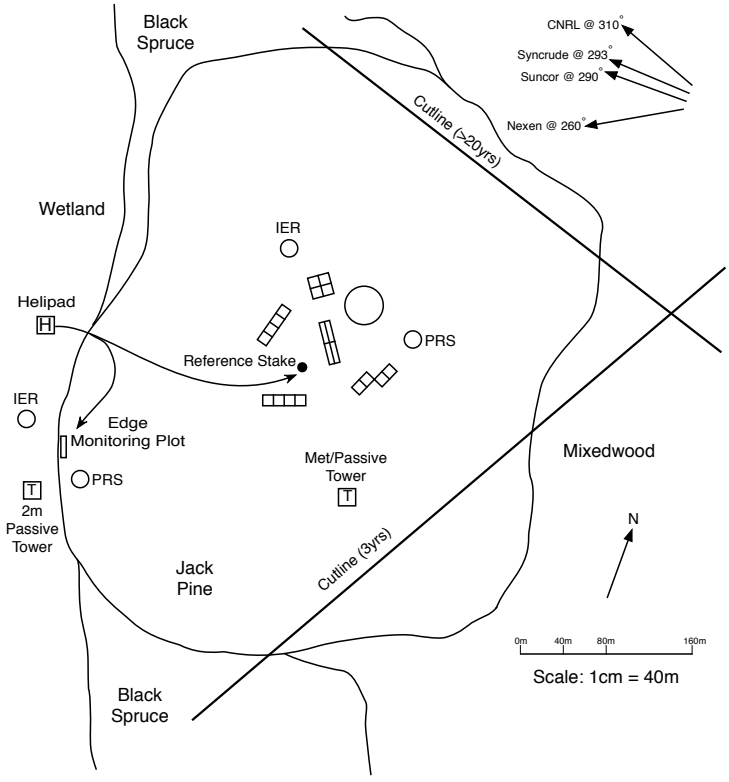

Figure 8: Example Combined Stand Interior & Stand Edge Monitoring Site Drawing

3.7 Plot and Site Maintenance

Regular site maintenance is required to ensure that plot stakes and tree labels continue to be easily read. Absence of maintenance may introduce variability into the program, potentially leading to samples and/or measurements being taken in an incorrect place.

All monitoring and investigative program components at each site are to be maintained as required. This is to include:

- maintaining the helicopter landing pad and trail to the monitoring site;
- inspecting and replacing the reference stake, as necessary;
- restoring or replacing plot stakes; and
- examining and restoring as necessary tree markings and labels.

Maintenance personnel should also conduct a visual inspection of the trees at the site, and of the surrounding area, and record their observations in field note format. Items to record include but are not limited to:

- signs of physical damage and/or biological stresses within the site (e.g., wildlife, wind damage, insect infestation, drought); and
- signs of physical damage outside of the site boundaries (e.g., wind damage, resource exploration), and/or biological stresses outside of the site.

Crews are encouraged to prepare detailed notes recording site observations, as these notes may be important in the interpretation of biophysical data acquired during the sampling and measurement programs. Maintenance activities at each site are to be recorded. Observations and site maintenance reports are to be submitted to the TEEM Program Manager at the end of each field day.

4.0 SOIL MONITORING PROGRAM (STAND INTERIOR)

The soil monitoring procedures at stand interior monitoring sites that comprise the 6-year cycle of activities are illustrated in Figure 9.

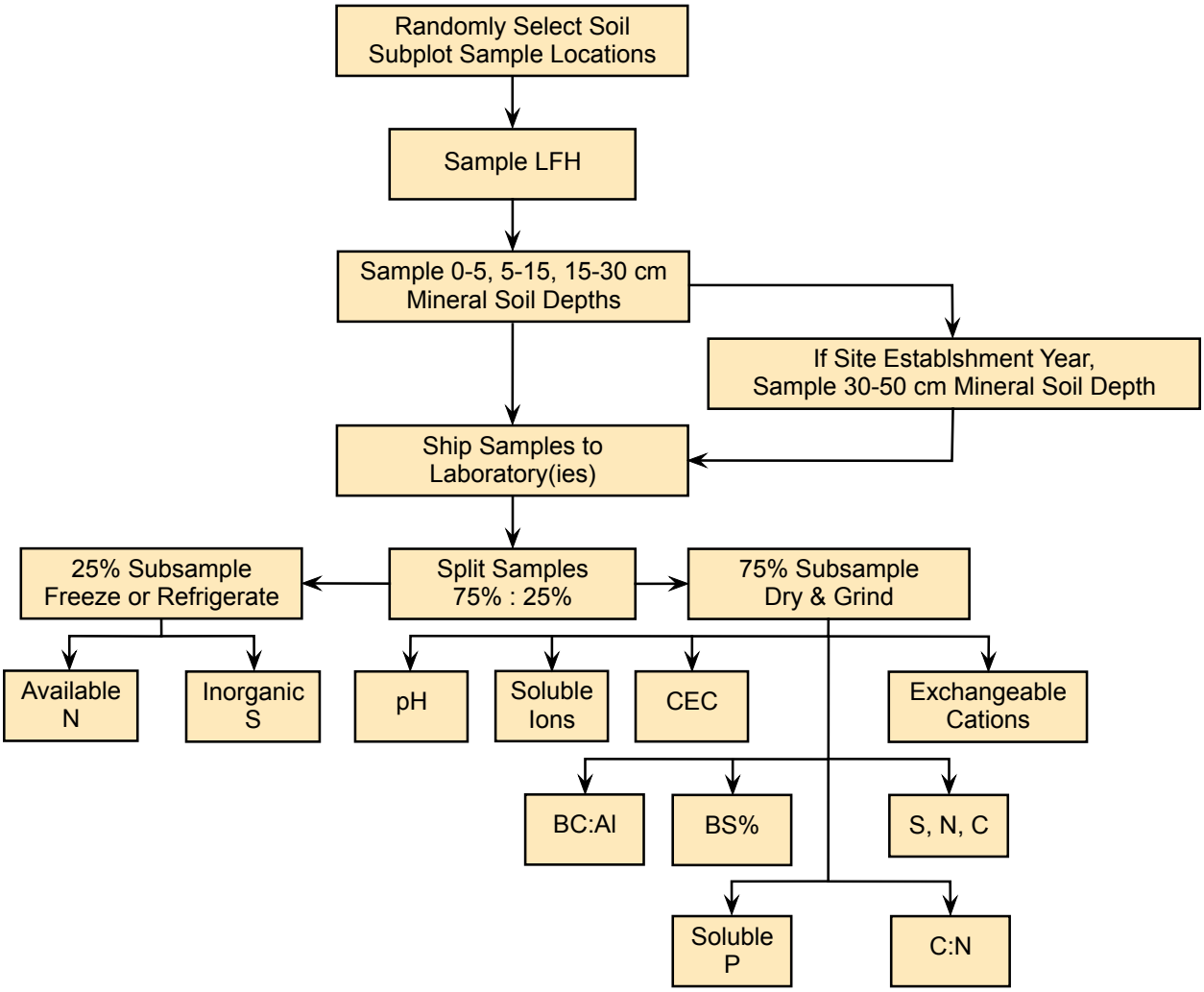

Figure 9: Jack Pine Stand Interior 6-Year Cycle Soil Monitoring Program

4.1.1 Replacing Compromised Soil Plots and/or Subplots

In the case where a previously established soil plot becomes unsuitable for continued use, a replacement plot is to be established according to the guidance provided for site establishment. The new soil plot would be numbered “5”, with subplots numbered “S5-1” to “S5-4”. Plot numbers are not to be reused. Similarly, if a subplot becomes unsuitable for continued use, a new subplot numbered “5” is to be established, contiguous with the remaining subplots in that plot (subplot numbers are not to be reused).

4.1.2 Soil Sample Location

Within each 10 m x 10 m soil subplot, nine sample locations are to be defined. Plots of smaller dimensions (i.e., 30 m x 10 m and 30 m x 7.5 m) are to contain six sample locations per subplot. These sampling locations are fixed points (Figure 10), however, they are not to be marked in the field.

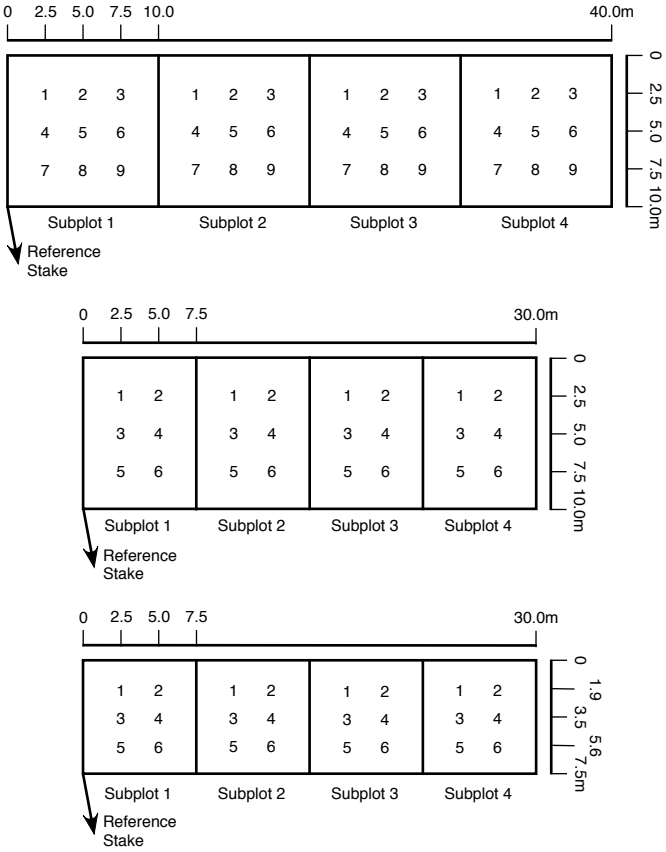

Figure 10: Soil Sample Locations within each Soil Subplot, within a Single Soil Plot (acceptable plot sizes shown)

One of the sample locations in each of the four soil subplots in each soil plot is to be sampled. A single number, from 1 to 9 (1 to 6 for the smaller subplots) is to be randomly selected for each subplot. The point within the subplot represented by the chosen number defines the location in the subplot at which the soil sample is to be taken. Because of the destructive nature of soil sampling, a location is to be used only once. If in subsequent years a previously sampled location is randomly selected, the random number representing that location is to be discarded and another chosen. This process is to be repeated until a sample point within each subplot, in all soil plots at all sites has been identified. The sample points chosen by this process are to be recorded on TEEM Form 11, as described in the **SOIL SAMPLE LOCATION & CHECKLIST PROCEDURE (#8)**.

To determine the location from which a field duplicate sample is to be taken, a random number from 1 to 4 is to be chosen (to identify the soil plot), followed by the selection of a second random number from 1 to 4 (to identify the soil subplot within the selected plot). The location from which the field duplicate samples are to be taken is to be recorded on TEEM Form 11 (**SOIL SAMPLE LOCATION & CHECKLIST PROCEDURE (#8)**).

If a tree, disturbance or other feature at or near the sample points interferes with proper sampling, the sampling point is to move the minimum distance required to a location where the interference ceases to occur. The direction of movement of a sample location is shown in Figure 11. Adjustments to soil sampling locations are to be measured, to the nearest 0.1 m, and recorded on TEEM Form 11 (**SOIL SAMPLE LOCATION & CHECKLIST PROCEDURE (#8)**).

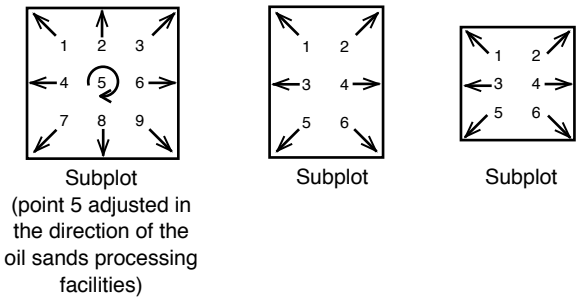

Figure 11: Soil Sample Location Adjustments

4.1.3 Sample Collection

In the 6-year cycle of soil sampling and monitoring, samples are collected by **depth** (except for the LFH horizon), which differs from the sampling by horizon conducted for baseline soil characterization using the soil pit. Practitioners must understand this critical requirement of the program.

All soil sampling is to be conducted using stainless steel tools, and while wearing powderless nitrile gloves.

4.1.3.1 LFH Sample Collection

An LFH sample is to be collected from the randomly selected, pre-determined location within each soil subplot. Using a stainless steel hand tool (e.g., scraper, spade, knife, spoon), the entire LFH layer is to be carefully removed from an area of about 2,500 cm^2 (larger area if material is sparse) at the sample location. Mineral soil is to be excluded from the LFH sample.

A field duplicate LFH sample is to be collected from one randomly chosen subplot, within one randomly chosen plot, at each site. From this location, approximately twice the amount of LFH material (over an area of up to 5,000 cm^2) is to be collected. This material, once cleaned, is to be placed on a clean surface, thoroughly mixed, and divided into two equal portions, one

representing the subplot sample, the other the field duplicate. One is to be bagged and labelled as the subplot sample; the other is to be bagged and labelled as the field duplicate.

Each cleaned LFH sample is to be placed into a labelled plastic storage bag and sealed, which itself is to be placed into a second, labelled plastic storage bag and sealed. Samples are to be labelled according to the **SAMPLE LABELLING PROCEDURE (#1)** and stored/shipped according to **SAMPLE STORAGE & SHIPPING PROCEDURE (#2)**.

4.1.3.2 Mineral Soil Sample Collection

Samples of each of the 0 to 5 cm, 5 to 15 cm, and 15 to 30 cm mineral soil layers are to be obtained from each subplot sample location, from each soil plot at each site, during each 6-year monitoring cycle. In the year of site establishment, a sample of the 30 to 50 cm layer[2] is also to be obtained from each sample location. Approximately 500 cm^3 of soil is required from each depth; this should be viewed as a minimum requirement.

A field duplicate sample from each soil layer is to be collected from the same location as was used for the collection of the field duplicate LFH sample. From this location, approximately twice the amount of mineral soil material (1,000 cm^3) is to be collected. This material is to be placed on a clean surface, and thoroughly mixed and divided into two equal portions, one representing the subplot sample, the other the field duplicate.

Each sample is to be placed into a labelled plastic storage bag and sealed, which itself is to be placed into a second, labelled plastic storage bag and sealed. Samples are to be labelled according to the **SAMPLE LABELLING PROCEDURE (#1)** and stored/shipped according to **SAMPLE STORAGE & SHIPPING PROCEDURE (#2)**.

4.1.4 Laboratory Analyses

Standardization of the laboratory component of the program is required to ensure that the results allow comparison across sites and over years. For some analyses, only one procedure is available, making standardization relatively simple. For others, however, several procedures may be available, and it is critical that the procedure required by the TEEM program be used, unless changes have been approved in advance by the TEEM Program Manager.

Because of the number of samples acquired, the need for specific analyses, and the schedule by which the laboratory results will be required, selection of a laboratory (or laboratories) should be made well in advance of the field program. The selected laboratory(ies) should be made aware of all analyses required, again well in advance of the field program, such that when the samples arrive laboratory staff are prepared to properly receive them and initiate the analyses or place the samples in appropriate storage. Field staff must also explicitly request the required analysis (or analyses) on the chain-of-custody form(s). This is a confirmatory step; should the request on the chain-of-custody form not match that expected by the laboratory, a discussion

[2] If changes in soil chemistry become apparent in the shallower depth samples, the TEEM committee may elect to add sampling of the 30 to 50 cm depth increment to the 6-year monitoring cycle

among the laboratory, field team members, project manager and/or TEEM Program Manager should occur so that the proper analysis (analyses) are completed by the laboratory.

4.1.4.1 pH

Soil pH is one of the most indicative chemical measurements in soil (Schumacher et al., 1995). Soil pH is a measure of the hydrogen ion activity in the soil solution, a direct measure of soil acidity. Soil pH is integral to many other soil properties such as the solubility of compounds, the availability of plant nutrients, the relative bonding of ions to exchange sites, and the activity of soil microorganisms. Decreases in soil pH resulting from soil acidification may reflect an overall decline in base saturation and an increase in the exchangeable acidity (Bach, 1980).

Samples taken from the LFH horizon and each mineral soil layer (by depth) are to be analysed for soil pH, using a $CaCl_2$ solution (Kalra and Maynard, 1991), as described in the **SOIL PH ANALYSIS PROCEDURE (#11)**.

4.1.4.2 Soluble Ions

The ions that are dissolved in soil solution are available for plant and microbe uptake. Changes in the concentration of soluble ions may have a direct effect on plant root uptake, microbial activity, or both. The concentrations of ions in soil solution represent the pool of ions available to plants through root uptake. The analysis of soluble ions in a soil sample is to be conducted according to the **SOIL SOLUBLE CATIONS ANALYSIS PROCEDURE (#20)**.

4.1.4.3 Cation Exchange Capacity (CEC)

Cation exchange capacity (CEC) is a bulk surrogate for the presence and availability of plant nutrients (Schumacher et al., 1995). CEC, usually expressed in $cmol^+/kg$ of soil, is a measurement of the quantity of readily exchangeable cations in the soil (Rhoades, 1982). These cations include Ca^{2+}, Mg^{2+}, Na^+, and K^+, critical nutrients for plant health. CEC is highly dependent on the quantity and character of the clay minerals present in the soil, and on soil pH. Decreases in soil pH will produce a related decrease in CEC. Analysis of soil cation exchange capacity is to be conducted according to the **SOIL CATION EXCHANGE CAPACITY ANALYSIS PROCEDURE (#13)**.

4.1.4.4 Exchangeable Cations

The analysis of exchangeable cation concentrations provides the necessary data for the calculation of the BC:Al ratio and the base saturation percentage (BS%). This analysis is to be conducted according to the **SOIL EXCHANGEABLE CATIONS ANALYSIS PROCEDURE (#14)**.

4.1.4.5 BC:Al Ratio

The ratio between base cations and aluminum in the soil is an important indicator for soil health. Soil base cations, Ca^{2+}, Mg^{2+}, and K^+, are important nutrients for plant growth, while Al^{3+} may be toxic to vegetation. Soil acidification and leaching process can lead to depletion of base cations and the release of adsorbed Al^{3+} into the soil water solution (Belyazid, 2005). This leads to a

larger fraction of exchange sites being occupied by aluminum at the expense of Ca^{2+}, Mg^{2+}, and K^{+}, and ultimately to a decrease in the BC:Al ratio (Cronan and Grigal, 1995).

The Acid Deposition Management Framework (Cumulative Environmental Management Association, 2004), a regional environmental management instrument implemented by Alberta Environment, includes the BC:Al ratio as an indicator of soil acidification. Monitoring of the BC:Al in the region is required; the analysis of BC:Al in sensitive soils in the Forest Health Monitoring Program fulfills this requirement.

The BC:Al ratio is a calculated value, derived according to the **SOIL BC:AL CALCULATION PROCEDURE (#15)**.

4.1.4.6 Base Saturation

Base saturation (Ross et al., 2008) is the proportion of cation exchange sites in the soil occupied by plant nutrient cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}). Non-nutrient cations (H^{+}, Fe^{2+}, Mn^{2+}, Cu^{2+}, Zn^{2+}, Al^{3+}, and others) can also occupy cation exchange sites. Some of these cations, including Al^{3+}, are toxic to plants. A positive relationship between pH and base saturation has been postulated in models used to predict soil changes caused by acid deposition (Reuss, 1983; Reuss and Johnson, 1985; Robarge and Johnson, 1992). Base saturation is also often referenced in the forest soil literature as an indicator of the effects of acidic deposition and the recovery from these effects (Reuss, 1983).

