Wood Buffalo Environmental Association

Procedures Manual

2024 Forest Health Monitoring

Terrestrial Effects Environmental Monitoring (TEEM) Program

Preface

Wood Buffalo Environmental Association
2024 Forest Health Monitoring Program

Procedures Manual

This version of the WBEA 2024 Forest Health Monitoring Program Procedures Manual is intended to provide guidance to personnel tasked with completing the 2024 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.

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1.0 INTRODUCTION

The Wood Buffalo Environmental Association's (WBEA) Forest Health Monitoring (FHM) Program, overseen by the Terrestrial Environmental Effects Monitoring (TEEM) committee, integrates soil and vegetation 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. The history of the TEEM program is described in Foster et al. (2019).

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. Changes in species composition, as changes in soil chemistry and effects on vegetative growth alter competitive relationships among species.

This is visualized in the FHM Program conceptual model (Figure 1; from Foster et al. 2019).

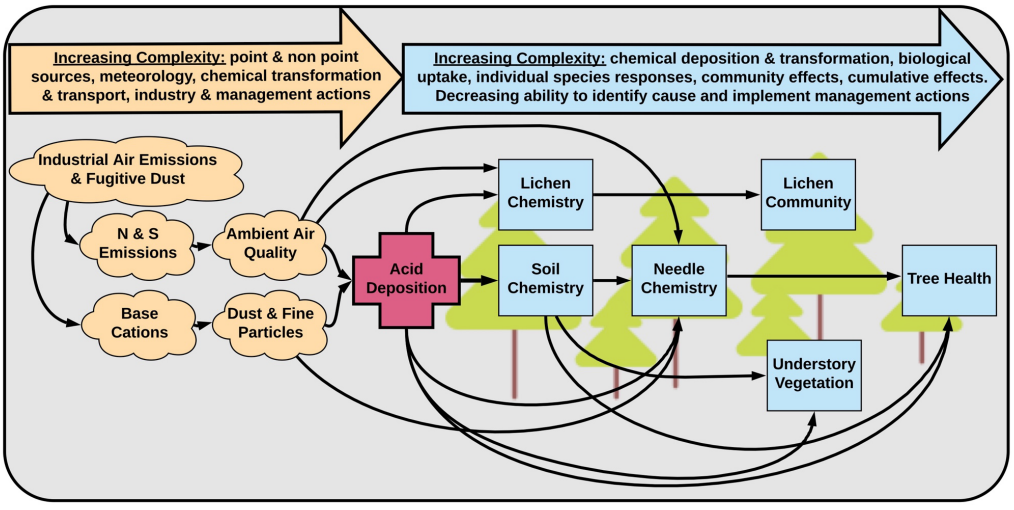

Figure 1: Forest Health Monitoring Program conceptual model

Light orange = acid deposition precursors and processes; red = stressor (acid deposition); and blue = ecological responses. In each of the precursor and processor and ecological response categories, system complexity increases from left to right (from Foster et al. 2019).

The design and methods of the FHM Program are based on the National Acid Rain Network Early Warning System (ARNEWS) (D'Eon et al., 1994; AGRA Earth & Environmental, 1999; Foster et al. 2019). This design focuses on monitoring within relatively large stands, as the ARNEWS objective was to evaluate broad-scale forest responses to acidic input. 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.

In 2011, the Forest Health Edge Monitoring program was established under the reasoning that 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. Monitoring at stand edges was expected to provide an earlier indication of responses to exposure to substances in the air to and/or deposition of these substances than would occur at the stand interior. A number of monitoring sites at these exposed stand edges were established for sampling and measurement of key parameters relating to air quality, deposition and ecological effects. The Edge program was paused in 2024 as the preliminary analyses showed no patterns between edge and interior sites and questions were raised regarding the efficacy of the methods. Procedures for the Edge program have been removed from this manual for 2024, until the future of the program is assessed.

Linking ecological responses to air emissions and deposition requires remote and widespread measurements of air quality and deposition levels. A number of monitoring sites have been equipped with towers equipped with passive and active (solar-powered) monitoring equipment. These complementary monitoring systems are operated by the WBEA according to procedures outside of the FHM Program. Personnel should be aware of the broad suite of WBEA programs and their part in it, paying particular attention to the interfaces with those tasked with execution of these other programs. Consultation with the Program Coordinator is required when in doubt about any aspect of the program or the procedures.

Due to the longevity of the program and the long interval between sampling campaigns, 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 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 Laboratory Selection

Selection of a laboratory (or laboratories) should be made well in advance of the field program to ensure that chosen laboratories have the time necessary to properly prepare to receive the samples, and to analyse and provide the results of the analyses to WBEA in a timely manner. 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.

Chain-of-custody documentation begins at the time of sample collection. This documentation is to include the information required to uniquely identify the sample, the date and time of acquisition, the personnel acquiring the sample, and any comments regarding the sample that personnel believe may help in the interpretation of the results of analysis of the sample. Laboratories may provide a chain-of-custody document that may be used at the discretion of the Program Coordinator.

The sample transfers custody only when a responsible individual explicitly relinquishes custody and the receiving individual explicitly accepts custody, with the transfer of custody documented. 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, holding times are appropriate). Should a sample be compromised, a notation detailing the circumstances in the chain-of-custody document is to be made, and the Program Coordinator is to be notified.

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 data loss and a monetary cost.

2.3 Sample Labelling

Samples are to be labelled according to **SAMPLE LABELLING PROCEDURE (#1)**. Sample names entered into chain-of-custody documentation 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 document 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 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 transit time and the expected delivery time to 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.

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

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 at the WBEA Centre.

SAMPLE STORAGE & SHIPPING PROCEDURE (#2) describes the storage requirements for the samples from the time of field collection through to sample archival. Samples are generally held in an interim storage facility (e.g., the WBEA Centre) for a few days, after which they are packaged and shipped to a laboratory. The receiving laboratory is to be notified upon shipment so that it is prepared to receive the samples. If the samples do not arrive as expected, the laboratory is to immediately notify the Program Coordinator, and contact with the shipping company made to initiate a trace on the shipment. Lengthy delays in shipment may compromise an entire sample set.

3.0 JACK PINE MONITORING SITE SELECTION & ESTABLISHMENT

3.1 Jack Pine Monitoring Site Selection Criteria

Selection of ecologically analogous jack pine sites has been emphasized since the inception of FHM Program in 1996 (Foster et al. 2017). This reduces variability within the measured parameters, increasing the ability to detect responses to deposition and exposure to air emissions.