The Acid Deposition Management Framework (Cumulative Environmental Management Association, 2004) includes BS% as an indicator of soil acidification. The BS% data provided by the Forest Health Monitoring Program provides data for regional evaluation of this indicator.

The BS% is calculated according to the **SOIL BASE SATURATION PERCENTAGE CALCULATION PROCEDURE (#16)**.

4.1.4.7 Total Sulphur, Nitrogen & Sulphur

Quantification of total carbon, in conjunction with total nitrogen and total sulphur, provides insight about the potential for uptake or release of nitrogen and/or sulphur by the soil organic matter due to microbial activity (Blume et al., 1990). Carbon, nitrogen, and sulphur cycle between organic and inorganic forms in the soil, soil microbes, and plant systems.

Carbon, nitrogen and sulphur dynamics may be altered in trees exposed to air emissions. Nitrogen and sulphur may accumulate in needles exposed to sulphur and nitrogen oxides, and ammonia. Carbon distribution may be altered in response to plant stress, including that caused by air contaminants. The Forest Health Monitoring Program assesses soil total C, N and S to study the interaction of inputs of nitrogen and sulphur with the cycling of C, N, and S in the soil system.

Total carbon, nitrogen, and sulphur are measured using dry combustion (Skjemstad and Baldock, 2008), described in the **TOTAL SULPHUR, NITROGEN & CARBON ANALYSIS PROCEDURE (#17)**.

4.1.4.8 Carbon to Nitrogen Ratio (C:N)

Nitrogen deposition can lead to a variety of effects that vary by ecosystem type (Brady and Weil, 2008; Galloway et al., 2008; Millennium Ecosystem Assessment, 2005; Rockström et al, 2009) or export of nitrogen from forest ecosystems to streams, rivers, and lakes (Pregitzer et al., 2004). If the balance between carbon and nitrogen in the soil is heavily weighted towards carbon, the decomposition of organic material in the soil by fungi and bacteria will deplete soil nitrogen. If the balance is heavily weighted towards nitrogen, the decomposition of organic material in the soil by fungi and bacteria will be unable to consume all available nitrogen leading to nitrogen excess. The Cumulative Environmental Management Association (2008) identified the C:N ratio as a potential marker of nitrogen accumulation forest soils. The carbon to nitrogen ratio (C:N) is calculated according to the **SOIL C:N CALCULATION PROCEDURE (#18)**.

4.1.4.9 Soluble Nitrogen

The majority of nitrogen in the soil that is available to plants as nitrate (NO_3^-) and ammonium (NH_4^+). Nitrate (NO_3^-) and ammonium (NH_4^+) levels in soil are to be determined according to the **SOIL SOLUBLE NITROGEN ANALYSIS PROCEDURE (#21)**, which is based on the methods described in Carter and Gregorich (2008) and Kalra and Maynard (1991).

4.1.4.10 Soluble Phosphorus

Phosphorus (P) is an essential nutrient (Schumacher et al., 1995). The availability of P to plants is influenced by soil pH, being most available to plants at a soil pH of 6 to 7.

Soluble phosphorus in soil samples is to be determined according to the **SOIL SOLUBLE PHOSPHORUS ANALYSIS PROCEDURE (#22)**, based on the Bray P-1 procedure as described in United States Department of Agriculture (2004), which is based on Bray and Kurtz (1945), Olsen and Sommers (1982) and Kuo (1996).

4.1.4.11 Inorganic Sulphur (S_i)

Sulphur, in the form of sulphate (SO_4^{2-}), is a principal anion in acid deposition (Schumacher et al., 1995), and SO_4^{2-} is generally the primary form of inorganic sulphur (S_i) found in mineral soils. In contrast, in organic horizons up to 50% of the total extractable S may be organically bound (S_o) (Maynard et al., 1987). The ability of soils to adsorb sulphate is one of the principal factors affecting the rate and extent of soil and watershed response to acidic deposition.

The Forest Health Monitoring Program includes analyses for inorganic sulphur (S_i) in soil. The analytical procedures for LFH (Kalra and Maynard, 1991) and mineral soil (Kalra and Maynard, 1991) samples differ; these are described in the **SOIL INORGANIC SULPHUR (S_i) ANALYSIS PROCEDURE (#23)**.

5.0 VEGETATION MONITORING PROGRAM (STAND INTERIOR & STAND EDGE)

Vegetation measurement, sampling and laboratory analysis procedures apply to both stand interior and stand edge locations, in the year of plot establishment and in subsequent cycles. The vegetation monitoring program is illustrated in Figure 12.

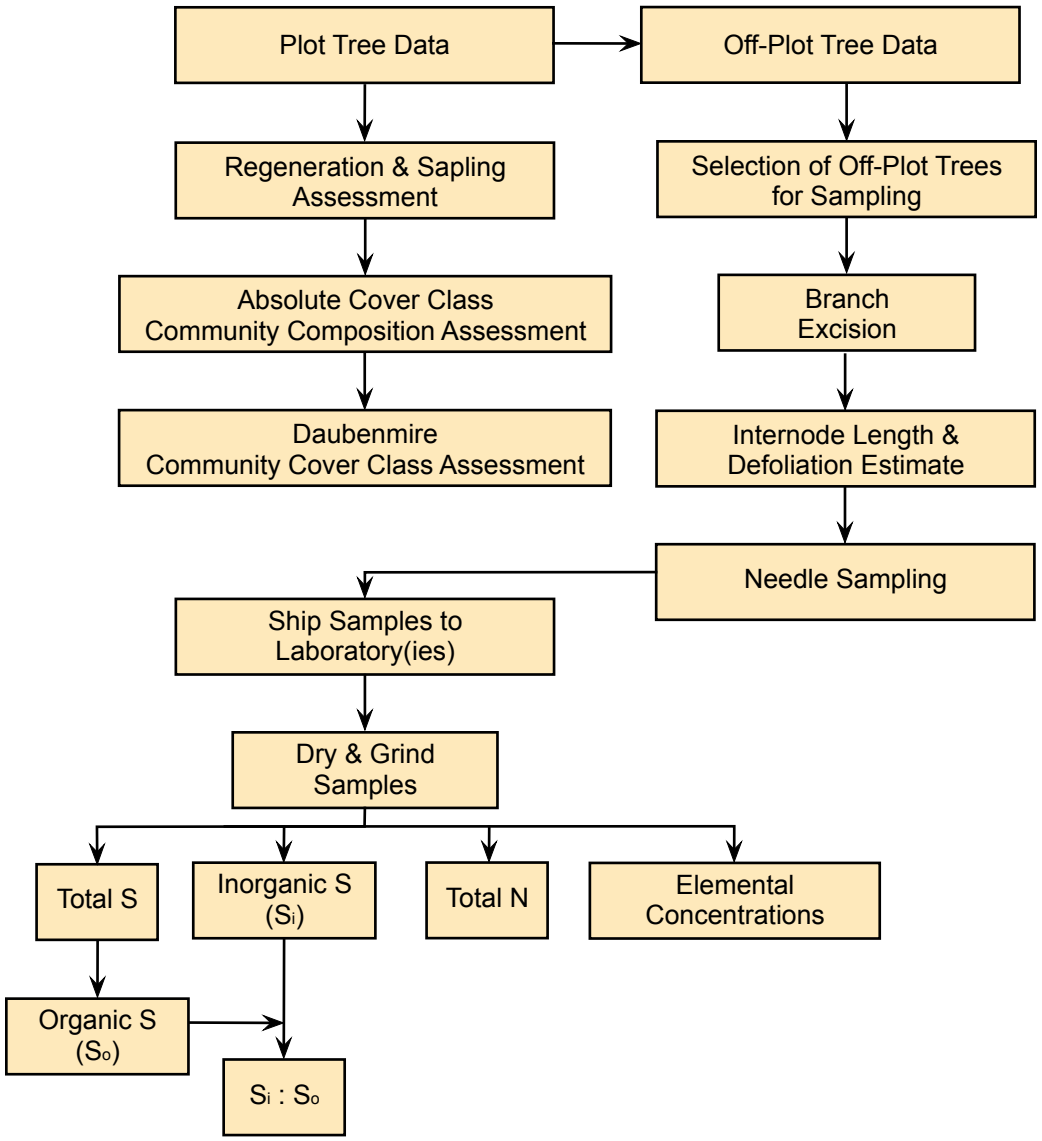

Figure 12: Vegetation Monitoring Program (Stand Interior and Stand Edge)

A number of jack pine stand interior and stand edge monitoring sites were affected by wildfire in 2011 (Richardson Fire) and 2016 (Horse River Fire). Fire is a natural process in the region and given the extent of these two fires (more than 1,000,000 ha burned in total) and the very limited availability of suitable stands providing opportunities for replacement of fire-affected, these sites have been retained in the TEEM Forest Health Monitoring Program. Regeneration at fire-

affected sites is currently in the early stages and monitoring the state of regeneration has been added to the Forest Health Monitoring Program in 2018.

5.1 Vegetation Monitoring Schedule

Stand interior vegetation monitoring is scheduled on a 6-year cycle, while stand edge vegetation monitoring is scheduled on a 3-year cycle, occurring concurrently with the stand interior vegetation monitoring every 2nd cycle.

Vegetation monitoring activities are to be conducted between August 1 and mid-September. Conducting all activities in this period allows for completion of current annual growth (CAG), while reducing the potential for physiological responses to the onset of autumn conditions (e.g., night frost).

5.2 Vegetation Plot Data

5.2.1 Tree Data

Morphometric data are collected from each numbered tree within the vegetation plot during each monitoring cycle. Data are to be collected according to the **TREE DATA PROCEDURE (#28)**, which includes completion of TEEM Form 03 and E03. Note that this procedure applies to numbered trees (by definition, these are trees that have a DBH ≥10 cm), therefore, application of this procedure at fire-affected sites will be restricted to those sites having trees in the vegetation plot and/or off-plot tree area that have survived the effects of fire.

An unmarked tree reaching a DBH of 10 cm or more is to be marked, and the coordinates for this tree are to be obtained using **VEGETATION PLOT TREE MAP PROCEDURE (#24)**.

5.2.2 Regeneration

The **REGENERATION AND SAPLING SURVEY PROCEDURE (#40)** is introduced into the TEEM Program in 2018, and applies to all sites, whether fire-affected or not. This procedure includes enumeration of seedlings in two categories: Regeneration (seedlings 16 to 200 cm tall) and Sapling (trees >200 cm tall and <10 cm DBH). Data are to be recorded using TEEM Forms 12 (stand interior) and E12 (stand edge).

5.2.3 Community Composition Assessment

Changes in soil chemistry and subsequent changes in vegetation growth and health may result in changes to the relative competitive ability of species currently growing at the jack pine monitoring sites. Altered competitive abilities may lead to changes in species composition, an ultimate outcome of atmospheric deposition of industrial emissions.

Plant community composition assessments are to be conducted at jack pine stand interior and edge TEEM Forest Health Monitoring Program sites, both those that have been unaffected by fire and those that were burned in 2011 or 2016.

5.2.3.1 Daubenmire Cover Class Assessment

Canopy cover, frequency of occurrence, and composition by canopy cover are to be evaluated within each of the small, medium and the large subplot (stand interior) or plot (stand edge) using the Daubenmire (1959; Coulloudon et al., 1996) method of cover class estimation, as described in the **PLANT COMMUNITY ASSESSMENT PROCEDURE (#38)**. Data are to be entered into TEEM Forms 08a and E08a.

Data from TEEM Forms 08a and E08a are to be transferred to TEEM Forms 09a and E09a (Daubenmire Summary). TEEM Forms 09a and 09b include pre-programmed equations for the calculation of Total Canopy, Canopy Cover (%), contribution of each species to overall Species Composition (%), and Frequency (%) of occurrence of each species.

5.2.3.2 Absolute Cover Class Assessment

Absolute cover, frequency of occurrence, and composition by canopy cover are to be recorded within each of the small, medium and the large subplot (stand interior) or plot (stand edge), as described in the **PLANT COMMUNITY ASSESSMENT PROCEDURE (#38)**. Data are to be entered into TEEM Forms 08b and E08b.

5.2.3.3 Standard Random Walk (Species List)

A "standard random walk" through the site is to be conducted according to the **PLANT COMMUNITY ASSESSMENT PROCEDURE (#38)**, to identify the presence of species not identified within the subplots. This is a presence/absence survey only; quantitative cover or abundance data are not required.

5.3 Off-Plot Tree Measurement & Sampling

The use of off-plot trees that are morphologically and physiologically similar to the trees within the vegetation plot permits destructive sampling, measurement of crown growth, examination of branch and needle growth and condition, and sampling and analysis of foliar tissues, without affecting the health and condition of trees in the marked vegetation plot.

Off-plot trees are selected, marked and used for destructive sampling at both stand interior and stand edge monitoring sites.

5.3.1 Examination & Replacement of Off-Plot Trees

An off-plot tree that has died since the previous sampling cycle or has been damaged or infected to the extent that it substantially differs from the rest of the trees at the site is to be replaced. The crown of off-plot trees used for destructive sampling in previous monitoring cycles must remain representative of the crowns of the trees in the stand as a whole.

In the event that an off-plot tree is no longer representative of the stand as a whole, a new tree or is to be selected. Replaced trees are to be numbered and labelled according to **TREE NUMBERING & LABELLING PROCEDURE (#5)**. The numbered tags are not to be removed from

numbered trees that no longer meet the criteria for the program, and the number painted on the tree should remain and be maintained. Labelling of trees removed from the program is required to ensure that a rejected tree does not re-enter the pool of off-plot trees at a later date.

No selection, numbering or labelling of off-plot trees at fire-affected sites is required until the trees achieve growth sufficient to reach 10 cm DBH. Thus, selection and numbering of off-plot tree seedlings is not required.

5.3.2 Aging Replacement Off-Plot Trees

Tree cores are to be obtained using **TREE CORING PROCEDURE (#25)**. Tree cores are to be processed and analysed according to the **TREE CORE PREPARATION & ANALYSIS PROCEDURE (#26)**, which includes completion of TEEM Form X05.

5.3.3 Off-Plot Tree Data

Morphometric tree data are to be collected from each of the 10 off-plot trees. These data allow for a comparison between the plot and off-plot trees in terms of growth, ensuring that any divergence between the two populations is noted. During the measurement process, tree tags, tree numbering, and DBH reference marks are to be checked and as required, repaired, refreshed or replaced.

Morphometric data are collected from each of the 10 numbered off-plot trees according to the **TREE DATA PROCEDURE (#28)**, which includes completion of TEEM Form X03 (stand interior sites) and EX03 (stand edge sites). **TREE DATA PROCEDURE (#28)** does not apply until trees at fire-affected sites achieve growth of at least 10 cm DBH.

5.4 Branch Excision, Internode Measurement, Defoliation & Needle Sampling

5.4.1 Selection of Off-Plot Trees for Sampling

The selection of trees for sampling differs between sites affected by recent regional wildfires, and those that have remained unaffected by fire.

5.4.1.1 Sites Unaffected by Fire

At sites unaffected by fire, five trees of the 10 off-plot trees are to be randomly chosen for sampling. Sampling of a subset of the off-plot trees in each sampling cycle will spread the damage caused by destructive sampling among the off-plot 10 trees, reducing the frequency at which off-plot trees will have to be replaced.

Six numbers from 1 to 10 are to be randomly selected in advance of the field program, and at each site the five trees represented by the first of the five selected numbers are to be sampled. A maximum of three branches are to be cut from any one tree. In the event that all three cut branches hang up in the canopy, the tree is to be left alone, and the sixth randomly chosen tree is to be used to acquire the necessary sample. This is illustrated in Table 2 for three fictitious jack pine monitoring sites, at which a different number of off-plot trees has been replaced at two

of the sites during the monitoring program. Note that only one set of random numbers is required in each sampling cycle, and that this set applies to all monitoring sites for that year.

Table 2: Illustration of the Use of Random Numbers to Select Stand Interior Off-Plot Trees for Branch Excision and Foliar Sampling

Site*	Available Off-Plot Trees	Random Numbers	Off-Plot Trees to be Sampled
JP001	X001, X002, X004, X005, X006, X009, X010, X011, X012, and X013	1, 3, 4, 6, and 10 (2)**	X001, X004, X005, X009, and X013 (X002)**
JP002	X001, X002, X003, X004, X005, X006, X007, X008, X009, and X010		X001, X003, X004, X006, and X010 (X002)**
JP003	X003, X004, X005, X006, X010, X014, X015, X016, X019, and X021		X003, X005, X006, X014, and X021 (X004)**

* Site designations are fictitious and are for illustrative purposes, and do not relate to any jack pine monitoring sites in the Forest Health Monitoring Program.

** Number in parentheses is the sixth number, representing the reserve tree from which a branch is to be excised, should three cut branches from one of the five selected trees hang up in the canopy.

TREE SHOOT DATA PROCEDURE (#29) is to be used to record off-plot tree data. The random numbers are to be entered into TEEM Form X06. The same random selection process is to be used to select the trees for sampling from the stand edge pool of off-plot trees, with the numbers selected to be entered into TEEM Form EX06.

5.4.1.2 Fire-Affected Sites

At fire-affected sites (stand interior and stand edge), five to 10 jack pine seedlings that represent (e.g., representative height, branching pattern, needle retention) the regenerating pine forest are to be selected from within the restored off-plot tree area for sampling. Neither labelling these saplings nor recording identifiers of the saplings from which branches were excised on TEEM Form X06 or EX06 are required.

5.4.2 Branch Excision

At sites unaffected by fire, a branch from each of the five selected off-plot trees is to be obtained from the upper third of the canopy, on the side of the tree facing the oil sands processing facilities. The branch is to be cut from the tree as close to the trunk as safely possible, using a pole pruner. Cut branches may hang up in the canopy. Within the limits of safety associated with the pole pruner, gentle attempts to dislodge the branch may be made. If a branch cannot be dislodged, another branch is to be selected and cut. A maximum of three branches are to be cut from any one tree. In the event that all three cut branches hang up in the canopy, the tree is to be left alone, and the sixth randomly chosen tree is to be used to acquire the necessary sample.

At fire-affected sites, branches, including the leader, are to be cut from the saplings using hand clippers or the pole pruner, as appropriate. The selected branches should contain the greatest

number of internodes, at a minimum having CAG, Age-1 and Age-2 growth for measurement and sampling.

5.4.3 Internode Length & Defoliation Estimate

The length of each internode on the each of the five main branches is to be measured and defoliation estimated according to the **TREE SHOOT DATA PROCEDURE (#29)**, which includes completion of TEEM Form X06 (stand interior) or TEEM Form EX06 (stand edge).

5.4.4 Foliar (Needle) Sample Collection

In 1998, samples of needle age classes from each of 10 trees were collected combined into a single, composite sample. In 2001, needles from each of the age classes from each branch were separately sampled. In 2004, a branch from each of five trees was excised, and needles from the same age class (CAG, Age-1, Age-2) being combined from all branches to create three composite samples, one for each age class, per site. In 2011-2013, the needles from each age class from each individual tree were sampled and analysed separately.

Compositing of samples from separate trees is no longer permitted. The procedure (**FOLIAR SAMPLE COLLECTION & CHECKLIST (#30)**) requires that samples of CAG, Age-1 and Age-2 age classes from each of the five off-plot trees be acquired and separately bagged. Samples are to be stored and transported according to the **SAMPLE STORAGE & SHIPPING PROCEDURE (#2)**).