The geographic and vegetative criteria defining the jack pine forest type suitable for inclusion in the FHM Program are shown in Table 1. These criteria are generally similar to those of the a1 ecosite phase (Beckingham and Archibald, 1996), which are included in Table 1 for comparison. While it is recognized that there will be variability around these criteria, site selection processes are to minimize variability among selected sites. Material deviations from criteria require evaluation and acceptance by a forest specialist before a site with such criteria can be accepted into the FHM program.

3.2 Site Selection Timing

Site selection and establishment activities are to be conducted in the summer, preferably in August. After September 1st, the risk of understory plants having senesced is high, which impacts the accuracy of the cover assessments (e.g., noted in 2018 by contractors that it was an issue by mid-September).

3.3 Site Establishment Process

The stand interior site establishment process is illustrated in Figure 2. The following sections will provide details for each step in the process.

3.3.1 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)**.

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).** TEEM Form 01 and 01b should be completed at time of site establishment.

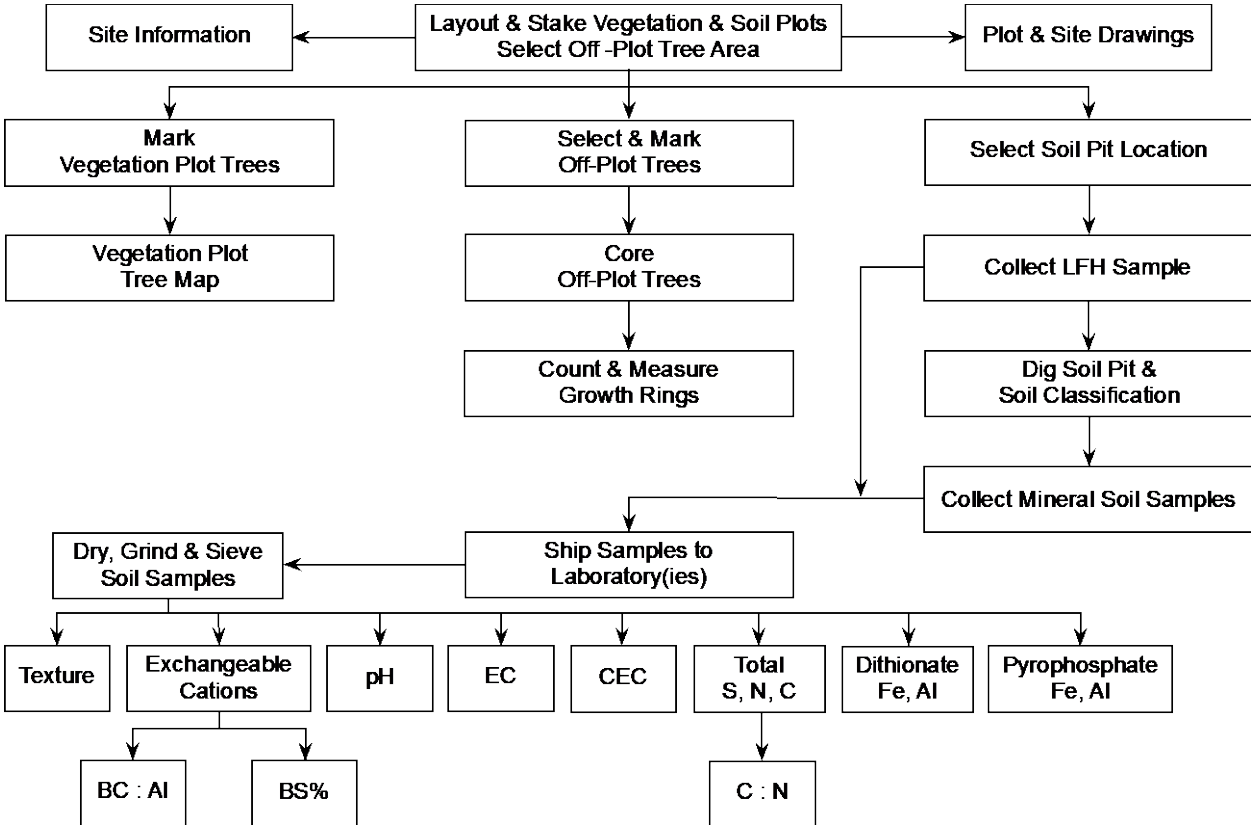

Figure 2: Stand Interior Site Establishment Flow-chart

3.3.2 Site Information

Site information for a new monitoring site is to be recorded according to **SITE INFORMATION PROCEDURE (#3)**, which includes completion of TEEM Form 01. Site information and observations should be from the perspective of the vegetation plot. 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.

Photographs of the site will be taken during site establishment. Photos are to be taken from the center of the vegetation plot at all four cardinal directions. Unique photo identifier and the cardinal direction are to be included on TEEM Form 01.

3.3.3 Plot Layout & Site Drawings

The plot layout and site drawings provide critical information for field personnel.

The plot layout drawing is to be prepared at a scale that permits presentation of all soil and vegetation plots, the off- plot tree area, the location of the soil pit, the location of the helipad, 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. Plot subplot and location numbers are required for soil plots. Subplot numbers are

required for vegetation plots. 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 are to be included on each drawing. Plot layouts should be hand-drawn in the field on TEEM Form 01b with all necessary information, and would then be digitized, as seen in Figure 3.

A site drawing showing the location of the plots in a wider context is also recommended. This drawing is to indicate the location of the helicopter landing site, nearby cutlines, forest stand edges, 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, scale bar and an arrow to true North are to be included. An example of a site drawing is presented in Figure 4.

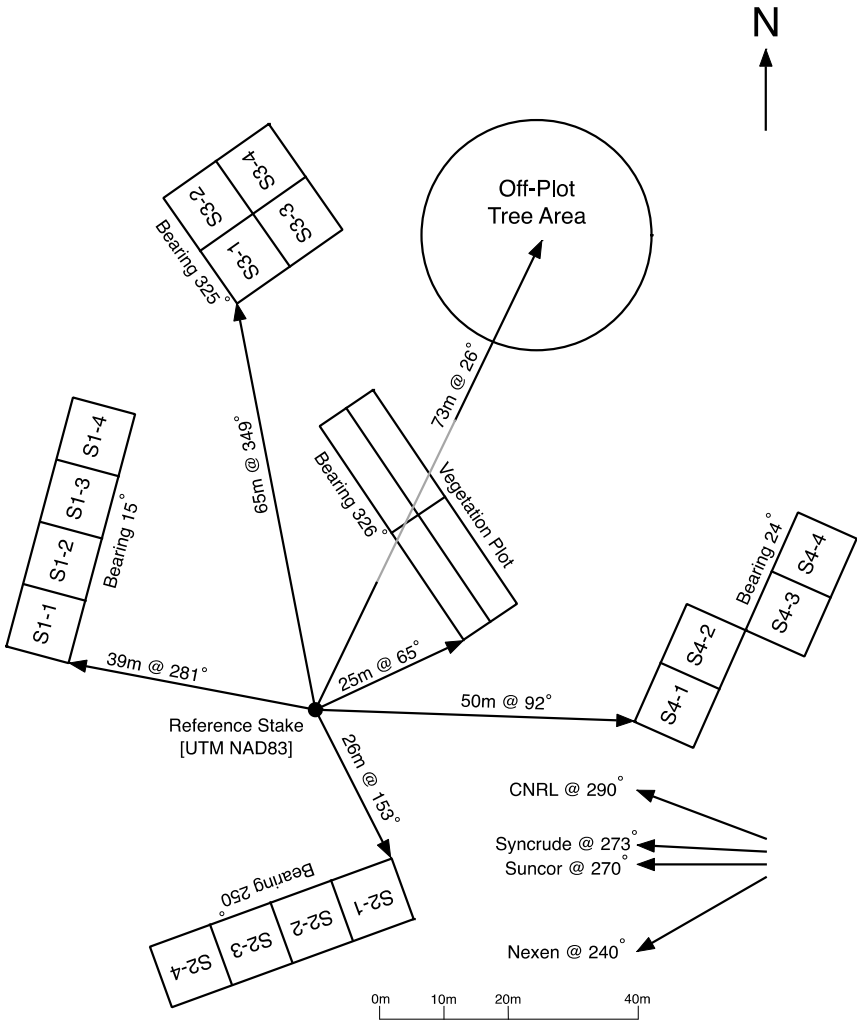

Figure 3: Example Stand Interior Plot Layout Drawing

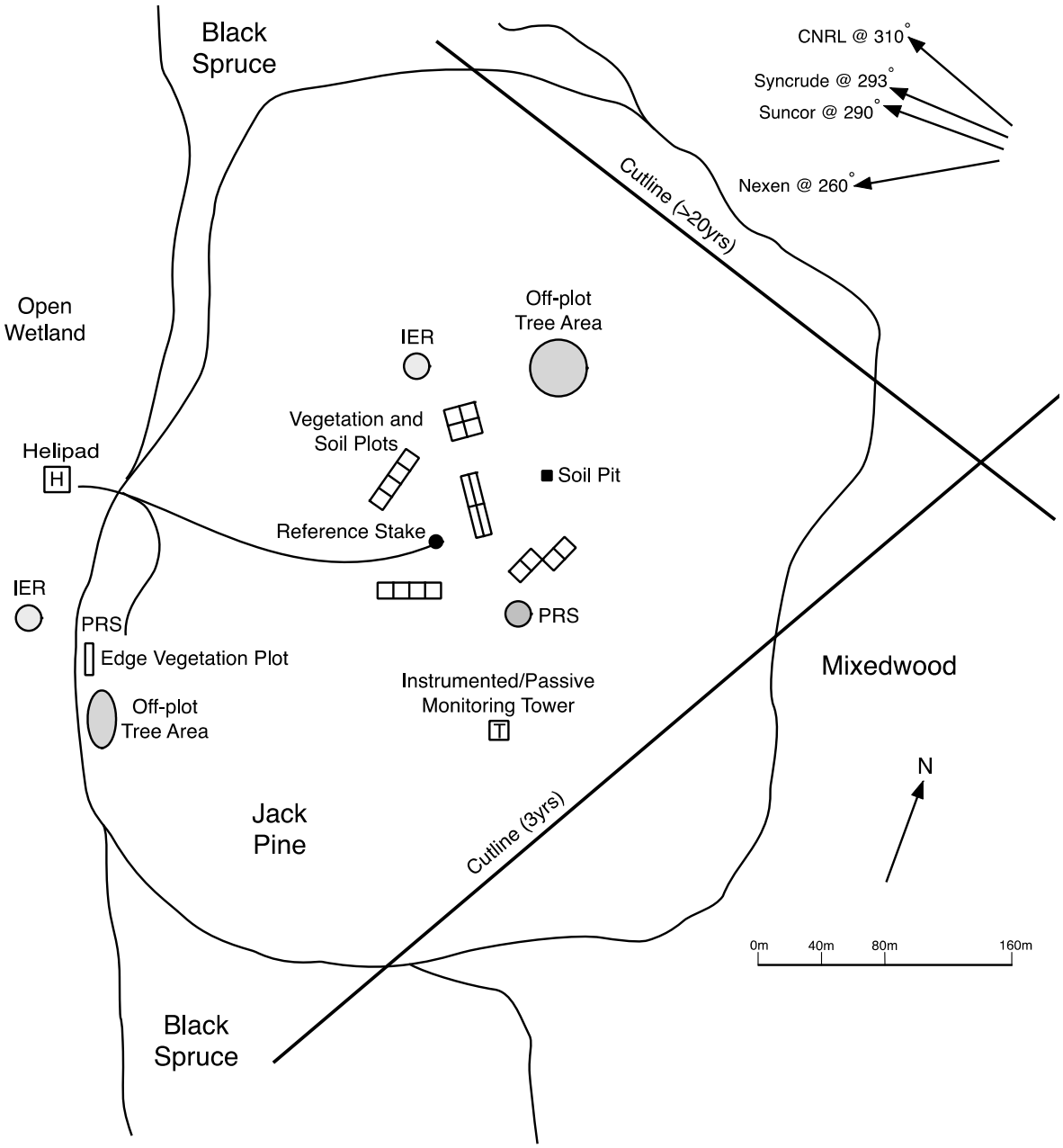

Figure 4: Example Site Drawing

Table 1: Vegetation Characteristics of Jack Pine Ecological Analogue Types

Criteria	Jack Pine Stand Characteristics (FHM Program)	a1 Ecosite Phase (Beckingham and Archibald 1996)
Geographic:		
Slope & position	Gentle, mid- to upper-slope, level, crest	2 to 30%, mid- to upper-slope, level, crest
Aspect	Any	Any
Moisture regime	-	Subxeric, xeric, (submesic)
Nutrient regime	Poor	Poor to very poor
Soil drainage	Rapid to well	Rapid to well
Parent material	Shallow calcareous bedrock, eolian, glaciofluvial	Glaciofluvial, fluvial, eolian, (morainal)
Organic horizon depth	-	≤5 cm (≤15 cm)
***Pinus banksiana*:**		
Stand characteristics	Large enough to maintain 3-tree height distance from plots to any transition zone to another forest type	-
Canopy cover	>20%	>20%
Tree age	40 to 70 years	-
Indicator species cover:		
Cladonia spp.**	50%	>10%
Arctostaphylos uva-ursi	≤5%	>20%
Vaccinium myrtilloides	≤5%	≤20%
Vaccinium vitis-idaea	≤5%	2% to 20%
Linnaea borealis	0%	≤5%
Pleurozium schreberi	≤10%	>5%
Dicranum polysetum	2%	≤5%
Ledum groenlandicum	0%	≤5%
Maianthemum canadense	≤5%	≤5%
Polytricium spp.	≤1%	≤20%
Alnus crispa	<1%	≤20%
Cornus canadensis	≤1%	-
Hudsonia tomentosa	-	≤2%
Cladonia gracilis	0%	≤5%
Picea spp.	0%	≤5%
Rosa acicularis	≤1%	≤2%
Geocaulon lividum	-	≤5%
Peltigera aphthosa	-	≤2%
Betula spp.	0%	≤20%
Populus spp	0%	-
Sheperdia canadensis	≤1%	-
Juniperus spp.	-	≤10%
Salix spp.	0%	-