5.5 Laboratory Analyses of Foliar Samples

Selection of a laboratory (or laboratories) should be made in advance of the field program. The laboratory(ies) selected should be made aware of all analyses required, again in advance of the field program, such that when the samples arrive, laboratory staff are prepared to properly receive them and initiate the analyses or place the samples in appropriate storage. Field staff must also explicitly request the required analysis (or analyses) on the chain-of-custody form(s). This is a confirmatory step; should the request on the chain-of-custody form not match that expected by the laboratory, a discussion among the laboratory, field team members, project manager and/or TEEM program manager is required to ensure that the proper analysis (analyses) are completed by the laboratory.

Samples from both fire-affected and unaffected sites follow the same sample preparation and analysis procedure.

5.5.1 Sample Preparation

Care in the preparation of the foliar samples for laboratory processing is required to maintain the integrity of the samples, and to prepare proper quantities of each sample for each of the required analyses. Sample cleaning, drying and grinding are to be conducted according to the **FOLIAR TISSUE SAMPLE PREPARATION PROCEDURE (#32)**. Samples are to be labelled according to the **SAMPLE LABELLING PROCEDURE (#1)**.

Each of the laboratory procedures that follow requires that a precise quantity (by weight) of ground foliar tissue be analysed. The weighing of ground foliar tissues into the reaction or extraction vessels at the initiation of a laboratory procedure is to follow the **FOLIAR TISSUE SAMPLE PREPARATION PROCEDURE (#32)**.

5.5.2 Total Sulphur (S_t)

The total sulphur (S_t) in foliar samples consists of inorganic sulphur (S_i) and organic sulphur (S_o). The S_o fraction in foliar samples reflects the process of assimilation of S by plant tissue and the S_i fraction reflects the accumulation of S by plant tissue (Legge et al., 1988a,b). The S_i fraction consists of elemental sulphur and SO_4^{2-}. The absolute values and the ratio of S_i:S_o can be used as indicators of plant tissue stress or recovery to changing inputs of S_i through acid deposition.

Total sulphur is measured using dry combustion using an automated sulphur analyser, according to **TOTAL SULPHUR, NITROGEN & CARBON ANALYSIS PROCEDURE (#17)**.

5.5.3 Inorganic Sulphur (S_i)

The procedure for determination of sulphate content in plant material is based on Brockley (2000). This involves a weak acid digestion of a foliar sample, followed by ion chromatographic analysis (**FOLIAR TISSUE INORGANIC SULPHUR (S_i) ANALYSIS PROCEDURE (#33)**).

5.5.4 Organic Sulphur (S_o) & S_i:S_o

The concentration of organic sulphur (S_o) in each foliar (needle) sample is derived through the subtraction of inorganic sulphur (S_i) concentration from total sulphur (S_t) concentration. The ratio of inorganic to organic sulphur concentrations can then be derived (**FOLIAR TISSUE ORGANIC SULPHUR (S_o) AND S_i:S_o RATIO CALCULATIONS PROCEDURE (#34)**).

5.5.5 Total Nitrogen

The abundance and chemical forms of nitrogen are of major interest when assessing the health of forest ecosystems (Schumacher et al., 1995), particularly in an area subject to deposition of elevated levels. In natural systems, nitrogen is found in a number of forms that can, under the correct chemical and microbiological conditions, convert from one form to another.

The procedure requires the analysis of total nitrogen content by dry combustion according to the **TOTAL SULPHUR, NITROGEN & CARBON ANALYSIS PROCEDURE (#17)**.

5.5.6 Elemental Concentrations

Acid deposition may alter soil nutrient balances, soil pH, mineralization and immobilization, ion activity, and ion diffusion (Schumacher, et. al. 1995). Acid deposition can reduce nutrient availability, and/or increase availability of elements that are toxic, and these soil effects may be reflected in the concentrations of various elements within plant tissues.

A number of elements are emitted (or have been emitted in the past) from oil sands operations, entrained in the air emissions from the upgraders, mine fleets and regional traffic. Other elements of importance may be naturally occurring, and emitted into the atmosphere as fugitive emissions (i.e., dust), and may affect plant growth and/or soil chemistry.

The technique used to measure elemental concentrations in plant tissues is capable of providing analytical data for a large number of elements. While many of these are present in air emissions, they are also naturally present in crustal materials. It can be difficult to distinguish between an elevated concentration in a foliage sample due to exposure to particulate emissions containing these metals, and an elevated concentration in a sample due to exposure to naturally occurring minerals in the soils at the site or in dust blown in from a distant source.

While a full scan approach provides data at little incremental laboratory cost, the incremental investment in data entry, analysis and interpretation is larger. A two-tiered approach is to be applied, segregating the data into a set of data in which concentrations of elements of interest are included (primary elements database; Table 3), and a second dataset that includes the concentrations of the remainder of the elements analysed (secondary elements database). This will focus attention on the former, while continuing to collect data of potential future interest without investing the time and resources into analyses and interpretations of currently minimal relevance or interest.

Table 3: Elements to be Included in the Priority Elements Database

Element		Emitted in Region	Nutrient	Toxic*
Aluminum	Al	Yes	No	Yes
Calcium	Ca	Yes	Macronutrient	No
Copper	Cu	Yes	Micronutrient	No*
Iron	Fe	Yes	Micronutrient	No*
Magnesium	Mg	Maybe	Micronutrient	No*
Manganese	Mn	Yes	Micronutrient	No*
Molybdenum	Mo	Yes	Micronutrient	No*
Nickel	Ni	Yes	No	Yes
Phosphorus	P	No	Macronutrient	No
Potassium	K	Yes	Macronutrient	No
Sodium	Na	Yes	(Micronutrient?)	No
Sulphur	S	Yes	Macronutrient	No*
Zinc	Zn	Yes	Micronutrient	No*

* Indicates no toxicity to vegetation at nutrient levels, toxicity at higher levels.

The **TREE TISSUE ELEMENTAL CONCENTRATIONS ANALYSIS PROCEDURE (#35)** is based on the United States Environmental Protection Agency (1996) Method 3052, and is to be used in the elemental analysis of foliar samples.

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PROCEDURES

Forest Health Monitoring Program 2018 Procedures

TEEM Forest Health Monitoring Program procedures have been developed to standardize data and sample collection.

Procedures #6, #27, #31, #36, #37 and #39 are not applicable in the 2018 monitoring campaign and have been removed from the 2018 TEEM Procedures Manual (this version). One new procedure (#40) has been added to the program for 2018. The procedures, and the TEEM data forms that are associated with specific procedures, are listed below.

Procedure Number	Procedure Name	TEEM Data Form Number & Name
1	Sample Labelling	
2	Sample Storage & Shipping	
3	Site Information	01 – Stand Interior Site Information E01- Stand Edge Site Information
4	Reference Stake Installation & Geo-Referencing	
5	Tree Numbering & Labelling	
7	Soil Description	10 – Soil Description
8	Soil Sample Location & Checklist	11 – Soil Sample Locations
9	Soil Sample Preparation & Weighing	
10	Soil Texture Analysis	
11	Soil pH Analysis	
12	Soil Electrical Conductivity Analysis	
13	Soil Cation Exchange Capacity Analysis	
14	Soil Exchangeable Cations Analysis	
15	Soil BC:Al Calculation	
16	Soil Base Saturation Percentage Calculation	
17	Total Sulphur, Nitrogen & Carbon Analysis	
18	Soil C:N Calculation	
19	Soil Complexed Aluminum & Iron Analysis	
20	Soil Soluble Cations Analysis	
21	Soil Soluble Nitrogen Analysis	
22	Soil Soluble Phosphorus Analysis	
23	Soil Inorganic Sulphur Analysis	

Procedure Number	Procedure Name	TEEM Data Form Number & Name
24	Tree Mapping Measurements	02 – Stand Interior Vegetation Plot Map E02 – Stand Edge Vegetation Plot Map
25	Tree Coring	
26	Tree Core Preparation & Analysis	X05 – Stand Interior Off-Plot Tree Growth Ring Analysis EX05 – Stand Edge Off-Plot Tree Growth Ring Analysis
28	Tree Data	03 – Vegetation Plot Tree Data X03 – Off-Plot Tree Data E03 – Edge Monitoring Site Tree Data EX03 – Edge Monitoring Site Tree Data
29	Tree Shoot Data	X06 – Off-Plot Tree Softwood Shoot Data E06 – Edge Tree Shoot Data
30	Foliar Sample Collection & Checklist	
32	Foliar Tissue Sample Preparation	
33	Foliar Tissue Inorganic Sulphur (S_i) Analysis	
34	Foliar Tissue Organic Sulphur (S_o) and S_i:S_o Calculations	
35	Tree Tissue Elemental Concentrations Analysis	
38	Plant Community Assessment	08a – Stand Interior Daubenmire Cover Class Assessment 08b – Stand Interior Absolute Cover Assessment 09 – Stand Interior Daubenmire Summary E08a – Stand Edge Daubenmire Cover Class Assessment E08b – Stand Edge Absolute Cover Class Assessment E09 – Stand Edge Daubenmire Summary
40	Regeneration and Sapling Survey	05 – Regeneration and Sapling Survey E05 – Regeneration and Sapling Survey

PROCEDURE #1
SAMPLE LABELLING

1.1 Background

Sample labeling is a critical activity in the preservation of sample integrity. Incorrect, incomplete, ambiguous, worn and lost labels create uncertainty regarding the contents of the sample, possibly causing the sample to be discarded. With proper labelling, replacement of worn labels, and ensuring label accuracy through the entire process, the label information created and affixed to a sample in the field should be no different than that ultimately affixed to a sample when it is placed into the TEEM archive.

1.2 Summary of Labelling Requirements

Labelling procedures are meant to convey all necessary sample information in a permanent and redundant manner, reducing the potential for loss of label information by wearing or loss of an individual label. A minimum of two labels is to be attached to all samples, using two different methods. The methods are specific to sample type, summarized in the following table and as defined in detail by sample type in the sections that follow.

Required Information	Format	Soil		Needles		Tree Core	
		Pit	Plot	Stand Interior	Stand Edge	Stand Interior	Stand Edge
Sample Date	YYYY-MM-DD	X	X	X	X	X	X
Site	5-character site name	X	X	X	X	X	X
Field Personnel	Initials	X	X	X	X	X	X
Horizon Designation	Soil pit horizon; add suffix “-x” to the horizon designation to identify field duplicate	X					
Soil Plot	Plot number, from 1 to 4; field duplicates labelled from A to D, for plots 1 to 4, respectively		X				
Soil sample location	Sample location, from 1 to 9 (or 1 to 6 in smaller plots)		X				
Depth Increment	One of: “LFH”, “0-5cm”, “5-15cm”, “15-30cm”, “30-50cm”		X				
Tree Number	The tree label (e.g., “010”, “X10” “E10” or “EX10”). Field duplicate samples are identified by the same tree label, preceded with a “D” (e.g., “D010”, “DX10”, or “DEX10”)			X	X	X	X
Sample Age Class	One of: “CAG”, “Age-1”, “Age-2”			X	X		

1.3 Soil Samples

Soil samples are to be contained in a plastic bag, which placed into a second plastic sealable zipper bag. Both bags are to be labelled, and a paper label placed between the two bags.

Label information for soil samples is defined in the table below. A permanent blue or black marker (e.g., "Sharpie" brand) is to be used to directly label plastic sample bags. Waterproof paper (e.g., "Write in the Rain" brand) and pencil are required to prepare paper labels to insert between sample bags.

Required Label Information for Soil Samples

Required Information	Soil Pit	Soil Plot	Required Format
Sample Date	X	X	Date as YYYY-MM-DD (July 9, 2011 would be recorded as "2011-07-09")
Field Personnel	X	X	The initials of the person(s) collecting the sample. Three initials (including middle initial) are to be used; if initials create ambiguity (e.g., John M. Smith and Jane M. Shaw conducted the sampling), use of a first or last name on the sample label is required to uniquely identify individuals.
Site	X	X	The 5-character sample site designation
Horizon Designation	X		The horizons sampled from the soil pit, abbreviated according to Canadian terminology. The abbreviation used on the label is to exactly match that entered into TEEM Form 10*. Field duplicates are to be indicated by adding the suffix "-x" to the horizon designation. Thus, the field duplicate for the LFH sample would be identified as "LFH-x"
Soil Plot		X	Soil plot number, from 1 to 4 The field duplicate sample is to be labelled from A to D, with "A" representing soil plot 1, "B" representing soil plot 2, "C" representing soil plot 3, and "D" representing soil plot 4, respectively
Soil Subplot		X	Soil subplot number, from 1 to 4. This applies to the field duplicate sample as well
Soil sample location		X	Sample location, from 1 to 9 (or 1 to 6 for smaller plots). This applies to the field duplicate sample as well
Depth Increment		X	One of: LFH 0 to 5 cm 5 to 15 cm 15 to 30 cm 30 to 50 cm (site establishment year only)

* TEEM Form 10 is part of the **SOIL DESCRIPTION PROCEDURE (#7)**

1.4 Jack Pine Needle Samples

Harvested shoots containing needles of a specific age class are to be collected into a plastic zipper bag in the field. At the end of the field day, samples are to be transferred to a brown paper bag for storage or shipping to the laboratory.

Label information for needle samples is defined in the table below. A permanent blue or black marker (e.g., “Sharpie” brand) is to be used to directly label plastic or paper sample bags, and waterproof paper (e.g., “Write in the Rain” brand) and pencil are required to prepare paper labels to insert into the sample bags.

Required Label Information for Jack Pine Needle Samples

Required Information	Interior Site	Edge Site	Required Format
Sample Date	X	X	Date as YYYY-MM-DD (July 9, 2011 would be recorded as “2011-07-09”)
Field Personnel	X	X	The initials of the person(s) collecting the sample. Three initials (including middle name) should be used; if initials create ambiguity (e.g., John M. Smith and Jane M. Shaw conducted the sampling), use of a first or last name on the sample label is required to uniquely identify individuals.
Site	X	X	The 5-character sample site designation
Tree Number	X	X	Tree tree label (e.g., “X06” for off-plot trees, “EX06” for edge plot trees) Field duplicate samples are identified by the same tree label, preceded with a “D” (e.g., “D010”, “DX10”, or “DEX10”)
Sample Age Class	X	X	One of: CAG (Current Annual Growth) 1-Year-Old 2-Year-Old

1.5 Tree Core Samples

Tree cores are to be placed into plastic straws and the ends stapled closed. A masking tape label is to be prepared by wrapping a length of tape around one end of the straw, and sticking one end of the tape to the other create a writing space of about 3 cm length. A permanent blue or black fine-point marker (e.g., “Sharpie” brand) is to be used to write the sample information on the tape. Label information for tree core samples is defined in the table below. This is the only sample type where a single label is permitted.

Required Information	Interior Site	Edge Site	Required Format
Sample Date	X	X	Date as YYYY-MM-DD (July 9, 2011 would be recorded as “2011-07-09”)
Field Personnel	X	X	The initials of the person collecting the core. Three initials (including middle name) should be used; if initials create ambiguity (e.g., John M. Smith and Jane M. Shaw conducted the sampling), use of a first or last name on the sample label is required to uniquely identify individuals
Site	X	X	The 5-character sample site designation
Tree No.	X	X	Tree label (“X10”, “EX10”)

1.6 Labelling Requirements when Transferring Samples

The information on a sample label must be completely transferred to a new container when transferring the sample to that container. If replacing a container with the same type of container, the label(s) on and/or in the new container must be of the same type and configuration as those associated with the old.

1.7 Label Replacement

Each time a sample is handled, the labels on the sample are to be examined. Damaged labels are to be replaced using the same materials as were used in the original label, and the labels must contain the same information as was contained on the original label, in its entirety.

PROCEDURE #2
SAMPLE STORAGE & SHIPPING

2.1 Background

Samples acquired in the TEEM Forest Health Monitoring Program are subject to post-sampling biogeochemical processes that may alter sample composition. Proper storage is required to preserve sample integrity, from initial sample acquisition in the field through to ultimate storage in the TEEM sample archive facility.

2.2 Storage & Shipping Plan

It may be necessary to store samples for periods of up to a few days before they can be shipped to the laboratory(ies). In advance of a field sampling campaign, a storage and shipping plan is to be developed that takes into consideration the number and volume of samples anticipated each day, the storage requirements for these samples, the size and number of containers needed to ship the samples to the laboratory(ies), the shippers available and any restrictions they may have, and the shipping schedules. The shipping plan must include a process to quickly return empty coolers from the laboratory, otherwise, the capacity of the interim storage facility may be exceeded.

2.3 Storage in the Field

Soil and needle samples are to be placed in coolers immediately after sampling. Pre-frozen (-20°C or colder) freezer packs in sufficient number to cool the samples during the remainder of the day are to be included in the cooler, distributed among the samples. The number of coolers and freezer packs required must be determined at the beginning of each field day, such that the appropriate field sample storage capacity is available for samples collected during the field day. Once full, a cooler should not be opened, as doing so will advance the warming of the samples.

2.4 Interim Storage

At the end of each field day, samples are to be removed from the coolers for inspection, and as required, actions taken to correct sample labelling and/or damage to sample containers (e.g., punctured sample bag). This inspection is to be conducted in a clean environment, under cool, shaded conditions, and by personnel wearing and using appropriate sampling equipment (e.g., nitrile gloves, stainless steel instruments).

Soil samples are to be stored at 4°C or colder. Freezing soil samples (to -20°C) will help maintain samples at a cold temperature for the duration of shipping. Plant tissue samples are to be stored at -20°C or colder.

2.5 Sample Shipping

Samples are generally shipped in large coolers.

Soil samples are to be cooled to 4°C or colder prior to packaging for shipping. Sufficient ice packs frozen to -20°C (or colder) are to be included in sufficient numbers in each cooler to maintain a maximum sample temperature of 4°C for the duration of the shipping period. Coolers are to be packed in a manner that does not exceed a maximum weight restriction of the chosen shipper.

Tissue samples are to be frozen (-20°C or colder) and packaged with a sufficient number of ice packs (frozen to -20°C or colder) to maintain a maximum temperature inside the cooler of 4°C for the duration of the shipping period.

The chain-of-custody forms for each sample set are to be signed and dated, a copy retained by the shipper, inserted into a waterproof, sealable plastic bag, and placed into one of the coolers. The coolers are to be tightly sealed, including drainage and/or vent ports. Leakage of meltwater from the coolers may cause the shipping company to suspend transport until the leaking liquid can be identified to the shipper's satisfaction. The laboratory and return addresses and phone numbers are to be clearly indicated on each cooler, and the cooler number and the total number of coolers being shipped (e.g., "4 of 10" or "4/10") identified. Waybills, shipping forms, and any other documentation provided by the shipping company are to be retained and provided to the TEEM Program Manager.

2.6 Storage at the Laboratory

Proper sample storage at each laboratory is the responsibility of laboratory personnel. This responsibility begins at the time of sample delivery and signing of the chain-of-custody form(s) by the laboratory representative. Each laboratory is to be made aware of the samples that will be sent to them prior to the field sampling campaign, including the types and number of samples, the expected analyses, and the approximate dates on which the samples will be delivered.

Upon arrival at the laboratory, soil samples are to be split into two subsamples, in an approximate 3:1 ratio. The larger subsample is to be immediately set out to dry, or frozen until capacity for drying is available. The smaller field moist subsample is to be labelled and double-bagged using sealable, plastic bags, and labelled according to the **SAMPLE LABELLING PROCEDURE (#1)**. This subsample is to remain in field moist condition, for the analysis of available nitrogen and sulphur. This analysis must be initiated immediately, or the subsample frozen until analysis.

2.7 Sample Archive

Residual samples, the amounts remaining after completion of all required laboratory analyses, are to be placed in the TEEM Forest Health Monitoring Program sample archive. The chain-of-custody form is to be signed and dated upon transfer of sample control from the laboratory to TEEM.

Prior to their placement in the archive facility, each sample is to be inspected, and as required, actions taken to correct sample labelling and/or damage to sample containers (e.g., punctured sample bag). This inspection is to be conducted in a clean environment, under cool, shaded conditions, and by personnel wearing and using appropriate sampling equipment (e.g., nitrile gloves, stainless steel instruments).

The majority of samples in the archive will be fully dried, and put into labelled, airtight containers. Some may remain in field moist condition; these are to be stored in a freezer (maximum temperature of -20°C).

PROCEDURE #3
SITE INFORMATION

3.1 Background

Topographic information about the site is required at the time of site establishment. This procedure applies to both stand interior and stand edge monitoring sites.

3.2 Jack Pine Monitoring Site Information

Site information for a new monitoring site is to be recorded on using TEEM Form 01 (stand interior site) or TEEM Form E01 (stand edge site) Practitioners should complete this form in detail, ensuring that a person who had not visited the site is able to visualize the location of the plot on the terrain. Site information and observations should be from the perspective of the vegetation plot. TEEM Forms 01 and E01 are to be completed as follows:

TEEM Forms 01 (Stand Interior) and E01 (Stand Edge) Monitoring Site Information

Field(s)	Field Name	Required Information
1 to 5	Site	5-Character site designation
6 to 9	Year of Establishment	The 4-digit year of plot establishment (e.g., “2011”)
10 to 17	Date of Plot Staking	The date of vegetation plot staking, in the format YYYY-MM-DD (July 9, 2011 would be recorded as “2011-07-09”)
18 to 20	Personnel	Three fields are provided for the full names of the personnel involved
21	Location	A written description of the location, including names, directions and distances to nearest landmarks (creeks, roads, etc.) and comments on the location of the helicopter landing pad relative to the reference stake. All information that is or may be relevant should be included
22 to 26	Datum, Zone	Projection
27 to 34	Easting	Easting coordinate in UTM (NAD83) format
35 to 42	Northing	Northing coordinate in UTM (NAD83) format
43 to 46	Elevation	A GPS unit with elevation capability is to be used to determine elevation, a four-digit value is used to determine elevation above sea level, to the nearest metre (e.g., 389 m asl would be recorded as “0389”)
47 to 49	Plot Orientation	Three-digit number indicating the compass bearing from true North of the longer axis of the vegetation plot (e.g., 82° would be recorded as “082”)
50 & 51	Slope	The slope in percent is recorded as a two-digit number (e.g., 4% would be recorded as “04”; a flat site would be recorded as “00”)
52 & 53	Aspect	The compass direction of the downward slope at the site in a 2-character format: N-, NE, E-, SE, S-, SW, W-, or NW (cardinal compass points are written as a 2-character code, the second code being a hyphen “-“). A flat site is to be recorded as “FL”

Field(s)	Field Name	Required Information
54	Terrain Position	A one-digit code is used to designate the position of the vegetation plot in relation to the surrounding topography: 1 = top and upper slope, including the convex area on the slope top 2 = midslope, an area of uniform slope between slope top and bottomland, or between a bench and either slope top or bottomland 3 = bench, an area of level terrain with midslope profiles above and below 4 = lower slope, the concave area on the lower part of the slope 5 = flatland, level or near level terrain 6 = bottomland, an area subject to a high water table As jack pine grows on well-drained, sandy soils that are generally elevated above the surrounding terrain, slope position for jack pine sites will usually be designated as 1 (top and upper slope), 5 (flatland), or 3 (bench). Application of any other designation should cause the practitioner to pause in site establishment, and confirm that the plots are being established in the correct location
55	Remarks	Comments and information allowing for clearer understanding of the data and information

Full use of the Remarks field is encouraged. Information or comments that may be helpful to staff preparing site documents and reports, to personnel conducting future sampling programs at the site, and observations that might assist in interpretation of sample data should be written into this field (use additional pages if necessary).

PROCEDURE #4
REFERENCE STAKE INSTALLATION & GEO-REFERENCING

4.1 Background

Staking and geo-referencing using a combination of GPS coordinates and ground measurements is required at each site. These coordinates and measurements permit the derivation of an accurate site drawing, of value in tracking site status and in evaluating the potential locations of additional monitoring components in a manner that does not compromise those already in place.

Once coordinates have been acquired at a monitoring site and the accepted as the formal coordinates for the site, personnel should use them to navigate to the monitoring sites and plots, refraining from taking additional coordinates. Obtaining additional coordinates creates potential confusion, as variances in coordinates for a single location will occur due to differences in GPS units, varying satellite coverage, and differences in GPS user skills.

4.2 Coordinate Formats

Forest Health Monitoring Program coordinates are to be in Universal Transverse Mercator (UTM) format (Easting, Northing). Proper use of UTM requires that GPS units be set to the North American Datum 83 (NAD83).

Helicopter pilots typically prefer to navigate using coordinates in decimal degree format (DD.ddddd). Helipad coordinates are to be provided in both UTM and DD.ddddd formats to facilitate efficient heli-flight navigation.

4.3 Common Procedure

The reference stake is a permanent installation. A 50-cm long white plastic, hollow stake (e.g., 2" PVC) is to be driven into the ground to a depth of about 25 cm, leaving about 25 cm of plastic stake above ground. In the centre of this stake, a 1-m (minimum) length of rebar (or equivalent) is to be driven into the ground until about 25 cm remains above the top of the plastic stake. Geo-referencing the layout of plots and equipment at the site from this stake will allow re-establishment of the site after a major disturbance, such as a forest fire.

Where the edge monitoring site is close to, and within sight of the reference stake at the interior stand monitoring site, the reference stake at the interior site is to be used as the geo-referencing location for both the interior and edge monitoring sites.

A GPS unit capable of providing an accuracy of 3 m or better is to be used to record the location of the reference stake. If the GPS unit is capable of averaging, the GPS unit is to be placed on top of or immediately adjacent to the reference stake and set to average over 20 or more readings. The combination of averaged location readings and a 3 m or better accuracy will ensure that the reference stake can be accurately located and can be found in future years.

Where plot corners and site features occur close to the reference stake, a 100 m tape measure can be used to measure distances from the reference stake to the plot corner nearest the reference stake, and to other site features. GPS coordinates may be used to locate plots and/or site features more distant than 100 m from the reference stake.

From the reference stake, a bearing is to be taken (corrected for declination) to the nearest corner of each vegetation and soil plot, to the centre of the off-plot tree area(s), the soil pit, and to any other monitoring system or equipment deployed at the site.

From the geo-referenced corner of each plot, a compass bearing (corrected for declination) down the long side of the plot is to be obtained.

GPS coordinates are to be obtained for any other feature relating to the monitoring program (e.g., helipad), and for any other terrain feature that may be relevant to orientation around the site and/or to the monitoring program itself.

PROCEDURE #5
TREE NUMBERING & LABELLING

5.1 Background

Plot and off-plot trees are to be uniquely marked, with redundancy in marking methods to ensure that at least one mark is clearly visible at all times. Each time a site is visited, tree markings are to be examined, and as necessary, refreshed or replaced.

5.2 Procedure Common to Interior Stand and Edge Stand Sites

Trees selected for monitoring are to be labelled using numbered aluminum tags attached to the trunk at about eye level using coated 18 or 24-gauge copper wire. The wire is to be wrapped tightly enough to prevent slipping of the tag, but loose enough to provide space for lateral growth of the tree.

A line 1.3 m above ground level is to be painted (using tree paint) onto both sides of the trunk, defining the level at which DBH measurements will be taken. Above this line, the tree number is to be painted on each side of the tree. (e.g., “1”).

5.3 Interior Stand Monitoring Sites

5.3.1 Interior Stand Vegetation Plot Trees

A three-digit tree number is assigned to each tree, in the format of “001”. This number is to be etched onto the aluminum tag attached to the tree.

5.3.2 Interior Stand Off-Plot Trees

The number assigned to off-plot trees is a two-digit number and preceded with an “X”. Thus, the 10th off-plot tree to be labelled at a site will have the number “X10”. This number is to be etched onto the aluminum tag attached to the tree and painted onto each side of the trunk (e.g., “X1”).

New numbers are to be assigned to replacement off-plot trees in sequence from the last number used at the site. Numbers are not to be reassigned.

5.4 Edge Stand Monitoring Sites

5.4.1 Edge Stand Vegetation Plot Trees

A two-digit tree number is assigned to each edge plot tree, in the format of "01", preceded with an "E". Thus, the 12th edge vegetation plot tree is to be assigned the number "E12". The number assigned to an edge monitoring site tree is permanent. This number is to be etched onto the aluminum tag attached to the tree. The number without the preceding "E" and leading zeros is to be painted onto each side of the trunk (e.g., "1").

5.4.2 Edge Stand Off-Plot Trees

The number assigned to off-plot trees is a three-digit number and preceded with an "EX". Thus, the 10th off-plot tree to be labelled at a site will have the number "EX10". This number is to be etched onto the aluminum tag attached to the tree, and painted on both sides of the tree without the preceding "E" and leading zeros is to be painted onto each side of the trunk (e.g., "X1").

New numbers are to be assigned to replacement off-plot trees in sequence from the last number used at the site. Numbers are not to be reassigned.

PROCEDURE #7
SOIL DESCRIPTION

7.1 Background

A soil pit for soil classification is required only at stand interior monitoring sites.

The soil exposed in the pit is to be described in sufficient detail that, together with the results of the laboratory analysis of pit samples, the soil can be classified into the appropriate subgroup of the Canadian System of Soil Classification (Soil Classification Working Group, 1998[1]), and assigned the appropriate soil map unit.

7.2 Soil Description

The soil pit information is acquired using TEEM Form 10, completed as follows:

TEEM Form 10 – Soil Description

Field(s)	Field Name	Required Information
1 & 2	Page _ of _	Complete as appropriate. The first page (Fields 1 to 62) is identified by an "A"; the second page (Fields 1 to 49 and 63 to 75) is identified by a "B"
3 to 7	Site	5-Character site designation
8 to 15	Assessment Date	The date, in the format YYYY-MM-DD (July 9, 2011 would be recorded as "2011-07-09")
16 to 18	Personnel	Three fields are provided for the full names of the personnel involved
19 to 23	Datum, Zone	Projection
24 to 31	Easting	Soil pit Easting coordinate in UTM (NAD83) format
32 to 39	Northing	Soil pit Northing coordinate in UTM (NAD83) format
40 to 49	Horizon Designation	The horizons exposed in the soil pit are to be named according to Canadian terminology. Ten fields are provided; use additional pages for soils having more than 10 distinct horizons
50	Depth from Top to Bottom	The depth from the H/A interface to the top and bottom of each horizon is to be recorded to the nearest centimetre
51 to 53	Colour	The colour of the horizon is to be assigned using the Munsell notation (Field 51), the colour name (Field 52), and a note as to whether the soil is moist or dry at the time of examination (Field 53)
54	Texture	Soil texture by feel is to be recorded
55 to 57	Mottles	The presence of mottles in each horizon is to be noted in terms of colour, abundance, and contrast with the soil matrix
58 to 62	Structure	Horizon structure is to be noted by grade (Field 58), distinctness (Field 59), class (Field 60), size (Field 61), and type (Field 62)
63	Consistency	By horizon, the resistance of the soil to deformation and the degree of cohesion/adhesion is to be noted

[1] Soil Classification Working Group (1998) *The Canadian System of Soil Classification (third edition)*. http://sis.agr.gc.ca/cansis/references/1998sc_a.html

Field(s)	Field Name	Required Information
64	Roots	The abundance, size, orientation, distribution and depth of penetration of roots are to be recorded
65	Pores	The abundance, size, orientation, distribution and depth of penetration of pores are to be recorded
66 to 69	Clay Films	Record the frequency, thickness, location and colour of clay films
70	Horizon Boundaries	Record the distinctness of the lower boundary of each horizon, the form of the horizon boundary, and any other characteristic of the boundary
71	Coarse Fragment Content	For the whole pit, provide an estimate in percent (v/v) of the coarse fragment content, and describe the shape, kind, size and name of coarse fragments
72 to 74	Photos	Record photograph number(s), the direction of view of each photograph(s), and other information that will assist in identifying the photograph(s) in the future
75	Remarks	Any other features observed

Full use of the remarks field is encouraged. Information or comments that may be helpful to staff preparing site documents and reports, to personnel conducting future sampling programs at the site, and observations that might assist in interpretation of sample data should be written into this box (use additional pages if necessary).

PROCEDURE #8
SOIL SAMPLE LOCATION & CHECKLIST

8.1 Soil Sample Location

Soil sampling by depth is required only at stand interior monitoring sites during the 6-year monitoring cycle. The locations of the soil samples taken from within each soil subplot during a the 6-year monitoring cycle are to be recorded in TEEM Form 11, as follows:

TEEM Form 11 – Soil Sample Locations

Field(s)	Field Name	Required Information
1 & 2	Page _ of _	Complete after collecting the last subplot soil sample
3 to 10	Assessment Date	Date as YYYY-MMM-DD (July 9, 2011 would be recorded as “2011-JUL-09”)
11 to 13	Personnel	Three fields are provided for the full name(s) of the personnel conducting the assessment
14 to 18	Site	5-Character site designation
19	Plot	The 1-digit soil plot number (1 to 4) The field duplicate sample is to be labelled from A to D, with “A” representing soil plot 1, “B” representing soil plot 2, “C” representing soil plot 3, and “D” representing soil plot 4
20	Subplot	The 1-digit soil subplot number (1 to 4). This applies to the field duplicate sample as well
21	Random Number	The 1-digit random number used to select the sampling location
22	Sample Location	The 1-digit number identifying the sample location. This applies to the field duplicate sample as well
23	Adjustment	Enter “Yes” if any adjustment was required in the sample location (i.e., to avoid interference from a tree, to avoid disturbance), or “No”. If “Yes”, describe in Field 24
24	Remarks	Enter remarks specific to the sample location. If “Yes” in Field 23 (Adjustment), enter measurements from subplot boundaries to sample location, and the reason that adjustment was required. Continue in general remarks (Field 25) if additional space is required
25	Remarks	Enter general remarks about soil sampling

8.2 Soil Sample Checklist

Prior to initiating the field program, a sample checklist is to be prepared and used by field personnel to ensure that all required samples are acquired, minimizing the potential for incorrect or incomplete sampling in the field. The soil sample checklist for the 6-year monitoring cycle in its current configuration is presented below.

6-Year Soil Monitoring Program – Soil Sample Checklist (per Site)

Depth	Number of Plots (a)	Number of Subplots (b)	Number of Samples by Depth (a x b)	Total Number of Samples
Site Establishment Year				
LFH	4	4	16	85
0 to 5 cm	4	4	16	
5 to 15 cm	4	4	16	
15 to 30 cm	4	4	16	
30 to 50 cm	4	4	16	
Field duplicate LFH	1	1	1	
Field duplicate 0 to 5 cm	1	1	1	
Field duplicate 5 to 15 cm	1	1	1	
Field duplicate 15 to 30 cm	1	1	1	
Field duplicate 30 to 50 cm	1	1	1	
6-Year Monitoring Cycle				
LFH	4	4	16	68
0 to 5 cm	4	4	16	
5 to 15 cm	4	4	16	
15 to 30 cm	4	4	16	
Field duplicate LFH	1	1	1	
Field duplicate 0 to 5 cm	1	1	1	
Field duplicate 5 to 15 cm	1	1	1	
Field duplicate 15 to 30 cm	1	1	1	

PROCEDURE #9
SOIL SAMPLE PREPARATION

9.1. Division of Soil Samples

Upon receipt at the laboratory, soil samples are to be split into two subsamples in an approximate 3:1 ratio. The larger of the subsamples will be dried, while the smaller is to be reserved in field moist condition for the analyses of soluble nutrients (sulphur and nitrogen). The field moist subsample is to be stored at 4°C, unless analyses will be substantially delayed, in which case, storage in a freezer (-20°C) is required.

9.2. Soil Sample Drying and Preliminary Sieving

The larger of the soil subsamples are to be dried, preferably in a dedicated drying room. Samples are transferred to a drying tray, and the paper label is to be placed in or under the drying tray. Oven drying is not required.

After drying, the 75% subsample is to be passed through a 2 mm sieve. Lumps of soil may be broken by hand. This sieved material is to be put into a sturdy plastic container, labelled according to the **SAMPLE LABELLING PROCEDURE (#1)**, and sealed until required for analysis.

9.3. Soil Sample Grinding

9.1.1 Field Moist Samples

Care must be taken to obtain a representative, field moist sample. In a cold room, LFH samples are to be roughly homogenized (10 to 20 seconds) in a commercial stainless steel food processor (chilled), taking care to prevent the samples from warming or losing moisture.

Once sufficient field moist material is obtained for analyses, the remainder is to be dried and milled.

9.1.2 Dried LFH and Mineral Soil Samples

Dried LFH material is to be ground to pass through a 2 mm screen using a Wiley mill equipped with hardened steel blades. Care must be taken to ensure mineral component does not enter the mill otherwise damage may result. Ground material is to be put into plastic container, leaving sufficient headspace to permit proper mixing of the material without opening the container. The

container is to be labelled according to the **SAMPLE LABELLING PROCEDURE (#1)** and sealed until required for analysis.

Grinding to a 100-mesh particle size is required for some of the analyses. A subsample of the 2 mm sieved sample is to be obtained in a manner that is representative of the sample, and ground using either a high-speed centrifugal mill, ball mill or ring grinder. The ground material is to be put into an appropriate container (plastic vial), leaving sufficient headspace to permit proper mixing of the material without opening the container. The container is to be labelled according to the **SAMPLE LABELLING PROCEDURE (#1)** and sealed until required for analysis.

9.4. Moisture Correction

Analytical results are generally to be reported on a moisture-corrected basis. To correct for sample moisture, a representative subsample (approximately 40 g, weighed to ±0.01g precision) is to be taken and dried in an oven set to 105°C, for 24 to 48 hours. Upon removal from the oven, the container is to be tightly sealed, cooled and weighed to the same level of precision (±0.01g). From these two weights, the percent water content is to be calculated, and the results of each of the analyses performed on this sample are to be corrected for this water content.

PROCEDURE #10
SOIL TEXTURE ANALYSIS

10.1 Background

Each mineral soil horizon sampled from the soil pit is to be analysed for soil texture using the Bouyoucos Hydrometer procedure (Kalra and Maynard, 1991[1]; Kroetsch and Wang, 2008[2]), as applied to sandy soil samples containing up to 5% of organic matter.

10.2 Reagents

1. Water of ASTM Type II quality, or better.
2. Sodium hexametaphosphate at 50g/L, adjusted to pH 8.2 using $Na_2(CO_3)_2$.
3. Commercial amyl alcohol defoaming agent.

10.3 QA/QC Controls

1. Blank (1 per batch): leave a dispersion cup empty, process as if the cup contains a soil sample.
2. Reference standard (1 per batch): transfer approximately 40 g (weighed to ±0.01 g precision) of a sample of known sand, silt and clay content into a dispersion cup.
3. Replicate (1 per batch): from one randomly selected sample within the batch, transfer approximately 40 g (weighed to ±0.01 g precision) of 2 mm air-dried soil into a second dispersion cup.