3.3.4 Vegetation Plot Establishment

A vegetation plot measuring 10 m x 40 m is to be established 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, structure and density.

The corners of this plot, the plot centre, and the midpoints along each axis, are to be marked with spray-painted green wood stake over which a short segment of hollow, white plastic stake is installed. This provides for visual reference points (wood stakes with PVC), and for detection of the plot corners (fibreglass stakes) 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 4).

Each tree within the plot is to be numbered and labelled according to **TREE NUMBERING & LABELLING PROCEDURE (#5)**.

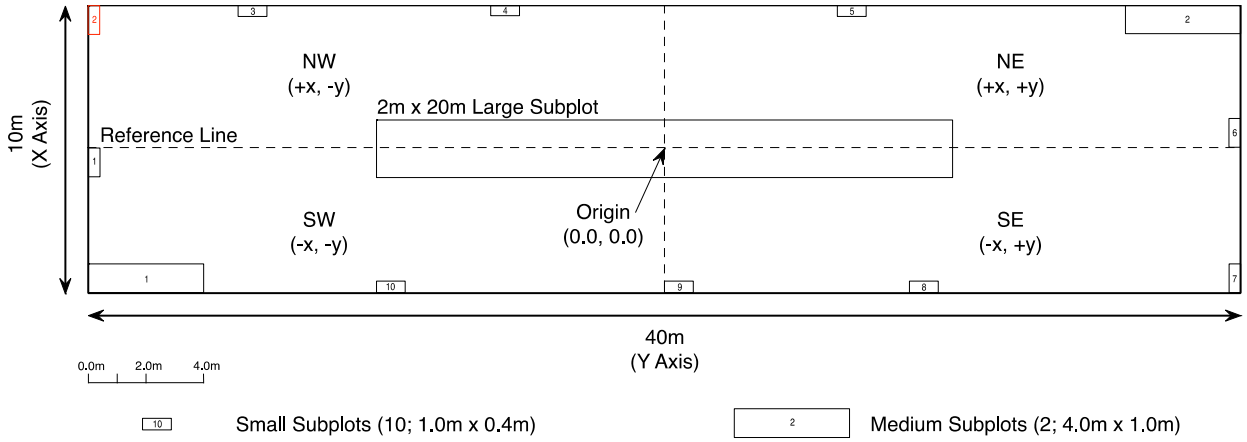

Figure 5: Vegetation Plot Layout

Assessments of plant community composition are to be made using a series of subplots delineated within the vegetation plot. Ten small (1.0 m x 0.4 m), two medium (4.0 m x 1.0 m), and one large (20 m x 2 m) subplots are to be arranged as shown in Figure 5. Small subplots are to be numbered in sequence (1 to 10) and medium subplots in sequence (1 to 2), beginning in the southwest corner of the main plot and proceeding clockwise. On the Plot Diagrams, the SW corner is marked with "VEG" and therefore numbering of subplots will start in this corner. 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.

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 **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 or below a height of 1.3 m 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 individual 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 **VEGETATION PLOT TREE MAP PROCEDURE (#24)**, which includes completion of TEEM Form 02 for any newly added trees or trees requiring an updated location. An example of coordinates assigned to trees in each of the four quadrants of the stand interior vegetation plot map is shown in Figure 6.

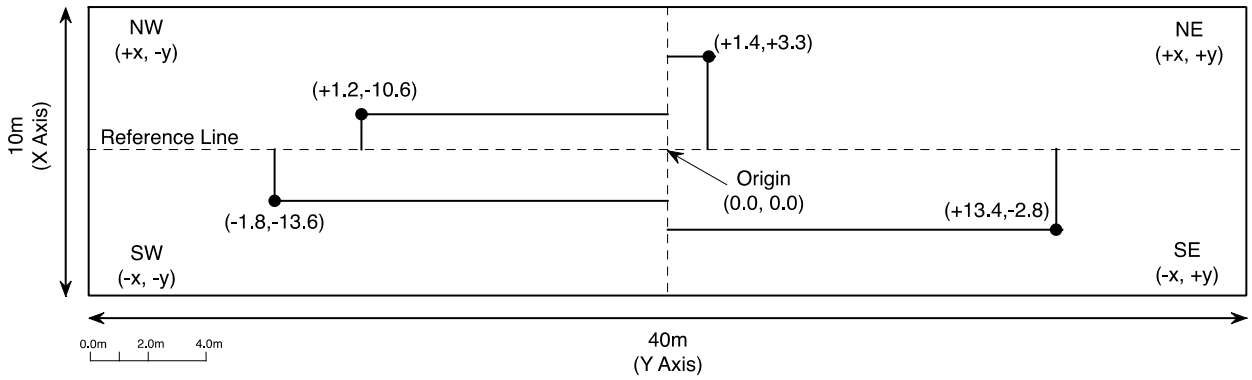

Figure 6: Vegetation Plot Tree Map Example

3.3.5 Off-Plot Tree Area Establishment

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 destructive sampling 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. The location of the off-plot trees must be recorded and marked on all site drawings.

From the pool of trees in the off-plot area(s), 10 trees are to be selected, numbered and labelled according to **TREE NUMBERING & LABELLING PROCEDURE (#5)**.

3.3.5.1 Off-Plot Tree Age

Tree age is to be determined for each of the 10 off-plot trees, at each of the stand interior sites. Tree cores are to be obtained using **TREE CORING PROCEDURE (#25)**. If tree cores are taken during a sampling campaign, TEEM Form X03 should indicate from which trees cores were taken. Tree cores are to be processed and analysed according to the **TREE CORE PREPARATION & ANALYSIS PROCEDURE (#26)**, which includes completion of TEEM Form X05.

3.3.6 Soil Plots and Soil Pit Establishment

Each monitoring site requires four soil plots and a soil pit. The four soil plots will be sampled during site establishment and during each 6-year campaign. The soil pit is only sampled during site establishment to characterize the soil type.

3.3.6.1 Soil Plot Location and Staking

A standard 40 m x 10 m (400 m^2) plot is preferred; however, where site characteristics do not permit the establishment of the preferred plot configuration, alternate configurations are permitted (Figure 7). Note that in all configurations the subplots within each main plot are to be contiguous, connected by at least one corner stake. Soil plots are to be a minimum of 10 m from the vegetation plot and each other.

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. A 300 m^2 plot has a reduced long side from 40 m to 30 m (subplots 10 m x 7.5 m), and a 225 m^2 plot has the long side reduction along with a reduction of the short dimension from 10 m to 7.5 m (subplots 7.5 m x 7.5 m). The configurations illustrated in Figure 7 may also be used for these smaller plots. Plot sizes are documented in the Site Information Forms for each site.

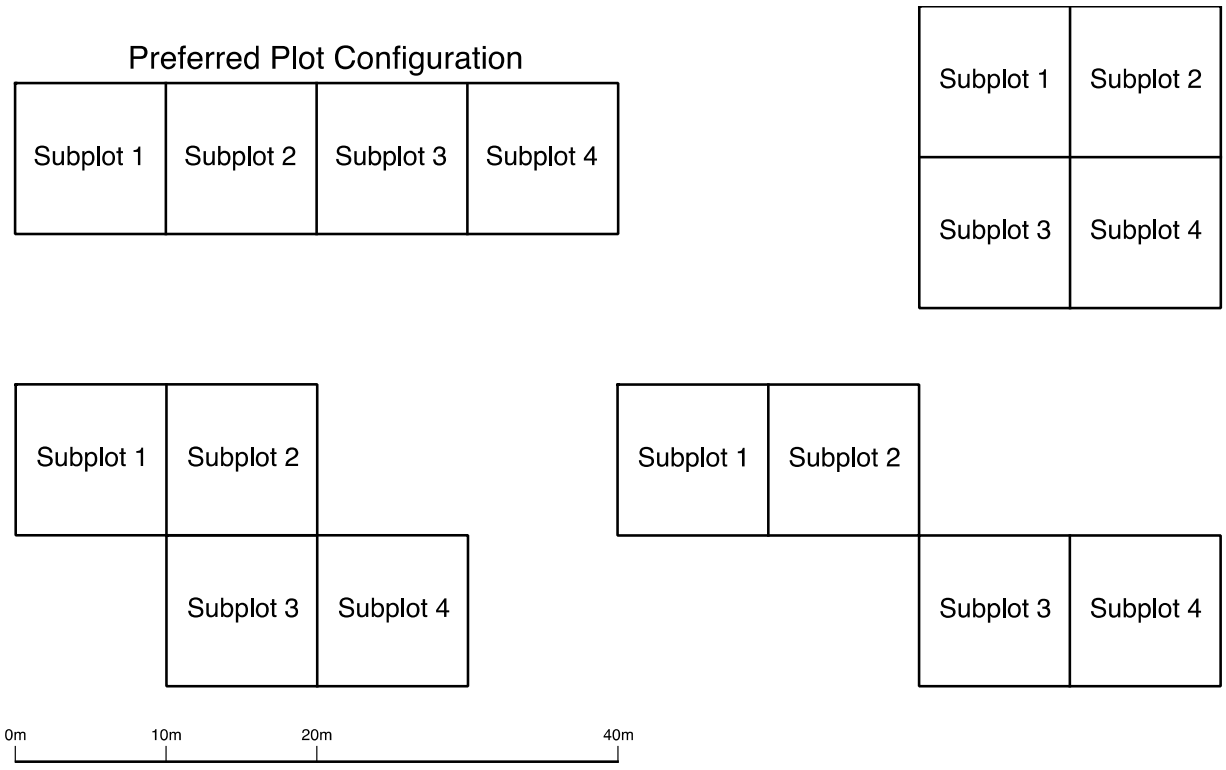

Figure 7: Stand Interior Soil Plot Configurations

Each soil plot is to be divided into four subplots. The corners of the plot and each subplot are to be staked with a spray-painted orange wood stake over which a hollow, white plastic PVC tube is installed. This provides for visual reference points (wooden stakes), and for detection of the plot corners (plastic stakes) 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, as rusting and leaching of metallic substances may compromise soil samples.

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”). The placement of plots and subplots must be recorded and marked on all site drawings. A Sharpie is used to mark the subplot locations on the wooden stakes.

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. Distances and bearings from the reference stake are to be collected for the new soil plot.

3.3.6.2 Soil Pit Size and Location

At stand interior monitoring locations a soil pit is required for sampling during site establishment only. 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.

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 about 1 m deep, preferably into the C horizon. Coordinates for the pit location (UTM; NAD83) are to be recorded.

The pit is to be a minimum of 10 m from the vegetation plot, and at least 5 m from any of the soil plots. 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. All soil sampling is to be conducted using stainless streel tools and while wearing powderless nitrile gloves. 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 for safety reasons.

Photographs are to be taken of the pit wall prior to sampling. Photograph numbers are to be recorded on and included with TEEM Form 10.

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.

3.3.7 Soil Pit 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.

3.3.8 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 as described below differs from the sampling required during the 6-year monitoring cycle.

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

3.3.8.1 LFH Sample Collection

An LFH sample 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)**.

3.3.8.2 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, and photographs are to be included with the TEEM Form 10 submitted to the Program Coordinator.

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 soil horizons 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 and 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)**.

3.3.9 Soil Pit Sample Laboratory Analyses

3.3.9.1 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 **SOIL SAMPLE PREPARATION & WEIGHING PROCEDURE (#9)**.

3.3.9.2 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 **SOIL TEXTURE ANALYSIS PROCEDURE (#10)**, which is based on Kalra and Maynard (1991) and Carter and Gregorich (2008).

3.3.9.3 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)**.

3.3.9.4 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 **SOIL ELECTRICAL CONDUCTIVITY ANALYSIS PROCEDURE (#12)**, which is based on Miller and Curtin (2008).

3.3.9.5 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 **SOIL CATION EXCHANGE CAPACITY ANALYSIS PROCEDURE (#13)**, which is based on Kalra and Maynard (1991) and Skinner et al. (2001).

3.3.9.6 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 **SOIL EXCHANGEABLE CATIONS ANALYSIS PROCEDURE (#14).**

3.3.9.7 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)**.

3.3.9.8 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)**.

3.3.9.9 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)**.

3.3.9.10 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)**.

3.3.9.11 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)**.