10.4 Analysis

1. Transfer 40 g (weighed to ±0.01 g precision) 2 mm air-dried mineral soil to a dispersion cup.
2. Add 200 mL water.
3. Add 100 mL sodium hexametaphosphate solution and stir on the milkshake machine for 15 min.
4. Transfer the soil suspension quantitatively to the sedimentation cylinder.

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[1] Kalra YP, Maynard DG (1991) *Methods Manual for Forest Soil and Plant Analysis. Information Report NOR-X319*. Section 9. Forestry Canada Northwest Region, Northern Forestry Centre, Edmonton, Alberta

[2] Kroetsch D, Wang, C (2008) Particle size distribution. Section 55. *In* Carter MR, Gregorich EG (2008) *Soil Sampling and Methods of Analysis, Second Edition.* Canadian Society of Soil Science, CRC Press, Boca Raton FL. pp 713-725

5. Add water to bring the sample volume to 1 L (the blank is to consist of 100 mL hexametaphosphate solution and 900 mL water).
6. Cover the cylinder with a watch glass and let it stand overnight to equilibrate to room temperature or in a water bath that holds temperature to between 20°C and 25°C, on a vibration-free bench.
7. Insert the plunger close to the bottom of the cylinder and stir the suspension vigorously for 2 min. by moving the plunger up and down the whole length of the column (about 25 strokes), in order to loosen sediment settled on the bottom of the cylinder. Move the plunger cautiously near the top of the cylinder to avoid spilling the contents. It is important not to remove plunger out of the suspension or bubbles may form, disrupting sedimentation. Finish stirring with two or three slow, smooth strokes.
8. Remove the plunger, tipping it slightly to remove adhering drops of suspension.
9. Immediately lower a hydrometer gently into the suspension.
10. Add a couple of drops of amyl alcohol if the surface of the suspension is covered with foam.
11. Take the hydrometer reading (top of the meniscus) exactly 40 sec. after the completion of stirring.
12. Remove the hydrometer. Determine the temperature of the suspension at about 5 cm depth. Clean the hydrometer with water for the following suspensions.
13. Let the cylinder stand undisturbed for 2 hr.
14. Take hydrometer readings. Use the same hydrometer for all cylinders.

10.5 Calculations

1. Corrected hydrometer readings are obtained by subtracting the blank reading.
2. Calculate Sand, Silt and Clay contents as follows:

$$\text{Sand}(\%) = 100 - [(R_{40s} - R_{bl}) \text{ X } (100/\text{Moisture-corrected Sample Weight})]$$
$$\text{Clay}(\%) = (R_{2h} - R_{bl}) \text{ X } (100/\text{Moisture-corrected Sample Weight})$$
$$\text{Silt}(\%) = 100 - (\text{Sand}(\%) + \text{Clay}(\%))$$

R_{bl} = hydrometer reading of the blank
R_{40s} = hydrometer reading at 40 sec.
R_{2h} = hydrometer reading at 2 hr

PROCEDURE #11
SOIL pH ANALYSIS

11.1 Background

LFH and mineral soil samples used for this analysis are to be air-dried. The pH of a soil sample is measured using the procedure based on Kalra and Maynard (1991[1]).

11.2 Reagents

1. Water of ASTM Type I quality
2. 0.01 M $CaCl_2$, with a pH between 5.0 and 6.5 (adjusted with $Ca(OH)_2$ or HCl as required).

11.3 QA/QC Controls

1. Commercial standards: analyse a minimum of one each of pH 4 and 7 standards per sample batch.
2. Reference standard (1 per batch): transfer approximately 10 g (weighed to ±0.01 g precision) of a soil of known pH into a beaker.
3. Replicate (1 per batch): from one randomly selected sample within the batch, transfer 10 g (weighed to ±0.01 g precision) of 2 mm air-dried soil into a second dispersion cup.

11.4 Organic (LFH) Material

1. Weigh 10 g (weighed to ±0.01 g precision) of air-dried, 2 mm LFH material into a beaker.
2. Add 40 mL 0.01 *M* $CaCl_2$ solution.

11.5 Mineral Soil Material

1. Weigh 10 g (weighed to ±0.01 g precision) of 2 mm air-dried mineral soil into a beaker.
2. Add 20 mL of 0.01 *M* $CaCl_2$ solution.

[1] Kalra YP, Maynard DG (1991) *Methods Manual for Forest Soil and Plant Analysis. Information Report NOR-X319*. Chapter 7(ii). Forestry Canada Northwest Region, Northern Forestry Centre, Edmonton, Alberta

11.6 Analysis

1. Allow soil to absorb $CaCl_2$ solution without stirring.
2. Thoroughly stir for 10 sec., then stir for 10 seconds five times over 30 min.
3. Allow suspension to settle for 30 min.
4. Measure pH by immersing a combination electrode in the supernatant solution.
5. Record pH value when the reading has stabilized.

PROCEDURE #12
SOIL ELECTRICAL CONDUCTIVITY ANALYSIS

12.1 Background

Soil salinity is to be assessed by measuring the electrical conductivity (EC) of a soil extract (Miller and Curtin, 2008[1]).

12.2 Reagents

1. Water of ASTM Type I quality, or better

12.3 QA/QC Controls

1. Commercial standard (1 per batch): standard of known EC.
2. Reference standard (1 per batch): transfer 10 g (weighed to ±0.01 g precision) of LFH, or 20 g (weighed to ±0.01 g precision) of 2 mm air-dried mineral soil, of known EC into a 50 mL polypropylene centrifuge tube. Add water of a volume appropriate for the sample (defined above).
3. Replicate (1 per batch): from one randomly selected sample within the batch weigh approximately 10 g (weighed to ±0.01 g precision) of LFH, or 20 g (weighed to ±0.01 g precision) of 2 mm air-dried mineral soil into a 50 mL polypropylene centrifuge tube. Add water of a volume appropriate for the sample (defined above).

12.4 Organic (LFH) Soil

1. Weigh approximately 10 g (weighed to ±0.01 g precision) of air-dried, 2 mm LFH material into a 50 mL polypropylene centrifuge tube.
2. Add sufficient water to achieve 1:4 soil to water (w/v) ratio.

12.5 Mineral Soil

1. Weigh approximately 20 g (weighed to ±0.01 g precision) of 2 mm air-dried mineral soil into a 50 mL polypropylene centrifuge tube.
2. Add sufficient water to achieve 1:2 soil to water (w/v) ratio.

[1] Miller JJ, Curtin D (2008) Electrical conductivity and soluble ions. Section 15. *In* Carter MR,Gregorich E. G. (eds) *Soil Sampling and Methods of Analysis, Second Edition*, Canadian Society of Soil Scientists

12.6 Analysis

1. Shake the centrifuge tubes for 1 hr.
2. Decant, and centrifuge supernatant at 2,000 g for 10 min.
3. If analysis cannot be completed immediately after centrifugation, store filtrate at 4°C. Allow stored samples to warm to room temperature before analysis.
4. Read conductivity of extracts using EC probe and meter. Report results in units of S m^{-1} or dS m^{-1}

PROCEDURE #13
SOIL CATION EXCHANGE CAPACITY ANALYSIS

13.1 Background

The CEC analysis is based on the methods of Kalra and Maynard (1991[1]) and Skinner et al. (2001[2]).

13.2 Reagents

1. Water of ASTM Type I quality.
2. 1.0 M NH_4Cl, unbuffered.
3. 95% USP ethyl alcohol (ethanol).
4. 10% NaCl, acidified to 0.005 M using HCl.

13.3 QA/QC Controls

1. Standard solutions for calibration of the segmented flow analyser.
2. Reference standard (1 per batch): transfer approximately 0.5 g (weighed to ±0.01 g precision) of LFH, or approximately 2.5 g (weighed to ±0.01 g precision) of 2 mm air-dried mineral soil, of known CEC.
3. Blank (1 per batch): a sample tube without soil material added.
4. Replicate (1 per batch): from one randomly selected sample within the batch; approximately 10 g (weighed to ±0.01 g precision) of LFH, or approximately 20 g (weighed to ±0.01 g precision) of 2 mm air-dried mineral soil.

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[1] Kalra YP, Maynard DG (1991) *Methods Manual for Forest Soil and Plant Analysis. Information Report NOR-X319*. Section 15(ii). Forestry Canada Northwest Region, Northern Forestry Centre, Edmonton, Alberta

[2] Skinner MF, Zabowski D, Harrison R, Lowe A, Xue D (2001) Measuring the cation exchange capacity of forest soils. Comm. Soil Sci. Plant Anal. 32:1751-1754

13.4 Sample Weighing

Sample weight is dependent on the type of soil to be analysed.

For the organic horizon (LFH), weigh approximately 0.50 g (weighed to ±0.01 g precision) of air-dried, 2 mm material into an appropriate container.

For mineral horizons, weigh approximately 2.50 g (weighed to ±0.01 g precision) of air-dried, 2 mm mineral soil into an appropriate container.

13.5 NH_4Cl Extraction for Exchangeable Cations

1. Place a filter pad on top of the filter frit, within the sample tube, and close the tube.
2. Place the soil onto the filter pad, levelling if necessary.
3. Connect sample tube to upper disk of extractor.
4. Weigh lower collection syringe and plunger assembly (weighed to ±0.01 g precision) and connect assembly to lower disk of extractor.
5. Attach sample tube assembly to the collection syringe.
6. Fill sample tube to the 22.5 mL mark with 1.0 M NH_4Cl.
7. Stir, then rinse the stirring rod with NH_4Cl, bringing total volume to 25 mL.
8. Let stand for 20 min.
9. Extract rapidly (over 15 min) until about 15 mL of the solution has entered the collection syringe.
10. Wash the walls of the sample tube with extraction solution and top up to 45 mL.
11. Set extractor on 12-hour setting and leave it running overnight.
12. The next morning, turn off the extractor and pull the plungers down as far as the extractor will allow. Disconnect collecting syringes from rubber connectors and sample tubes.

Begin ethanol wash procedure (below), complete next two steps while ethanol wash is in progress.

13. Weigh syringe(s) containing the NH_4Cl extract (weighed to ±0.01 g precision).
14. Mix the NH_4Cl extract thoroughly, then either immediately initiate the **SOIL EXCHANGEABLE CATIONS ANALYSIS (#14)**, or place extract into storage (4°C).

13.6 Ethanol Wash

1. Reset extractor to starting position.
2. Attach new collection syringes to the sample tubes.
3. Rinse sides of sample tubes with 95% ethanol, filling tubes to the 22.5 mL mark.
4. Stir and rinse, bringing total volume to 25 mL.

5. Let stand for 20 min.
6. Extract rapidly (half-hour setting) until about 15 mL of ethanol have drained into the collection syringe. Turn off extractor.
7. Wash down sides of sample tubes and top up with ethanol to 45 mL.
8. Set extractor for 1.5 to 1.75 hr.
9. After extractor stops, turn off switch, pull plungers down, and remove syringes. Discard ethanol wash.
10. Remove reservoir tube and return extractor to starting position.
11. Reattach collection syringes to sample tube and add about 45 mL ethanol. Do not stir. Immediately extract again for approximately 45 min.
12. When extractor has stopped, remove collection syringes and discard ethanol wash.

13.7 NaCl Extraction

1. Attach pre-weighed (weighed to ±0.01 g precision) collection syringes.
2. Add 20 mL 10% NaCl solution to sample, stir.
3. Rinse with NaCl solution, bring total volume to the 25 mL mark.
4. Extract rapidly (half-hr setting), until about 15 mL has entered the collection syringe.
5. Wash sample tube sides with NaCl, bring volume to 15 mL mark, fill reservoir to 30 mL mark (total NaCl volume used should be about 60 mL).
6. Set extractor for 1.5 hr.
7. When completed, remove and weigh collection syringes (weighed to ±0.01 g precision).
8. Mix NaCl extract thoroughly, transfer to 50 mL centrifuge tube.
9. If samples cannot be analysed within 24 hr, freeze samples. For analysis, samples must be warmed to room temperature.
10. Analyse colourimetrially using a Segmented Flow Analyzer.

13.8 Calculations

Results are to be reported in units of $cmol^{+}/kg$, taking into account the reported sample reading from the flow analyser corrected for the sample blank, cation charges, molecular weights, volume of extractant (converted from weights), weight of sample, and the dilution factor.

PROCEDURE #14
SOIL EXCHANGEABLE CATIONS ANALYSIS

14.1 Background

The NH_4Cl extract containing the base cations that was set aside during the analysis of cation exchange capacity (**CATION EXCHANGE CAPACITY PROCEDURE (#13)**) is to be analysed for the concentrations of Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Mn^{2+}, Al^{3+}, and Fe^{2+}.

14.2 QA/QC Controls

Standards of appropriate concentrations for each of the analyte ions are to be used to calibrate the ICP-AES instrument.

14.3 Analysis

The NH_4Cl extract containing the base cations generated during the initial stages of extraction for Cation Exchange Capacity is to be analysed using ICP-AES for the concentrations of Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Mn^{2+}, Al^{3+}, and Fe^{2+}. Samples stored at 4°C are to be warmed to room temperature prior to analysis.

14.4 Calculations

Results are to be reported as cation concentration ($cmol^{+}/kg$), taking into account the reported ppm result from the ICP-AES instrument, cation charges, molecular weights, volume of extractant (converted from weights), weight of sample, and the dilution factor.

PROCEDURE #15
SOIL BC:Al RATIO CALCULATION

15.1 Background

The BC:Al ratio is a calculated value, based on the molar charge ($cmol^+/kg$) of Ca^{2+}, Mg^{2+}, K^+, Na^+ and Al^{3+} in the soil exchangeable cation extract that was analysed by ICP-AES (**SOIL EXCHANGEABLE CATION ANALYSIS PROCEDURE (#14)**).

15.2 Calculation

The BC:Al is derived by dividing the sum of the molar charges ($cmol^+/kg$) of Ca^{2+}, Mg^{2+}, K^+, and Na^+ by the molar charge ($cmol^+/kg$) of Al^{3+}. The ratio is unitless.

PROCEDURE #16
SOIL BASE SATURATION PERCENTAGE CALCULATION

16.1 Background

The Base Saturation Percentage (BS%) is derived from the exchangeable cation concentration divided by the cation exchange capacity.

16.2 Calculation

The BS% is calculated as the sum of molar charge ($cmol^+/kg$) of the exchangeable cations (Ca^{2+}, Mg^{2+}, K^+, Na^+) measured by ICP-AES (**SOIL EXCHANGEABLE CATIONS ANALYSIS PROCEDURE (#14)**) divided by the CEC ($cmol^+/kg$) (**SOIL CATION EXCHANGE CAPACITY PROCEDURE (#13)**), multiplied by 100.

The ratio is expressed as a percentage.

PROCEDURE #17
TOTAL SULPHUR, NITROGEN & CARBON ANALYSIS

17.1 Background

Total sulphur, nitrogen and carbon content in soils, plant tissues and lichens are to be measured using dry combustion (Skjemstad and Baldock, 2008[1]). Samples are flash combusted under helium in the presence of oxygen and the generated gases (SO_2, NO_2 and CO_2) are separated and analysed. Preference is given to an instrument capable of providing simultaneous measurement of sulphur, nitrogen and carbon. Instruments capable of performing one analysis alone, or two of the analyses simultaneously, are acceptable.

17.2 QA/QC

1. Appropriate commercial standards, matching the sample matrix as closely as possible.
2. Reference standard (1 per batch): an appropriate amount of LFH or mineral soil, plant tissue, or lichen tissue, of known total sulphur, nitrogen and carbon content.
3. Replicate (1 per batch): from one randomly selected sample within the batch.

17.3 Analysis

Micro-analysers require less sample material (e.g., 20 mg) than do macro-analysers (e.g., 500 mg). To ensure sample homogeneity, micro-analysers require a finely ground (<100 mesh) sample.

1. Weigh into a combustion crucible an appropriate amount of finely ground (100 mesh) sample material
2. Where required, add catalyst to the crucible.
3. Follow instrument procedures for combustion and analysis.

17.4 Calculations

The concentration of sulphur, nitrogen and carbon in the sample are to be recorded in μg S/g, μg N/g, and μg C/g, all on a dry weight (moisture-corrected) basis.

Details regarding the analytical, instrumented process, and instrument settings are to be reported with the data.

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[1] Skjemstad JO, Baldock JA (2008) Total and Organic Carbon. Chapter 21 *In* Carter MR and Gregorich EG (Eds.) *Soil Sampling and Methods of Analysis* 2nd Edition, Canadian Society of Soil Science, CRC Press Boca Raton, FL. pp 225-237

PROCEDURE #18
SOIL C:N CALCULATION

18.1 Background

The C:N ratio is indicative of nitrogen loading to soils.

18.2 Calculation

The carbon to nitrogen ratio (C:N) is calculated by dividing the carbon content of a sample by the nitrogen content, both derived from the results of the dry combustion analysis (**SOIL CARBON, NITROGEN & SULPHUR ANALYSIS PROCEDURE (#17)**).

The ratio is unitless.

PROCEDURE #19
SOIL COMPLEXED ALUMINUM & IRON ANALYSIS

19.1 Background

The extractions and analysis are based on Courchesne and Tunnel (2008[1]). The pyrophosphate extraction yields an extract containing organically-complexed Al and Fe, while the dithionate extraction yields an extract containing bulk (total) Al and Fe, within mineral soils. These results are used in the classification of the soil.

Both procedures below require that the mineral soil sample to be ground to pass through a 100 mesh screen.

19.2 Reagents

1. Water of ASTM Type I quality
2. 0.1 M sodium pyrophosphate
3. 0.68 M sodium citrate
4. Dithionite (sodium hydrosulfite; $Na_2S_2O_4$) crystal

19.3 QA/QC Controls

1. Standard solutions for calibration of the AAS or ICP instrument.
2. Reference standard (1 per batch): approximately 0.5 g (weighed to ±0.01 g precision) of LFH, or approximately 2.5 g (weighed to ±0.01 g precision) of 2 mm air-dried mineral soil, of known Al and Fe content.
3. Blank (1 per batch): a centrifuge tube without soil material added.
4. Replicate (1 per batch): from one randomly selected sample within the batch.

19.4 Pyrophosphate Extraction

1. Weigh approximately 300 mg (weighed to ±0.01 g precision) of ground (100 mesh) soil into a 50 mL screw-cap plastic centrifuge tube (use approximately 1 g for samples low in extractable Fe and Al, weighed to ±0.01 g precision).

[1] Courchesne F, Tunnel M-C (2008) Extractable Al, Fe, Mn, and Si. Section 26. *In* Carter MR, Gregorich EG (Eds) *Soil Sampling and Methods of Analysis, Second Edition*. Canadian Society of Soil Science, CRC Press Boca Raton, FL. pp 307-315

2. Add 30 mL of 0.1 *M* sodium pyrophosphate solution.
3. Stopper tightly and gently shake overnight.
4. Decant 2 mL into a small centrifuge tube, centrifuge at 20,000 g for 10 min.
5. Dilute the clarified sample 1:10 with water.

19.5 Dithionate Extraction

1. Weigh approximately 500 mg (weighed to ±1 mg precision) of ground (100 mesh) soil into a 50 mL screw-cap plastic centrifuge tube.
2. Add 25 mL of 0.68 *M* sodium citrate solution.
3. Add approximately 0.4 g of dithionite (sodium hydrosulfite: $Na_2S_2O_4$), using a calibrated scoop.
4. Stopper tightly and gently shake overnight.
5. Decant 2 mL into a small centrifuge tube, centrifuge at 500 g to 2,000 g for 20 min.
6. Dilute the clarified sample 1:10 with water.

19.6 Analysis

Determine Fe and Al in the pyrophosphate and dithionate extracts using AAS or ICP.

PROCEDURE #20
SOIL SOLUBLE CATIONS ANALYSIS

20.1 Background

The concentrations of the nutrient base cations in soil solution represent the pool of ions available to plants through root uptake. The analysis of soluble Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} is based on the methods of Kalra and Maynard (1991[1]) and Miller et al. (2008[2]).

20.2 Reagents

1. Water of ASTM Type I quality

20.3 QA/QC

1. Standard solutions for calibration of the ICP instrument.
2. Reference standard (1 per batch): 5 g (weighed to ±0.01 g precision) of LFH, or 10 g (weighed to ±0.01 g precision) of mineral soil, of known Na^{+}, K^{+}, Ca^{2+}, and Mg^{2+} content.
3. Blank (1 per batch): a polypropylene tube without soil material.
4. Replicate (1 per batch): from one randomly selected sample within the batch.

20.4 Organic (LFH) Soil Sample Preparation

1. Weigh about 5 g (weighed to ±0.1 g precision) of 2 mm air-dry LFH material into a plastic polypropylene tube.
2. Add sufficient water to achieve 1:8 soil to water ratio; add the water slowly so as to avoid overflowing of the tube.

20.5 Mineral Soil Sample Preparation

1. Weigh about 10 g (weighed to ±0.1 g precision) of 2 mm air-dry soil into a polypropylene tube.
2. Add sufficient deionized water to achieve 1:2 soil to water ratio.

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[1] Kalra YP, Maynard DG (1991) *Methods Manual for Forest Soil and Plant Analysis. Information Report NOR-X319*. Section 8(iv). Forestry Canada Northwest Region, Northern Forestry Centre, Edmonton, Alberta

[2] Miller JJ, Curtin D (2008) Electrical Conductivity and Soluble Ions. Section 15. *In* Carter MR, Gregorich EG *Soil Sampling and Methods of Analysis, Second Edition.* Canadian Society of Soil Science, CRC Press Boca Raton, FL. pp 141-159

20.6 Extraction & Analysis

1. Shake tubes at moderate speed for 1 hr.
2. Decant into a clean tube, centrifuge at 2,000 g for 15 min.
3. Store clarified sample at 4°C if analyses cannot be run immediately after centrifugation.
4. Filter using a 0.45 µm micropore filter, or pass through a serum separator.
5. Determine Na^{+}, K^{+}, Ca^{2+}, Mg^{2+} concentrations using ICP.
6. Report concentrations in units of $cmol^{+}/kg$.

PROCEDURE #21
SOIL SOLUBLE NITROGEN ANALYSIS

21.1 Background

The majority of nitrogen in the soil that is available to plants as nitrate (NO_3^-) and ammonium (NH_4^+). The analysis of the nitrate (NO_3^-) and ammonium (NH_4^+) levels in soil is based on the methods of Carter and Gregorich (2008[1]) and Kalra and Maynard (1991[2]).

There is some flexibility in this method, including the weights of samples analysed, the amount of extractant, and the instrument used in the quantification of NO_3^- and NH_4^+. Standard laboratory practices permit these variances, however, all variances employed must be reported with the results to the TEEM Program Manager.

21.2 Reagents

1. Water of ASTM Type I quality
2. 2 *N* KCl

21.3 QA/QC

1. Standard solutions for calibration of the analytical instrument.
2. Reference standard (1 per batch): 1 g (weighed to ±0.01 g precision) of LFH, or 2.5 g (weighed to ±0.01 g precision) of mineral soil, of known Na^+, K^+, Ca^{2+}, and Mg^{2+} content.
3. Blank (1 per batch): a polypropylene tube without soil material.
4. Replicate (1 per batch): from one randomly selected sample within the batch.

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[1] Maynard DG, Kalra YP, Crumbaugh JA (2008) Nitrate and Exchangeable Ammonium Nitrogen. Section 6.2. *In* Carter MR, Gregorich EG (2008) *Soil Sampling and Methods of Analysis, Second Edition*. Canadian Society of Soil Scientists

[2] Kalra YP, Maynard DG (1991) *Methods Manual for Forest Soil and Plant Analysis. Information Report NOR-X319*. Section 11(ii). Forestry Canada Northwest Region, Northern Forestry Centre, Edmonton, Alberta

21.4 Organic (LFH) Soil Sample Preparation

Care must be taken to obtain a representative, field fresh sample (**Soil Sample Preparation Procedure #9**).

1. Weigh about 1 g (weighed to ±0.01 g precision) of field moist LFH into a 50 mL polypropylene tube.

21.5 Mineral Soil Sample Preparation

1. Weigh about 2.5 g (weighed to ±0.01 g precision) of field moist mineral soil into a 50 mL polypropylene tube.

21.6 Extraction & Analysis

1. Add 25 mL 2 *N* KCl solution.
2. Shake sample for 1 hr.
3. Decant into a centrifuge tube, centrifuge at 2,000 g for 15 min.
4. If analysis cannot take place within 24 hr after extraction, refrigerate (4°C) clarified samples until analysis can be completed.
5. Determine NH_4^+ and NO_3^- in extracts using colourimetric determination, segmented flow analyser equipped with a dialysis membrane (to ensure suspended solids and coloured co-extractives don't interfere), or ion selective electrode.

21.7 Calculations

The concentrations of NH_4^+ and NO_3^- in the sample are to be expressed in g/kg soil, on a dry-weight (moisture-corrected) basis.

PROCEDURE #22
SOIL SOLUBLE PHOSPHORUS ANALYSIS

22.1 Background

Soluble phosphorus in soil samples is to be determined according to the Bray P-1 procedure as described in United States Department of Agriculture (2004[1]), which is based on Bray and Krutz (1945[2]). This procedure has been most successful on acid soils (Olsen and Sommers, 1982[3]). The acid solubilizes calcium and aluminum phosphates, and partially extracts iron phosphates compounds. Aluminum in solution forms a complex with the NH_4F, limiting re-adsorption of phosphorus on iron oxides (Kuo, 1996[4]).

22.2 Reagents

1. Water of ASTM Type I quality
2. Bray-1 extracting solution:
    1. Dissolve 8.88 g of NH_4F in 4 L of water.
    2. Add 200 mL 1.0 *N* HCL.
    3. Dilute to 8 L using reverse osmosis-deionized water.
    4. Confirm pH of 2.60 (±0.05).
3. Colour Reagent:
    1. Dissolve 2.0 g ammonium molybdate tetrahydrate $[(NH_4)_6Mo_7O_{24}•4H_2O]$ in 800 mL water in a 1 L volumetric flask.
    2. Add 0.025 g antimony potassium tartrate.
    3. Add 20 mL 0f 54% H_2SO_4.
    4. Add 2 g ascorbic acid.
    5. Bring to 1 L with water.
4. Standard phosphorus stock solution (prepare weekly):
    1. Dissolve 1.0985 g of oven-dried (2 hr at 105°C) potassium dihydrogen phosphate (KH_2PO_4) in Bray-1 extractant (about 150 mL) in a 250 mL volumetric flask.
    2. Bring to 250 mL with extracting solution.

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1 United States Department of Agriculture (2004) *Soil Survey Laboratory Methods Manual. Soil Survey Investigations Report No. 42.* Version 4.0. November 2004. Procedure 4D3b1. pp 234-239

2 Bray RH, Kurtz LT (1945) Determination of total, organic, and available forms of phosphorus in soils. Soil Sci. 59:39-45

3 Olsen SR, Sommers LE (1982) Phosphorus. *In* Page AL, Miller RH, Keeney DR (eds.) *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties.* 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI. p. 403-430

4 Kuo S (1996) Phosphorus. *In* Sparks DL (ed.) *Methods of Soil Analysis. Part 3. Chemical Methods*. No. 5. ASA and SSSA, Madison, WI. p. 869-919

22.3 QA/QC

5. Phosphorus calibration solutions (prepare weekly) by dilution of the standard phosphorus stock solution to prepare 0.0, 0.1, 0.5, 1.0, 5.0 and 10.0 mg/L calibration curve standards.
6. Reference standard (1 per batch): 2.5 g (±0.001) of LFH or mineral soil (both ground to 2 mm particle size), of known soluble phosphorus content.
7. Blank (1 per batch): a polypropylene tube without soil material.
8. Replicate (1 per batch): from one randomly selected sample within the batch.

22.4 Soil Sample Preparation

9. Weigh about 2.5 g (weighed to ±0.001 g precision) of 2 mm, air-dry soil (either LFH or mineral soil) into a 50 mL centrifuge tube.

22.5 Extraction & Analysis

10. Add 25 mL of Bray-1 extracting solution to centrifuge tube.
11. Place tube on shaker, shake for 15 min at medium speed.
12. Centrifuge at 2,000 g for 10 min.

Steps 2 (shaking time and speed) and 3 (centrifugation) must be rigidly standardized (within a laboratory, among laboratories, and from year to year). As long as sample and extractant are in contact, extraction continues, therefore, deviations in shaker and/or centrifuge times will cause variability within the available phosphorus dataset.

13. If analysis cannot take place within 24 hr after extraction, refrigerate (4°C) clarified samples until analysis can be completed.
14. Dilute 0.15 mL sample (supernatant) with 3.6 mL of colour reagent using a digital dilutor
15. Completely mix the sample and colour reagent.
16. Allow 30 min for colour development.
17. Analyse using a segmented flow analyser (use of a dialysis membrane is recommended if analyte concentration is high enough and particulates are of concern), or UV/Vis spectrophotometer set at an absorbance of 882 nm.

22.6 Calculations

Convert phosphorus concentration (mg/L) in the extract to soil phosphorus concentration (g P/kg) as follows:

Soil P (g/kg) = [(A x B x C x R x 1000 x 1000)/E] where:

A = instrument reading (mg/L)
B = extract volume (L)
C = dilution, if performed
R = field-moist/oven-dry ratio (**SOIL SAMPLE PREPARATION PROCEDURE (#9)**)
E = sample weight (g)

Report soluble phosphorus concentrations to the nearest 0.0001 g P/kg soil.

PROCEDURE #23
SOIL INORGANIC SULPHUR ANALYSIS

23.1 Background

Sulphur, in the form of sulphate (SO_4^{2-}), is a principal anion in acid deposition, and SO_4^{2-} is generally the primary form of inorganic sulphur (S_i) found in mineral soils.

The analytical procedures for LFH (Kalra and Maynard, 1991[1]) and mineral soil (Kalra and Maynard, 1991[2]) samples differ. The LFH material must be in field-moist condition.

23.2 Reagents

1. Water of ASTM Type I quality
2. 0.01 N NH_4Cl
3. 500 mg L^{-1} $Ca(H_2PO_4)_2$

23.3 QA/QC

1. Standard solutions for calibration of the analytical instrument.
2. Reference standard (1 per batch): an amount of field-moist sample approximately equivalent to 2 g (weighed to ±0.01 g precision) of LFH, or 2 g (weighed to ±0.01 g precision) of air dry mineral soil, of known inorganic sulphur content.
3. Blank (1 per batch): a polypropylene tube without soil material.
4. Replicate (1 per batch): from one randomly selected sample within the batch.

23.4 Organic (LFH) Soil Sample Analysis

A field-moist sample is required for this analysis (**SOIL SAMPLE PREPARATION PROCEDURE (#9)**). An amount approximately equivalent to 2 g dry weight of LFH material is to be extracted and analysed. **SOIL SAMPLE PREPARATION PROCEDURE (#9)** describes the method by which the

[1] Kalra YP, Maynard DG (1991) *Methods Manual for Forest Soil and Plant Analysis. Information Report NOR-X319*. Section 14(i). Forestry Canada Northwest Region, Northern Forestry Centre, Edmonton, Alberta

[2] Kalra YP, Maynard DG (1991) *Methods Manual for Forest Soil and Plant Analysis. Information Report NOR-X319*. Section 14(ii). Forestry Canada Northwest Region, Northern Forestry Centre, Edmonton, Alberta

moisture content is to be determined, for calculation of inorganic sulphur concentration on a dry weight basis.

1. Blend field moist sample to uniform state.
2. Weigh a field-moist sample approximately equivalent to 2 g (weighed to ±0.01 g precision) into a polypropylene tube.
3. Add 20 mL 0.01 *M* NH_4Cl.
4. Shake for 1 hr.
5. Centrifuge 2,000g for 10min.
6. Filter through 0.45 µm nylon membrane syringe filter.
7. If analysis cannot take place within 24 hr after extraction, freeze (-20°C) clarified samples until analysis can be completed.
8. Use ICP-AES to determine total sulphur concentration in an aliquot of the extract.
9. Use ion chromatography to determine sulphate (SO_4^--S) concentration in an aliquot of the extract.

23.5 Mineral Soil Sample Analysis

An air-dried sample, passed through a 2 mm screen, is required for this analysis.

1. Weigh about 2 g (weighed to ±0.01 g precision) of 2 mm air dry mineral soil.
2. Add 20 mL $Ca(H_2PO_4)_2$ solution.
3. Shake for 1 hr.
4. Centrifuge 2,000g for 10min.
5. Filter through 0.45 um nylon membrane syringe filter.
6. If analysis cannot take place within 24 hr after extraction, freeze (-20°C) clarified samples until analysis can be completed.
7. Use ICP-AES to determine total sulphur concentration in an aliquot of the extract.

23.6 Calculations

Report total dissolved sulphur and sulphate-S concentrations in both LFH and mineral soils on a dry weight basis.

PROCEDURE #24
VEGETATION PLOT TREE MAP

24.1 Background

The location of each tree within stand interior vegetation plots is to be mapped relative to the plot centre. The location of each tree within stand edge vegetation plots is to be mapped relative to the plot corner nearest the reference stake. These measurements will be used to prepare a map of trees within the plot.

24.2 Tree Species Codes

The codes to be used to identify tree species on TEEM Forms 02 and E02 are as follows:

Tree Species Codes for TEEM Form 02 and E02

Common Name	Scientific Name	Code
Balsam fir	*Abies balsamea*	Fb
Tamarack larch	*Larix laricina*	Lt
Jack pine	*Pinus banksiana*	Pj
Lodgepole pine	*Pinus contorta v. latifolia*	Pl
Black spruce	*Picea mariana*	Sb
White spruce	*Picea glauca*	Sw
Balsam poplar	*Populus balsamifera*	Pb
Trembling aspen	*Populus tremuloides*	Aw
White birch	*Betula papyrifera*	Bw

24.3 Stand Interior Vegetation Plot Tree Map

Each tree within the stand interior vegetation plot is to be mapped as a function of distance from the plot centre. Measurements (to the nearest 0.1 m) are to be recorded on TEEM Form 02, as follows:

TEEM Form 02 – Stand Interior Vegetation Plot Tree Map

Field(s)	Field Name	Required Information
1 & 2	Page _ of _	Complete after collecting the map information from the last plot tree. If vegetation plot map data are collected over a two or more days, a new form is to be used at the start of each day. The total number of pages used to collect the plot map data is to be entered into Field 2
3 to 7	Site	5-Character site designation
8 to 11	Year of	The 4-digit year of plot establishment

	Establishment	
12 to 19	Assessment Date	The date of vegetation plot map data collection, in the format YYYY-MM-DD (July 9, 2011 would be recorded as "2011-07-09")
20 to 22	Personnel	The full names of field personnel collecting the plot map data
23 to 25	Tree Number	A 3-digit number, such that the 26th mapped tree would be recorded as "026"
26 & 27	Tree Species	The 2-character code representing the species
28	Status	"A"= alive and "D" = dead
29 to 32	Distance Along Centre Line (X)	The centre of each tree bole, measured from the plot centre ("0,0"). Plus (+) and minus (-) signs (Field 29) designate the plot quadrant. Distances along the X axis are measured from 0 to 5.0 m (±0.1 m)
33 to 37	Distance Along Reference Line (Y)	The centre of each tree bole, measured from the plot centre ("0,0"). Plus (+) and minus (-) signs (Filed 29) designate the plot quadrant. Distances along the Reference Line (Y axis) are measured from 0 to 20.0 m (±0.1 m)
38	Remarks	Note any features of the tree that may be related to or affect the health of the tree, and any unusual observations

24.4 Stand Edge Vegetation Plot Tree Map

Each tree within the stand edge vegetation plot is to be mapped as a function of distance from the plot corner closest to the reference stake. Measurements (to the nearest 0.1 m) along the long and short plot edges are to be recorded on TEEM Form E02, as follows:

TEEM Form E02 – Stand Edge Vegetation Plot Tree Map

Field(s)	Field Name	Required Information
1 & 2	Page _ of _	Complete after collecting the map information from the last plot tree. If vegetation plot map data are collected over a two or more days, a new form is to be used at the start of each day. The total number of pages used to collect the plot map data is to be entered into Field 2
3 to 7	Site	5-Character site designation
8 to 11	Year of Establishment	The 4-digit year of plot establishment
12 to 19	Assessment Date	The date of vegetation plot map data collection, in the format YYYY-MM-DD (July 9, 2011 would be recorded as "2011-07-09")
20 to 22	Personnel	The full names of field personnel collecting the plot map data
23 to 25	Tree Number	A 3-digit number, such that the 7th mapped tree would be recorded as "E07"
26 & 27	Tree Species	The 2-character code representing the species
28	Status	"A" = alive and "D" = dead
29 to 32	Distance Along Plot Long Edge	The centre of each tree bole, measured along the long edge of the plot from the plot corner closest to the reference stake. Distances are measured from 0 to 20 m, to tenths of metres.
33 to 35	Distance Along Plot Short Edge	The centre of each tree bole, measured along the short edge of the plot, from the plot corner closest to the reference stake. Distances are measured from 0 to 5 m, to tenths of metres.
36	Remarks	Note any features of the tree that may be related to or affect the health of the tree, and any unusual observations

PROCEDURE #25
TREE CORING

25.1 Background

The coring of trees provides a sample for analysis of tree age. During site establishment, cores are to be obtained from off-plot trees at each of the stand interior and stand edge monitoring locations. Cores are also to be obtained from off-plot replacement trees at the time of their selection. Cores may also be required at other times to confirm the tree age.

25.2 Tree Coring

At breast height (1.3 m), a core through the pith of each numbered off-plot tree is to be obtained using an increment borer (Grissino-Mayer, 2003[1]; Maeglin, 1979[2]). A wide-diameter (5 mm) "Suunto" brand borer is recommended.

In the event that a core does not intersect the pith of the tree, a second core may be obtained from the same tree. If the pith is missed on the second attempt, the tree is to be removed from the program, and a replacement off-plot tree selected and cored.

The hole(s) in the tree trunk is(are) to be left open, as plugging may increase the potential for physical and/or pathogenic damage (Grissino-Mayer, 2003[1]).

Each core is to be stored in a plastic straw, which is to be stapled closed and affixed with a label prepared according to the **SAMPLE LABELLING PROCEDURE (#1)**. Small slits should be cut (lengthwise) into the straw to allow moisture to escape. Straws containing the cores are to be placed into in a PVC tube of 10 cm diameter and 25 cm length (capped) for transport, to minimize breakage. Cores are not to be frozen at any time.

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1 Grissino-Mayer HD (2003) A manual and tutorial for the proper use of an increment borer. Tree-Ring Res. 59:63-79.

2 Maeglin RR (1979) *Increment Cores. How To Collect, Handle, and Use Them.* General Technical Report FPL 25, Forest Products Laboratory, Forest Service, United States Department of Agriculture. 18 pp.

PROCEDURE #26
TREE CORE PREPARATION & ANALYSIS

26.1 Background

Tree cores are used to determine tree age.