4.0 SITE PREPARATIONS FOR MONITORING CAMPAIGNS

Prior to a sampling campaign, all sites will need to be maintained and prepared for monitoring. This ensures that contractors visiting the plots can work as efficiently as possible. Tasks to complete prior to the monitoring campaign include:

- Plot and Site Maintenance
- Updating Plot Diagrams
- Updating Site Information Sheets

4.1 Plot and Site Maintenance

Regular site maintenance is required to ensure that site access, trails, plot stakes and tree labels continue to be visible, and is to include:

- maintaining the helicopter landing pad and trail to the monitoring site;
- inspecting and replacing the reference stake, as necessary;
- replacing plot stakes;
- restoring degraded tree markings and labels; and
- replacing tight wires on labelled plot and off-plot trees to prevent tree girdling and damage.

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.

Personnel 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 included in DocIT and then also included in relevant site documents.

4.2 Updating Plot Diagrams

All plot diagrams should be reviewed and updated prior to the field campaign. This will include applying any notes from the previous campaign and, as needed, ground-truthing the diagrams. Plot diagrams should then be updated so that field personnel have the most accurate images.

4.3 Updating Site Information Forms

Site information forms are to be completed prior to the field season for all sites to be monitored. Data contained in these forms include key coordinates, access, burn history, vegetation plot and off-plot tree numbers, trees for destructive sampling, soil plot sizes and soil locations to be sampled. This form, along with the plot diagram for that site, will be provided to the necessary personnel in advance to ensure important sampling information is available.

5.0 SOIL MONITORING PROGRAM (6-YEAR CYCLE)

The soil monitoring procedures at stand interior monitoring sites that comprise the 6-year cycle of activities are illustrated in Figure 8.

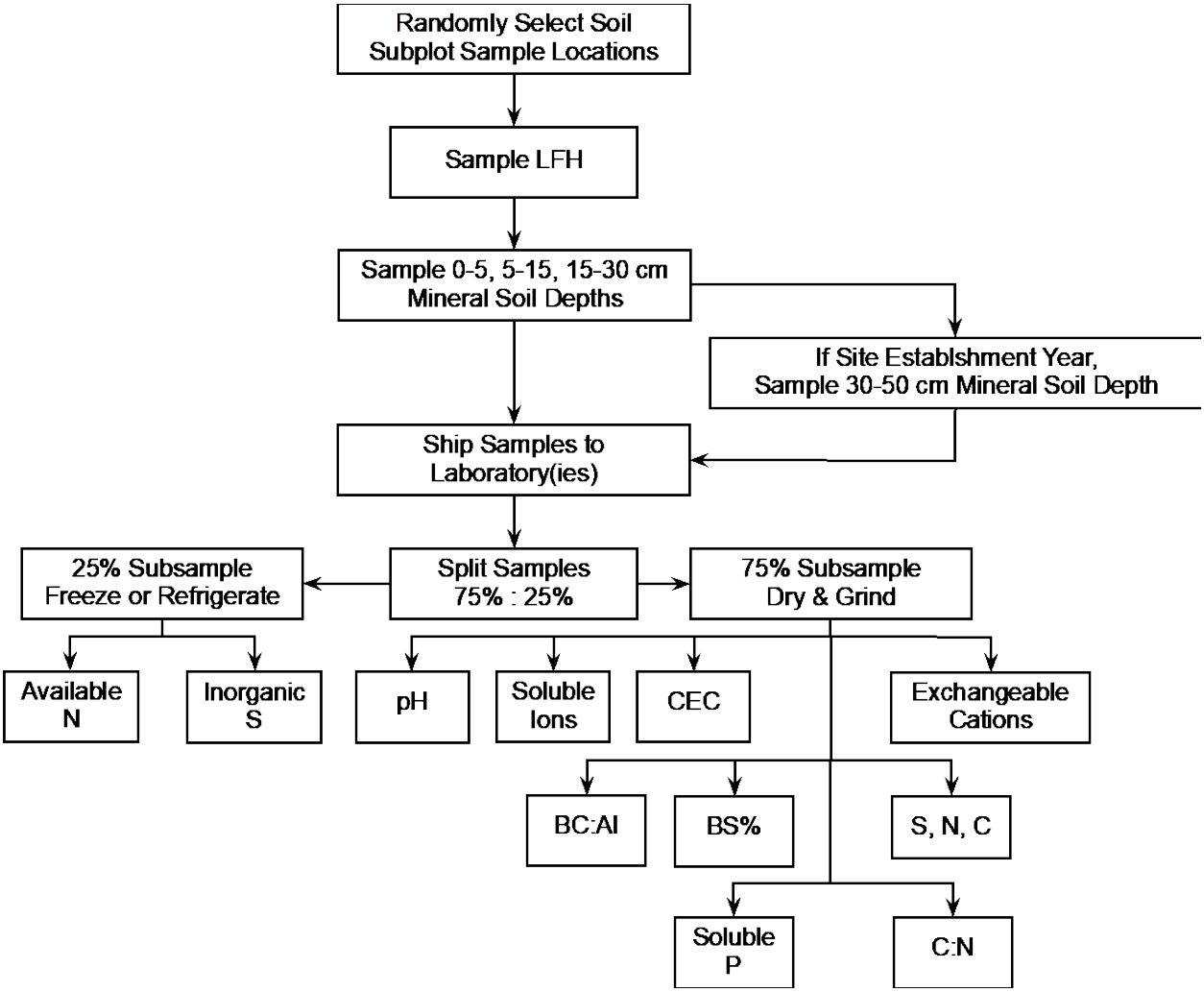

Figure 8: Soil Monitoring Program Flow-chart

5.1 Soil Sample Location

Nine fixed points within each subplot define soil sampling sample locations within each 10 m x 10 m soil subplot (Figure 9). **Note: In 2011 and 2018, nine locations were sampled at the smaller subplots (Sites 3010 and 3015). This process will be continued to ensure no overlap in sampling location.** Sampling locations are not to be marked in the field and a location is not to be re-sampled in future years.

In 2018 each soil subplot was sampled. Based on a power analysis in 2024, the number of subplots sampled was reduced to two out of the four subplots per plot will be sampled. Each 6-year sampling campaign, either even subplots or odd subplots will be sampled; in 2024, odd numbered subplots are to be sampled (e.g., S1-1 and S1-3, S2-1 and S2-3). If original subplots have been replaced, the replaced subplot will be sampled based on the number that the subplot replaced (e.g., if subplot 4 was replaced by subplot 5, then subplot 5 would be sampled in an "even" year). The process to select sample points (including the point from which a field duplicate sample is to be taken) and record those chosen are to be recorded on TEEM Form 11, as described in **SOIL SAMPLE LOCATION & CHECKLIST PROCEDURE (#8)**.