26.2 Core Drying

As soon as possible after return from the field, the cores are to be dried in their straws at 60°C, for a minimum of 5 days.

26.3 Mounting Cores

Mounting boards that can accommodate up to five cores are to be prepared. Five grooves each measuring 6 mm wide and 4 mm deep are to be cut into each board, with the grooves equally spaced.

1. Cut the end off of each straw and push the core out of the straw with a piece of doweling. If the core is in pieces, make sure that the orientation of each piece remains correct.
2. Place a bead of glue (“Lepage Sure Grip” carpenter’s glue or equivalent) in one groove – the glue should come up the sides of the core but not spill onto the top of it. All pieces are to be placed in the board so that the vessels are aligned vertically in the mount (if the core is mounted out of phase the rings will not be visible, and the sample will be unusable). Any shiny areas on the core are to be orientated to the sides of the board.
3. If the core is twisted (i.e., starts in phase and then turns out of phase down the core), steam the core for about 1 minute on a kettle and gently twist the core straight. Place the core in the mount. If the cores start to curl, gently push them back into place.
4. Cover the cores using a small piece of plastic and place a heavy object evenly over the mount.
5. Allow the glue to dry for 24 hours. Do not clamp the boards together. The cores are to be checked after 24 hours to confirm that they are securely mounted; if not, add more glue.
6. Sample label information for each of the mounted cores is to be written on the back of the board as any information on the front of board may be sanded off.

26.4 Sanding Cores

1. Each core is to be sanded first with 120 grit sandpaper to create a flat surface on the top of the mounted core. Sand the sample evenly and avoid creating waves on the core surface.
2. Sand the flattened surface with 220 grit sandpaper; this may be done with a belt sander.
3. Sand the flattened surface with 320 grit sandpaper; this may be done with a belt sander.
4. Sand the flattened surface with 500 grit sandpaper; this must be done by hand, with the sandpaper installed into a hand sander that is clamped into a vice. The block and core are then to be pushed over the surface of the sandpaper.
5. Polish the flattened surface with 1,000 grit sandpaper; this must be done by hand with the sandpaper installed into a hand sander that is clamped into a vice. The block and core are then to be pushed over the surface of the sandpaper.

26.5 Scanning Cores

The highest resolution scanner available ("Epson Perfection V7500 Pro" or equivalent) is to be used to obtain electronic core images.

1. Place the core board perpendicular to the scanner bar.
2. Set the scanner to 1,800 DPI, or the highest resolution that it will scan before it extrapolates the resolution.
3. Scan a colour image to a bitmap (.bmp) file format (do not use .jpg). Limit the scan to the core (not the entire board) to minimize file size.
4. Carefully examine image for quality. If inadequate, additional sanding and/or scanning will be required.

26.6 Measuring Growth Rings

The ring measurement and cross dating programs "CooRecorder" and "C-Dendro"[1], respectively, are to be used to measure growth rings on each core.

1. Open the image of a core in "CooRecorder" and set the image DPI, and select "sorted data".
2. Begin measurement at the ring closest to the bark and then sequentially measure rings inward.
3. Measure straight across each ring, avoiding measurement at any angle.
4. The completed series is then to be brought into "C-Dendro" for validation and cross-dating and for converting data into ring width files.

[1] CooRecorder and C-Dendro are available from Cybis Elektronik & Data AB, Pålnäsvägen 1, SE-133 33 Saltsjöbaden, Sweden (http://www.cybis.se/forfun/dendro/index.htm)

The number of growth rings, plus 10, in each core represents the age of the tree, providing that the core intersected the pith of the tree. The addition of 10 to the number of growth rings accounts for the number of years required for the tree to grow to breast height (1.3 m). The "C-Dendro" results are to be entered on TEEM Form X05 (stand interior) or TEEM Form EX05 (stand edge), as follows:

TEEM Forms X05 and EX05 – Off-Plot Tree Growth Ring Analysis

Field(s)	Field Name	Required Information
1 & 2	Page _ of _	Complete as appropriate. The first page (Fields 1 to 86) is identified by an "A"; the second page (Fields 87 to 132) is identified by a "B". If tree growth ring data are collected on different days, complete a separate form for each day. The total number of pages used to collect the growth ring data is to be entered into Field 2
3 to 7	Site	5-Character site designation
8 to 15	Tree Core Sample Date	The date tree cores are collected, in the format YYYY-MM-DD (July 9, 2011 would be recorded as "2011-07-09")
16 to 23	Tree Core Measurement Date	The date tree core ages are measured, in the format YYYY-MM-DD (July 9, 2011 would be recorded as "2011-07-09")
24 to 26	Cores Acquired By	Three fields are provided for the full name(s) of the personnel taking the tree core samples
27 & 28	Cores Measured By	Two fields are provided for the full name(s) of the personnel measuring the tree core samples
29 to 38	Off-Plot Tree Numbers	The 3-character tree number, in the form "X10"
40 to 129	Tree Ring Width by Year	The width of the current year tree ring is to be recorded (in mm, to 0.01 mm). Measurements are to be in mm, to 0.01 mm; 1.27 mm would be recorded as "127". The width of each ring working from the current year ring to the pith is to be recorded for as many rings as are present in the core
131	Tree age	The age of the tree is to be determined by counting the number of growth rings, and adding 10 (entered in Field 130)
132	Remarks	Observations of unusual growth years (e.g., fire scars), if a tree core did not intersect the pith and any correction applied to derive tree age, and any measurement difficulties (broken cores) are to be recorded

PROCEDURE #28
TREE DATA

28.1 Background

Tree data are required from each numbered tree within the vegetation plot and off-plot tree area, at both the stand interior and stand edge monitoring sites, during each cycle of monitoring. Tree tags are and DBH reference marks are to be checked and as required, repaired or replaced (**TREE NUMBERING & LABELLING PROCEDURE (#5)**).

28.2 Common Procedures

28.2.1 Tree Species Codes

Where required, the tree species are to be identified and entered into the appropriate TEEM data form using the following codes:

Tree Species Codes

Common Name	Scientific Name	Code
Balsam fir	*Abies balsamea*	Fb
Tamarack larch	*Larix laricina*	Lt
Jack pine	*Pinus banksiana*	Pj
Lodgepole pine	*Pinus contorta v. latifolia*	Pl
Black spruce	*Picea mariana*	Sb
White spruce	*Picea glauca*	Sw
Balsam poplar	*Populus balsamifera*	Pb
Trembling aspen	*Populus tremuloides*	Aw
White birch	*Betula papyrifera*	Bw

28.2.2 Dominance

Dominance of each numbered tree is coded as follows:

1 = Dominant – the tree crown extends above the general level of the crown canopy and receives full sunlight from above and partial sunlight from the sides.

2 = Co-dominant – the tree crown is at the general level of the crown canopy, receiving full sunlight from above but little sunlight from the sides.

3 = Intermediate – tree crown extends into the general level of the crown, but is shorter than co-dominant trees, receiving little direct sunlight from above.

4 = Suppressed – tree crown entirely below the general level of the canopy.

The dominance of dead trees is to be estimated at the time when they were last alive

28.2.3 Diameter at Breast Height

The diameter of the tree at breast height (DBH) is to be measured at the line painted on the trunk 1.3 m above ground level (**TREE NUMBERING & LABELLING PROCEDURE (#5)**) using a diameter tape, the measurement taken to the nearest 0.1 cm and recorded as a four-digit number (e.g., a DBH of 10.3 cm is recorded as 0103). Abnormalities in tree form (forked stems, branch or swelling at 1.3 m) are to be noted, and adjustments in the diameter measurement (at higher or lower than 1.3 m) are to be recorded.

28.2.4 Crown Closure

For each living dominant and co-dominant tree, an estimate of the number of sides of the tree's crown that touch or overlap with neighbouring dominant and co-dominant trees is to be made according to the following codes:

0 = Tree does not touch or overlap any neighbouring Dominant or Co-dominant tree.

1 = Neighbouring trees touch or overlap one quadrant of the subject tree.

2 = Neighbouring trees touch or overlap two quadrants of the subject tree.

3 = Neighbouring trees touch or overlap three quadrants of the subject tree.

4 = Neighbouring trees touch or overlap four quadrants of the subject tree.

8 = Not applicable, subject tree is intermediate or suppressed.

28.2.5 Stem Form

Considering the normal stem form for the species, record stem form according to the following codes:

0 = Normal stem, no abnormalities.

1 = Main stem broken off.

2 = Top of tree broken off.

3 = Main stem abnormally forked below the living crown.

4 = Stem significantly twisted (into a spiral).

5 = Tree leaning more than 15° from vertical.

9 = Other (describe in remarks field).

- = Not applicable, tree is dead.

28.2.6 Tree Height and Crown Heights

Total height, the height to the top of the tree, is to be measured using a laser rangefinder. The measurement is taken to the nearest 0.1 m and recorded on the data sheet as a three-digit number (e.g., 18.9 m is to be recorded as “189”).

Height to the top of the live crown is to be measured in the instance where dead branches form the top of the tree. If the top of the tree is alive, the Total Height may be recorded as the Height to the Top of Live Crown without repeating the measurement. The measurement is taken to the nearest 0.1 m and recorded on the data sheet as a three-digit number (e.g., 18.1 m is to be recorded as “181”).

Height to the base of the crown is to be measured from the ground to the bottom of the living, productive foliage of the lowest branch. This is a subjective decision, based on the decision of whether the branch contributes to the health of the tree. The measurement is taken to the nearest 0.1 m using a laser rangefinder and recorded on the data sheet as a three-digit number (e.g., 15.2 m is to be recorded as “152”).

28.2.7 Remarks

Tree characteristics that pose difficulties in any of the measurements should be noted, and any decisions made that will affect future measurements must be recorded (e.g., “DBH measured at a height of 1.6 m, 30 cm above abnormal swelling”).

Personnel are encouraged to include in the Remarks field any observation that may assist in data interpretation and/or the understanding of the status of tree, plot, or site health.

28.3 Tree Data

Tree data are required from each numbered and mapped tree within the stand interior vegetation plot; these data are to be recorded using TEEM Form 03 (stand interior vegetation plot), X03 (stand interior off-plot trees), E03 (stand edge vegetation plot), or EX03 (stand edge off-plot trees), as follows:

TEEM Forms 03, X03, E03 and EX03 –Tree Data

Field(s)	Field Name	Required Information
1 & 2	Page _ of _	Complete after collecting the data from the last plot tree
3 to 7	Site	5-Character site designation
8 to 15	Assessment Date	Date as YYYY-MMM-DD (July 9, 2011 would be recorded as “2011-07-09”)
16 to 18	Personnel	Three fields are provided for the full names of the personnel involved
19 to 21	Tree Number	A 3-digit number, such that the 26th mapped tree would be recorded as “026”
22 & 23	Tree Species	Tree species 2-character code
24	Dominance	Dominance of each numbered tree is coded according to Section 21.2.1 (above)
25 to 28	DBH	The diameter of the tree at breast height is to be measured according to Section 21.2.2 (above)

Field(s)	Field Name	Required Information
29	Crown Closure	Crown closure described according to Section 21.2.3 (above)
30	Stem Form	Stem form described according to Section 21.2.4 (above)
31 to 33	Total Height	Total tree height measured according to Section 21.2.5 (above)
34 to 36	Height to Top of Live Crown	Height to top of live crown measured according to Section 21.2.5 (above)
37 to 39	Height to Base of Crown	Height to base of live crown measured according to Section 21.2.5 (above)
40	Remarks	Observations related to the status of tree, plot and/or site health status

PROCEDURE #29
TREE SHOOT DATA

29.1 Photography

Prior to conducting any assessment, measurement or sampling, each cut branch is to be photographed, and the photograph number is to be noted on TEEM Form X06 or TEEM Form EX06.

29.2 Internode Measurement

The length of each internode on the each of the five main branches is to be measured (in cm, to the nearest 0.1 cm) using a ruler or calipers. Measurements are to be recorded using three digits (e.g., 4.9 cm is to be recorded as “049”) on TEEM Form X06 or TEEM Form EX06.

29.3 Needle Retention

Defoliation of each internode is to be estimated according to the codes, below. Measurements and defoliation estimations are to be carried back from the current year internode for at least 4 more years (to the 4-year-old age class), and to the 7-year-old age class if possible. Defoliation estimates are quantified as follows:

0 = None

1 = 1 to 25% defoliation

2 = 26 to 50% defoliation

3 = 51 to 75% defoliation

4 = 76 to 100% defoliation

\- = Not applicable

These data and observations are to be recorded in the Defoliation fields in TEEM Forms X06 and EX06.

29.4 Off-Plot Tree Shoot Data

TEEM Forms X06 and EX06 are to be completed as follows:

TEEM Form X06 and EX06 – Off-Plot Tree Shoot Data

Field(s)	Field Name	Required Information
1 & 2	Page _ of _	Complete as appropriate
3 to 7	Site	5-Character site designation
8 to 15	Assessment Date	The date, in the format YYYY-MM-DD (July 9, 2011 would be recorded as “2011-07-09”)
16 to 18	Personnel	Three fields are provided for the full names of the personnel involved
19 & 20	Random number	The random number used to select the five off-plot trees for sampling. Enter as a 2-digit number (e.g., random number “3” is to be entered as “03”)
21 to 23	Off-Plot Tree Numbers	A 2-digit number, following the “X” that is pre-entered on the form. The 10th tree would be recorded as “X10”
26	Current Year Internode Defoliation	The extent of defoliation in the current year internode
27 to 29	Current Year Internode Length	The length of the current year internode
30	1 Year Old Internode Defoliation	The extent of defoliation in the 1-year-old internode
31 to 33	1 Year Old Internode Length	The length of the 1-year-old internode
34	2 Year Old Internode Defoliation	The extent of defoliation in the 2-year-old internode
35 to 37	2 Year Old Internode Length	The length of the 2-year-old internode
38	3 Year Old Internode Defoliation	The extent of defoliation in the 3-year-old internode
39 to 41	3 Year Old Internode Length	The length of the 3-year-old internode
42	4 Year Old Internode Defoliation	The extent of defoliation in the 4-year-old internode
43 to 45	4 Year Old Internode Length	The length of the 4-year-old internode
46	5 Year Old Internode Defoliation	The extent of defoliation in the 5-year-old internode
47 to 49	5 Year Old Internode Length	The length of the 5-year-old internode
50	6 Year Old Internode Defoliation	The extent of defoliation in the 6-year-old internode
51 to 53	6 Year Old Internode Length	The length of the 6-year-old internode
54	7 Year Old Internode Defoliation	The extent of defoliation in the 7-year-old internode
55 to 57	7 Year Old Internode Length	The length of the 7-year-old internode
58	Remarks	Observations of interest unrelated to the internode measurements or defoliation estimates
59	Photo. No.	The branch photograph number

PROCEDURE #30
FOLIAR SAMPLE COLLECTION

30.1 Background

Needles from each of the current annual growth (CAG), 1-year-old (Age-1), and 2-year-old (Age-2) internodes are to be collected for laboratory analyses. The amount of sample collected must be sufficient to allow completion of the required laboratory analyses, with some material remaining should one or a few analyses need to be repeated.

30.2 Foliar (Needle) Sampling

Personnel are to wear powderless nitrile gloves when handling branches and needles. Clippers pre-washed with isopropyl alcohol are to be used to cut shoot segments into the required age classes.

Current annual growth (CAG) needles, 1-year-old needles (Age-1) and 2-year-old needles (Age-2) from cut off-plot tree branches are to be sampled separately. A sample that will yield 15 to 20 g of dry foliar material is to be obtained for each needles age class. A minimum sample is 10 g, on a dry weight basis. In the event that needle material is limited, a second branch may be obtained to obtain this minimum quantity.

From the five branches excised for needle sampling, one of the branches having sufficient needle material to allow the collection of a second sample set (CAG, Age-1, Age-2) is to be randomly chosen. To obtain a field duplicate sample, twice the number or volume of shoots (e.g., equivalent to a minimum of 20 g dry weight) is to be obtained and placed on a clean surface. The shoots are to be gently mixed, taking care to not break needles. The mixed sample is to be divided into two equal portions, one as the sample from the off-plot tree, the other as the field duplicate for the site. A total of 18 samples to be obtained per site, per the checklist below:

Foliar Sample Checklist – Off-Plot Trees
Stand Interior and Stand Edge Sites

Age Class	Number of Off-Plot Trees	Total Number of Samples
CAG	5	15
Age-1	5	
Age-2	5	
Field Duplicate Set (CAG, Age-1, Age-2)	1	3
Total Samples per Site		**18**

PROCEDURE #32
FOLIAR TISSUE SAMPLE PREPARATION

32.1 Background

This procedure describes the handling and preparation of needle samples for laboratory analyses. Handling of these samples is generally to be conducted wearing powderless nitrile gloves, or equivalent.

32.2 Sample Drying

Drying of samples results in the cessation of cellular activity, both in tissue and microbial cells. This is a requirement of sample preservation. It is also necessary to dry needle samples to facilitate fascicle removal and to ensure proper grinding.

Samples are to be dried in small, labelled (**SAMPLE LABELLING PROCEDURE (#1)**) paper bags in an oven maintained at 70°C for a minimum of 24 hr.

32.3 Sample Cleaning

On a clean, inert surface, needles are to be carefully removed from the branch segments, and the fascicles removed.

The samples are to be immediately ground (see below). If grinding is delayed, the samples are to be placed in a glass vial, capped and stored in cool, dry conditions until drying capacity becomes available. Alternatively, dried samples can be placed into labelled paper bags, and sealed in a larger plastic bag, until grinding becomes possible.

32.4 Sample Grinding

Grinding reduces the material to small particles, which permits complete mixing and analyses of a homogeneous subsample representative of the larger sample.

Within 1 hour of removal from the oven, each dried sample is to be ground in zirconium oxide jar sets. The ground material is to be transferred into a cleaned glass vial, and sealed completely to prevent sample exposure to atmospheric moisture. The dried, ground sample is to fill the container to no more than two-thirds capacity, leaving sufficient head-space required to re-mix

the sample by rolling, tilting and inverting immediately prior to removing a subsample for analysis.

32.5 Sample Re-drying

Dried, ground samples are to be re-dried immediately prior to the weighing of a subsample for each analysis. Loosely capped vials containing ground materials are to be placed in an oven (70 °C) overnight, and the caps securely tightened the following morning.

After the vial has cooled to room temperature, a subsample can be removed and weighed for the laboratory analysis. Providing that the vials remain securely sealed, the re-drying process does not need to be repeated daily. If the samples have been stored for an extended period (a month or more), re-drying is necessary.

32.6 Sample Weighing

1. Gently roll and tilt the glass jar containing the dried, ground sample for 10 sec to ensure complete mixing of the ground material.
2. Allow the mixed sample to sit until suspended particles have settled.
3. Remove and weigh the appropriate amount of sample for analysis (according to the individual procedure).
4. Securely seal the sample container immediately after weighing.

After weighing, sealed sample containers are to be stored in cool, dark conditions.

32.7 Sample Archive

Any remaining sample is to be placed into the TEEM sample archive facility. Samples are to be stored in tightly capped, labelled (**SAMPLE LABELLING PROCEDURE (#1)**), glass vials.

PROCEDURE #33
FOLIAR TISSUE INORGANIC SULPHUR ANALYSIS

33.1 Background

The procedure for plant tissue sulphate analysis is based on Brockley (2000[1]).

33.2 Reagents

1. Water of ASTM Type I quality
2. 0.01 *M* HCL

33.3 QA/QC

1. Standard solutions for calibration of the analytical instrument.
2. Reference standard (1 per batch): approximately 0.5 g (weighed to 0.01 g precision) of dried, ground needles of known inorganic sulphur content
3. Blank (1 per batch): a digestion tube without sample.
4. Replicate (1 per batch): from one randomly selected sample within the batch.

33.4 Extraction & Analysis

1. Weigh approximately 0.5 g (weighed to 0.01 g precision) of dried, ground needles into a pre-weighed digestion tube.
2. Add 40 mL 0.01 *M* HCl.
3. Boil for 1 hr.
4. Weigh tube with sample, calculate loss of water.
5. Pour aliquot into 15 mL centrifuge tubes, centrifuge at 2,000 g for 15 min
6. Filter extract through 0.45 µm Millipore (or equivalent) filter.
7. Analyse an aliquot of the extract using ion chromatography.

33.5 Calculations

The concentration of inorganic sulphur (S_i) in the sample is to be expressed in µg/g, on a dry-weight (moisture-corrected), water-loss basis.

[1] Brockley RP (2000) Using foliar variables to predict the response of lodgepole pine to nitrogen and sulphur fertilization. Can. J. For. Res. 30:1389-1399

PROCEDURE #34
FOLIAR TISSUE ORGANIC SULPHUR (S_O) & S_I:S_O CALCULATIONS

34.1 Background

Organic sulphur in foliar samples is the difference between total sulphur and inorganic sulphur concentrations. The S_i:S_o ratio is also derived by calculation.

34.2 Organic Sulphur Concentration

The concentration of organic sulphur (S_o) in each foliar (needle) sample is derived through the subtraction of the foliar inorganic sulphur (S_i) concentration (**FOLIAR TISSUE INORGANIC SULPHUR ANALYSIS (#33)**) from the total foliar sulphur (S_t) concentration (**TOTAL SULPHUR, NITROGEN & CARBON ANALYSIS PROCEDURE (#17)**):

$$S_o = S_t - S_i$$

S_o is to be recorded in units of μg S_o/g DW.

34.3 Si:So Ratio Calculation

The S_i:S_o ratio is derived by dividing the concentration of foliar inorganic sulphur (S_i) (**FOLIAR TISSUE INORGANIC SULPHUR ANALYSIS (#33)**) by the concentration of foliar organic sulphur, derived above:

$$S_i:S_o = S_i/S_o$$

This ratio is unitless.

PROCEDURE #35
FOLIAR TISSUE ELEMENTAL CONCENTRATIONS ANALYSIS

35.1 Background

This procedure is may be used to analyse for levels of a large number of elements in tree tissues. Of primary interest are the elements listed in the table below. Nevertheless, analysis using FLAA, CVAA, GFAA, ICP- AES, or ICP-MS allows sensitive, simultaneous determination of a broader suite of elements. Concentrations of elements not included in the following table are to be reported, however, for data management reasons, these results are to be captured in a secondary elements database, which is archived for potential future use.

Elements to be Included in the Priority Elements Database

Element		Emitted in Region	Nutrient	Toxic*
Aluminum	Al	Yes	No	Yes
Calcium	Ca	Yes	Macronutrient	No
Copper	Cu	Yes	Micronutrient	No*
Iron	Fe	Yes	Micronutrient	No*
Magnesium	Mg	Maybe	Micronutrient	No*
Manganese	Mn	Yes	Micronutrient	No*
Molybdenum	Mo	Yes	Micronutrient	No*
Nickel	Ni	Yes	No	Yes
Phosphorus	P	No	Macronutrient	No
Potassium	K	Yes	Macronutrient	No
Sodium	Na	Yes	(Micronutrient?)	No
Sulphur	S	Yes	Macronutrient	No*
Zinc	Zn	Yes	Micronutrient	No*

* Indicates no toxicity to vegetation at nutrient levels, toxicity at higher levels.

Some element results are trustworthy only if specialized sampling and sample handling procedures were employed during sample acquisition (e.g., As, Hg, Pb, Se).

35.2 Reagents

1. Water of ASTM Type I quality.
2. Concentrated HNO_3.
3. Concentrated HCl.

35.3 QA/QC

1. A set of calibration standards appropriate for the instrument.
2. Appropriate commercial standards, matching the sample matrix as closely as possible, or use of spiked samples to assess instrument response.
3. Reference standard (1 per batch): an appropriate amount of tree tissue material, of known total content of one or more elements.
4. Replicate (1 per batch): from one randomly selected sample within the batch.

35.4 Microwave Digestion

Control of digestion conditions requires a temperature sensor in one or more vessels during the entire decomposition. The microwave decomposition system should sense the temperature to within ±2.5°C and permit adjustment of the microwave output power within 2 sec. Temperature sensors should be accurate to ±2°C (including the final reaction temperature of 180°C). The procedure requires microwave-transparent, reagent-resistant, and suitably inert reaction vessels. All sample containers must be prewashed with detergents, acids, and water.

1. Weigh approximately 0.25 g (weighed to 0.001 g precision) of dried, ground sample into a digestion vessel.
2. Add 9 mL (±0.1 mL) concentrated HNO_3 and swirl the vessel gently so that all material comes in contact with the acid.
3. Digest according to microwave specifications.
4. Add HCl to stabilize elements in solution, concentration & volume to match matrix of the calibration standards.
5. Transfer and bring to desired volume (50 mL or 100 mL), using a diluent that matches the solvent used to prepare the standards.
6. If the digested sample contains particulates, centrifuge (up to 3,000 rpm, 10 min.) or allow particulates to settle (overnight).
7. Analyse solution elemental concentrations using flame atomic absorption spectrometry (FLAA), graphite furnace atomic absorption spectrometry (GFAA), inductively coupled plasma atomic emission spectrometry (ICP- AES), or inductively coupled plasma mass spectrometry (ICP-MS).

35.5 Calculations

All elemental concentrations are to be presented in μg/g on a dry weight (moisture-corrected) basis.

Total sulphur (S) concentrations obtained in this analysis should compare favourably (within 10%) with those determined by dry combustion analysis (**TOTAL SULPHUR, NITROGEN & CARBON ANALYSIS PROCEDURE (#17)**).

PROCEDURE #38
PLANT COMMUNITY COMPOSITION ASSESSMENT

38.1 Background

Changes in soil chemistry and subsequent changes in vegetation growth and health may result in changes to the relative competitive ability of species growing at the jack pine monitoring sites. Altered competitive abilities may lead to changes in species composition.

Cover is to be assessed using the cover class estimation method of Daubenmire (1959[1]; Coulloudon et al., 1996[2]), and by recording absolute cover.

In addition to the quantitative community assessments in the vegetation plot, a species list for the site overall is to be compiled over a 30-min walk through the stand.

38.2 Cover Assessments (Daubenmire & Absolute)

For consistency within a single monitoring cycle, the assessment is to be performed at all sites by the same qualified vegetation ecologist. An ecologist with substantial taxonomic knowledge and experience in the boreal forest is to conduct this assessment. This assessment is to be conducted in August to mid-September.

The Daubenmire cover class assessment is to be conducted in each of the small, medium and large subplots within the stand interior vegetation plot. The Daubenmire cover class assessment within stand edge vegetation plots is to be conducted within the small and medium subplots and in the vegetation plot as a whole.

In each subplot, estimate the cover (as a percentage of the subplot) for all individuals of a plant species in the subplot, ignoring other species (i.e., estimations are for each plant species separately). Canopies extending over the subplot are to be included in the estimation of cover, even if the plants are not rooted in the subplot. Imagine a line drawn about the leaf tips of the undisturbed canopies (ignoring inflorescence) and project these polygonal images onto the ground. This projection is the “canopy coverage”, expressed as a percentage of the species’ cover within the subplot. Record this percent cover on TEEM Form 08b or E08b.

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1 Daubenmire R (1959) A canopy-coverage method of vegetational analysis. Northwest Sci. 33:43-64

2 Coulloudon B, Eshelman K, Gianola J, Habich N, Hughes L, Johnson C, Pellant M, Podborny P, Rasmussen A, Robles B, Shaver P, Spehar J, Willoughby J (1996) Sampling Vegetation Attributes. Interagency Technical Reference, Cooperative Extension Service, U.S. Department of Agriculture, U.S. Department of the Interior. Revised in 1997 and 1999. Technical Reference 1734-4.

From the canopy coverage, determine the appropriate Daubenmire Cover Class, according to the following table, and enter the cover class into TEEM Form 08a (stand interior) or E08a (stand edge).

Daubenmire Cover Classes

Cover Class	Canopy Coverage	Midpoint of Range
1	0 to 5%	2.5%
2	6 to 25%	15.0%
3	26 to 50%	37.5%
4	51 to 75%	62.5%
5	76 to 95%	85.0%
6	96 to 100%	97.5%

The remainder of TEEM Forms 08a and E08a is to be completed as follows:

TEEM Forms 08a and E08a

Field(s)	Field Name	Required Information
1 & 2	Page _ of _	Complete after collecting the data from the last plot tree
3 to 7	Site	5-Character site designation
8 to 15	Assessment Date	Date as YYYY-MMM-DD (July 9, 2011 would be recorded as “2011-07-09”)
16 to 18	Personnel	Three fields are provided for the full names of the personnel involved
19	Species	Enter each species present in the subplot on a separate line
20 to 29	Small Subplot No.	Enter the Daubenmire Cover Class for each species in each small subplot
30 & 31	Medium Subplot No.	Enter the Daubenmire Cover Class for each species in each medium subplot
32	Large Subplot	Enter the Daubenmire Cover Class for each species in the large subplot (Form 08) or plot (E08)
33	Remarks	Enter observations, difficulties and any other information that may be useful in guiding the interpretation of the data

TEEM Forms 08b and E08b, including the cover class for each subplot, are to be completed as follows:

TEEM Forms 08b and E08b

Field(s)	Field Name	Required Information
1 & 2	Page _ of _	Complete after collecting the data from the last plot tree
3 to 7	Site	5-Character site designation
8 to 15	Assessment Date	Date as YYYY-MMM-DD (July 9, 2011 would be recorded as “2011-07-09”)
16 to 18	Personnel	Three fields are provided for the full names of the personnel involved
19	Species	Enter each species present in the subplot on a separate line

Field(s)	Field Name	Required Information
20 to 29	Small Subplot No.	Enter the estimated % cover for each species in each small subplot
30 & 31	Medium Subplot No.	Enter the estimated % cover for each species in each medium subplot
32	Large Subplot	Enter the estimated % cover for each species in the large subplot (Form 08) or plot (E08)
33	Remarks	Enter observations, difficulties and any other information that may be useful in guiding the interpretation of the data

38.3 Daubenmire Summary

The TEEM Program Manager is to complete the Daubenmire Summary (TEEM Forms 09a and E09a); these are not field data collection forms. These forms include pre-programmed equations for the calculation of Total Canopy, Canopy Cover (%), contribution of each species to overall Species Composition (%), and Frequency (%) of occurrence of each species. The data to be entered into, and the calculations that are performed within, TEEM Forms 09a and E09a are as follows:

TEEM Forms 09a and E09a – Daubenmire Summary

Field(s)	Field Name	Required Information
1 & 2	Page _ of _	Complete after collecting the data from the last plot tree
3 to 7	Site	5-Character site designation
8 to 15	Assessment Date	Date as YYYY-MMM-DD (July 9, 2011 is to be recorded as “2011-07-09”)
16 to 18	Personnel	Three fields are provided for the full names of the personnel involved
19	Species	Enter each species present in the subplot on a separate line
20	#	The number of subplots in which the species occurred at a Cover Class of 1
21	#	The number of subplots in which the species occurred at a Cover Class of 2
22	#	The number of subplots in which the species occurred at a Cover Class of 3
23	#	The number of subplots in which the species occurred at a Cover Class of 4
24	#	The number of subplots in which the species occurred at a Cover Class of 5
25	#	The number of subplots in which the species occurred at a Cover Class of 6
26	Product	**DO NOT ENTER DATA INTO THIS FIELD.** This is an automated calculation. The result of the multiplication of the number of subplots containing the species at a Daubenmire Cover Class 1 (Field 20) times the midpoint percentage for this cover class (2.5%)
27	Product	**DO NOT ENTER DATA INTO THIS FIELD.** This is an automated calculation. The result of the multiplication of the number of subplots containing the species at a Daubenmire Cover Class 2 (Field 21) times the midpoint percentage for this cover class (15%)
28	Product	**DO NOT ENTER DATA INTO THIS FIELD.** This is an automated calculation. The result of the multiplication of the number of subplots containing the species at a Daubenmire Cover Class 3 (Field 22) times the midpoint percentage for this cover class (37.5%)

Field(s)	Field Name	Required Information
29	Product	**DO NOT ENTER DATA INTO THIS FIELD.** This is an automated calculation. The result of the multiplication of the number of subplots containing the species at a Daubenmire Cover Class 4 (Field 23) times the midpoint percentage for this cover class (62.5%)
30	Product	**DO NOT ENTER DATA INTO THIS FIELD.** This is an automated calculation. The result of the multiplication of the number of subplots containing the species at a Daubenmire Cover Class 5 (Field 24) times the midpoint percentage for this cover class (85%)
31	Product	**DO NOT ENTER DATA INTO THIS FIELD.** This is an automated calculation. The result of the multiplication of the number of subplots containing the species at a Daubenmire Cover Class 6 (Field 25) times the midpoint percentage for this cover class (97.5%)
32	Total Canopy	**DO NOT ENTER DATA INTO THIS FIELD.** This is an automated calculation. The sum of the products (i.e., the sum of Fields 26 to 31)
33	Canopy Cover %	**DO NOT ENTER DATA INTO THIS FIELD.** This is an automated calculation. The percent canopy cover of the species, derived by the division of the Total Canopy (Field 32) by the total number of subplots (10), rounded to the nearest whole number
34	Canopy Cover Total	**DO NOT ENTER DATA INTO THIS FIELD.** This is an automated calculation. The sum of the Canopy Cover values calculated for each species (i.e., the sum of all Field 33 values)
35	Species Composition %	**DO NOT ENTER DATA INTO THIS FIELD.** This is an automated calculation. The contribution of the Canopy Cover of each species (Field 33) to the total composition of the cover, calculated by dividing each species' Canopy Cover (Field 33) by the Canopy Cover Total (Field 34), multiplied by 100, rounded to the nearest whole number
36	Frequency %	**DO NOT ENTER DATA INTO THIS FIELD.** This is an automated calculation. The number of subplots in which the species occurred, divided by the total number of subplots, multiplied by 100

38.4 Standard Random Walk

In addition to the quantitative cover data collected within each of the vegetation subplots, a "standard random walk" through the site is to be conducted to identify the presence of species not present within the subplots. This is a presence/absence survey only; quantitative cover or abundance data are not required.

The "standard" component of the walk is to be measured in time – the walk is to be conducted for a period of 30 min. The "random" component of the walk relates to the absence of a specific survey pattern or trail that must be followed. The walk is to cover the entire jack pine monitoring site, avoiding stand edges where transition from the jack pine ecological analogue forest type gives way to other vegetation types and soil conditions. The walk must avoid entry into the vegetation and soil plots.

Remarks as to the distribution or number of occurrences of each species should be made. The species list derived on the standard random walk is to be recorded in field note format (a TEEM Form is not provided).

PROCEDURE #40
REGENERATION AND SAPLING SURVEY

40.1 Background

This procedure applies to the vegetation plot at both the stand interior and stand edge monitoring sites, and to sites both unaffected by and those burned in regional wildfires since 2011. This procedure is based on the ARNEWS Regeneration and Sapling Survey (D'Eon et al., 1994[1]).

Regeneration is defined as seedlings that are between 16 and 200 cm tall, having a DBH <10cm. Included are all tree species that have the potential to grow to their normal, mature size in the region. Shrub species are excluded.

Saplings are young trees (exclude shrub species) that are at least 2 m tall, with a DBH <10cm. Tree species codes for use in completing TEEM Forms 12 and E12 are as follows:

Tree Species Codes for TEEM Form 12 and E12

Common Name	Scientific Name	Code
Balsam fir	*Abies balsamea*	Fb
Tamarack larch	*Larix laricina*	Lt
Jack pine	*Pinus banksiana*	Pj
Lodgepole pine	*Pinus contorta v. latifolia*	Pl
Black spruce	*Picea mariana*	Sb
White spruce	*Picea glauca*	Sw
Balsam poplar	*Populus balsamifera*	Pb
Trembling aspen	*Populus tremuloides*	Aw
White birch	*Betula papyrifera*	Bw

40.2 Regeneration (Seedling) Survey

Within each small and medium subplot within the vegetation plot at each stand interior monitoring site, count the number of seedlings (by tree species) within 20-cm height classes, excepting the tallest (156 to 200 cm) height class which forms a single category. A measuring device up to 2 m tall, marked to define height classes, is to be used to determine which seedlings are to be counted (tallied) within each of the eight height classes. Data are to be recorded on TEEM Form 12.

[1] D'Eon SP, Magasi LP, Lachance D, DesRochers P (1994) *ARNEWS. Canada's National Forest Health Monitoring Plot Network. Manual on Plot Establishment and Monitoring (Revised).* Information Report PI-X-117. Petawawa National Forestry Institute, Chalk River, ON.

Within the vegetation plot at each stand edge monitoring site, count the number of seedlings (by tree species) within 20-cm height classes, excepting the tallest (156 to 200 cm) height class, within each small and medium subplot. Data are to be recorded on TEEM Form E12.

40.3 Sapling Survey

At stand interior monitoring sites, count the number of saplings (by species) in each small, medium and large subplot within the vegetation plot, and record this count in the appropriate row on TEEM Form 12 (stand interior). At stand edge sites, record the number of samplings in each of the small and medium subplots in TEEM Form E12 (stand edge).

TEEM Forms 12 and E12 are to be completed as follows:

TEEM Form 12 and E12 – Regeneration and Sapling Survey

Field(s)	Field Name	Required Information
1 & 2	Page _ of _	Complete after collecting the data from the last plot at the site
3 to 7	Site	5-Character site designation
8 to 15	Assessment Date	Date as YYYY-MMM-DD (July 9, 2018 would be recorded as “2018-07-09”)
16 to 18	Personnel	Three fields are provided for the full names of the personnel involved
19	Subplot Size	Enter “Small” (interior, edge), “Medium” (interior, edge), or “Large” (interior only)
20	Subplot No.	Enter the number of the subplot (“1” to “10” for Small, “1” or “2” for Medium, “1” for Large)
21 & 22	Tree Species	Enter the code for each species (see below) present in each subplot on a separate line
23	16-35	Enter the number (count) of regenerating trees that are 16 to 35 cm tall
24	36-55	Enter the number (count) of regenerating trees that are 36 to 55 cm tall
25	56-75	Enter the number (count) of regenerating trees that are 56 to 75 cm tall
26	76-95	Enter the number (count) of regenerating trees that are 76 to 95 cm tall
27	96-115	Enter the number (count) of regenerating trees that are 96 to 115 cm tall
28	116-135	Enter the number (count) of regenerating trees that are 116 to 135 cm tall
29	136-155	Enter the number (count) of regenerating trees that are 136 to 155 cm tall
30	156-200	Enter the number (count) of regenerating trees that are 156 to 200 cm tall
31	Total Regeneration	Enter the total number of regenerating trees in the subplot (total of fields 23 to 30)
32	Sapling Survey Count	Enter the total number of saplings (trees >200 cm, <10 cm DBH) in the subplot
33	Remarks	Enter observations, difficulties and any other information that may be useful in guiding the interpretation of the data