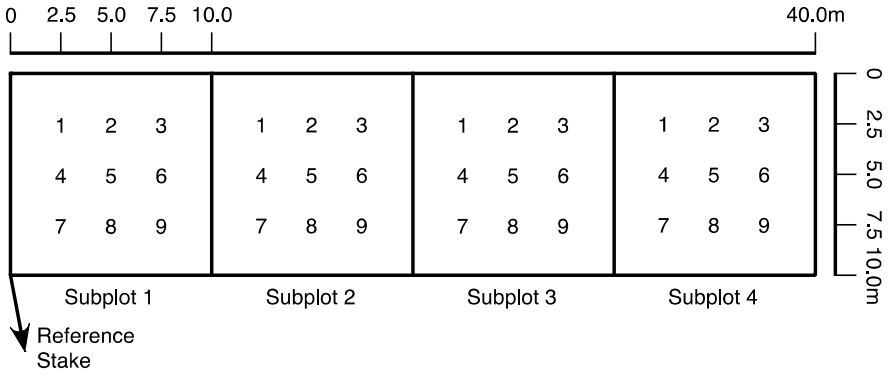

Figure 9: Soil Sample Locations

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 the two subplots chosen for that year (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 as a letter "D" after the location number (ex. S1-4-3D).

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 to be towards the perimeter of the subplot, except for location #5 which is to move in whatever direction that there is no longer a disturbance (Figure 10). Adjustments to soil sampling locations are to be measured, to the nearest 0.1 m, and recorded on TEEM Form 11.

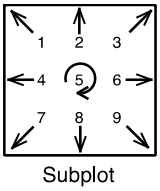

Figure 10: Soil Sample Location Adjustments

5.1.1 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 is to be numbered with the next available digit (e.g., “5” if replacing one of the original four soil plots), with subplots numbered from 1 to 4 (e.g., “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).

5.2 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.

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

5.2.1 LFH Sample Collection

An LFH sample is to be collected from the randomly selected, pre-determined location within each pre-selected 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 or 50cm x 50cm (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 the one randomly chosen subplot at each site. From this location, approximately twice the amount of LFH material (over an area of up to 5,000 cm^2 or approx. 70 cm x 70 cm) is to be collected. The LFH material, once cleaned, is to be placed on a clean surface, thoroughly mixed, and divided into two equal portions: one representing the subplot sample and the other the field duplicate. The sample should be bagged and labelled with a “D” after the location (e.g., S1-4-3D denoting plot 1, subplot 4, location 3 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 **SAMPLE LABELLING PROCEDURE (#1)** and stored/shipped according to **SAMPLE STORAGE & SHIPPING PROCEDURE (#2)**.

5.2.2 Mineral Soil Sample Collection

A sample of each of the 0 to 5 cm, 5 to 15 cm, and 15 to 30 cm mineral soil layers is to be obtained from two pre-selected subplot sample locations, 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 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 pre-determined location. From this location, approximately twice the amount of mineral soil material (1,000 cm^3) is to be collected. The material from that depth 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, which will be noted with a "D" in the sample name.

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)**.

5.3 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, 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 Program Coordinator.

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.

5.3.1 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)**.

5.3.2 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)**.

5.3.3 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)**.

5.3.4 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)**.

5.3.5 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)**.

5.3.6 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)**.

5.3.7 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)**.

5.3.8 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)**.

5.3.9 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).

5.3.10 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).

5.3.11 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)**.

6.0 VEGETATION MONITORING PROGRAM (6-YEAR CYCLE)

Vegetation measurement, sampling and laboratory analysis procedures apply during both plot establishment and each 6-year sampling campaign.

A number of 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 sites, 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 FHM Program in 2018 and continues in the 2024 campaign.

6.1 Vegetation Monitoring Schedule

Vegetation monitoring activities are to be conducted in August. 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, plant senescence). In past years, plant senescence has been observed in mid-September.

6.2 Vegetation Plot Data

Each sample campaign there are four main procedures associated with the vegetation plot. This includes data collected on trees reaching DBH of 10cm or more within the plot, sapling and seedling regeneration, community assessments on subplots, photographs to show change in the ecosystem over time, and canopy cover over the vegetation plot. The Standard Random Walk is included in this section, but the intent is to capture vegetation across the entire site, not just within the vegetation plot.

6.2.1 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 **TREE DATA PROCEDURE (#28)**, which includes completion of TEEM Forms 03.

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

6.2.2 Regeneration

The **REGENERATION AND SAPLING SURVEY PROCEDURE (#40)** was introduced into the TEEM Program in 2018, and applies to all sites, whether fire-affected or not. This procedure includes enumeration of seedlings of all tree species 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 Form 12.

6.2.3 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 TEEM Forest Health Monitoring Program sites, both those that have been unaffected by fire and those that were burned in wildfires since 2011.

6.2.3.1 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, as described in **PLANT COMMUNITY ASSESSMENT PROCEDURE (#38)**. Data are to be entered into TEEM Form 08b.

6.2.3.2 Standard Random Walk

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 and provide an estimate of distribution across the entire site. Data are to be entered into TEEM Form 13.

6.2.3.3 Site Photographs

Site photographs are to be taken each monitoring campaign to provide a visual reference to changes in the site, as described in the **PLANT COMMUNITY ASSESSMENT PROCEDURE (#38)**. Standing at the vegetation plot centre, one photo is taken in each of the cardinal directions (N, E, S, W) and one photo is taken looking directly up at the sky of the canopy. Ensure all photos are clear and in focus. Photos are to be labelled as "SiteNumber_Date_Direction/Canopy". Information is to be entered into TEEM Form 14.

6.2.4 Canopy Cover (Using Convex Densiometer)

The spherical densiometer is an instrument used to calculate quantitative estimates of relative canopy closure or density. A convex spherical densiometer is used and modification is based on the Strickler's wedge-shaped area method, as described in **CANOPY COVER USING CONVEX DENSIOMETER PROCEDURE (#41)**. Data on canopy cover at the vegetation plot in the four cardinal directions will be included on TEEM Form 15.

6.3 Off-Plot Trees

Off-plot trees are selected, marked and used for destructive sampling at all Forest Health monitoring sites. Each site should have 10 marked off-plot trees to be included in the sampling campaign.

All 10 off-plot trees are to be sampled with non-destructive methods each monitoring period, while a subset of five off-plot trees are randomly selected and used for destructive sampling each cycle.

6.3.1 Examination & Replacement of Off-Plot Trees

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

Replaced trees are to be numbered and labelled according to **TREE NUMBERING & LABELLING PROCEDURE (#5)**. Tags and painted numbers should not be removed from trees no longer being sampled in the off-plot; once tree no longer sampled, add a triangle above the number to indicate tree not to be used. Labelling of trees removed from the program is required to ensure that a rejected tree does not later re-enter the pool of off-plot trees.

At fire-affected sites, no selection, numbering or labelling of off-plot trees is required until the trees achieve growth sufficient to reach 10 cm DBH.

6.3.2 Aging Replacement Off-Plot Trees

At time of selection, off-plot trees are to be cored to determine age. If trees are replaced, tree cores from replacement off-plot trees are to be obtained using **TREE CORING PROCEDURE (#25)**. Tree cores are to be processed and analysed according to **TREE CORE PREPARATION & ANALYSIS PROCEDURE (#26)**, which includes completion of TEEM Form X05.

Any additional off-plot trees requiring coring will be noted on the Site Information Document. These generally include trees with anomalies in previous cores and therefore uncertain ages.

6.3.3 Off-Plot Tree Measurement Data

Morphometric tree data are to be collected from all of the 10 off-plot trees. These data allow for a comparison of growth between the plot and off-plot trees, 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 **TREE DATA PROCEDURE (#28)**, which includes completion of TEEM Form X03

6.3.4 Destructive Sampling of Off-plot Trees

6.3.4.1 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 one of the selected trees is or becomes unsuitable for sampling, 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
Site X	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)*
Site Y	X001, X002, X003, X004, X005, X006, X007, X008, X009, and X010		X001, X003, X004, X006, and X010 (X002)*
Site Z	X003, X004, X005, X006, X010, X014, X015, X016, X019, and X021		X003, X005, X006, X014, and X021 (X004)*

* 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 or the tree be otherwise deemed unsuitable for sampling.

TREE SHOOT DATA PROCEDURE (#29) is to be used to record off-plot tree data. The random numbers are to be entered onto each Site Information Form with the list of associated off-plot trees to be sampled. Data from these trees is to be entered on TEEM Form X06.

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 as 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.

6.3.4.2 Fire-Affected Sites

At fire-affected sites, 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 are required.

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.

6.3.4.3 Internode Length & Defoliation Estimate

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

6.3.4.4 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 and 2018, 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)**).

6.4 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, 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 Program Coordinator 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.

6.4.1 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)**.

6.4.2 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)**.

6.4.3 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)**).

6.4.4 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)**).

6.4.5 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)**; this procedure is used for both plant tissue and soils.

6.4.6 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 2024 PROCEDURES

Forest Health Monitoring Program procedures have been developed to standardize data and sample collection. The procedures, and the TEEM data forms that are associated with specific procedures, are listed below. Procedures shaded in grey in the table below (#6, #27, #31, #36, #37, #39) have been removed from the program.

Procedure Number	Procedure Name	TEEM Data Form Number & Name
1	Sample Labelling	
2	Sample Storage & Shipping	
3	Site Information	01 – Site Establishment: Site Information and Coordinates 01b – Plot Diagram Sketch 14 – Site Photos
4	Reference Stake Installation & Geo-Referencing	
5	Tree Numbering & Labelling	
6	Dispositions	
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
25	Tree Coring	X03 – Off-Plot Tree Data
26	Tree Core Preparation & Analysis	X05 – Stand Interior Off-Plot Tree Growth Ring Analysis
27	Tree Condition and Health Assessment	
28	Tree Data	03 – Vegetation Plot Tree Data X03 – Off-Plot Tree Data
29	Tree Shoot Data	X06 – Off-Plot Tree Softwood Shoot Data
30	Foliar Sample Collection & Checklist	
31	Lichen Sample Collection	
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	
36	Epicuticular Wax Structure	
37	Epicuticular Wax Composition	
38	Plant Community Assessment	08b – Stand Interior Absolute Cover Assessment 08c – Vegetation Plot Sketch 13 – Standard Random Walk 14 – Site Photos
39	Epiphytic Lichen Community	
40	Regeneration and Sapling Survey	05 – Regeneration and Sapling Survey
41	Canopy Cover using Convex Densiometer	15 – Canopy Cover using Densiometer

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, or the presentation of results of analyses with an incorrect site or sample name. 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 archive.

1.2 Summary of Labelling Requirements

Labelling procedures are meant to convey all necessary sample information in a permanent and redundant manner. A minimum of two labels is to be associated with all samples, using two different methods. The label information is specific to sample type, summarized in the following table and as described by sample type in the sections that follow.

Required Information	Format	Soil		Needles	Tree Cores
		Pit	Plot		
Sample Date	YYYY-MM-DD	X	X	X	X
Site	Four-digit site code	X	X	X	X
Field Personnel	Initials	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		X		
Soil sample location	Sample location, from 1 to 9 (or 1 to 6 in smaller plots). Add “D” after location to identify duplicate sample		X		
Depth Increment	One of: “LFH”, “0-5cm”, “5-15cm”, “15-30cm”		X		
Tree Number	The tree label (e.g., “010”, “X10”). Field duplicate samples are identified by the same tree label, preceded with a “D” (e.g., “D010”, “DX10”)			X	X
Sample Age Class	One of: “CAG”, “Age-1”, “Age-2”			X	

1.3 Soil Samples (Pits and Plots)

Soil samples are to be contained in a plastic bag that is sealed closed, which is placed into a second plastic bag that is also to be sealed closed. 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 both 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 (Site Est. Only)	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	Four-digit site number
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
Soil Subplot		X	Soil subplot number
Soil sample location		X	Sample location, from 1 to 9 (or 1 to 6 for smaller plots). Record a "D" behind the number if this sample was a duplicate.
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 shoot segments containing needles of specific age classes 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 the plastic and 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 paper sample bags.

Required Label Information for Jack Pine Needle Samples

Required Information	Interior Site	Required Format
Sample Date	X	Date as YYYY-MM-DD (July 9, 2011 would be recorded as “2011-07-09”)
Field Personnel	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	Four-digit site number
Tree Number	X	Tree tree label (e.g., “X06” for off-plot trees) Field duplicate samples are identified by the same tree label, preceded with a “D” (e.g., “D010”, “DX10”)
Sample Age Class	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 fine-point blue or black 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	Required Format
Sample Date	X	Date as YYYY-MM-DD (July 9, 2011 would be recorded as “2011-07-09”)
Field Personnel	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	Four-digit site number
Tree No.	X	Tree label (“X10”)

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.

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 are subject to post-sampling biological and/or chemical processes that may alter sample composition. Proper storage is required to preserve sample integrity, from initial sample acquisition in the field, transport, and processing at the laboratory, through to storage at the WBEA Centre.

2.2 Storage & Shipping Plan

It may be necessary to store samples for a few days before they can be shipped to a laboratory. 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, 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 collected samples through the field day are to be included in the coolers, 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. 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 sampling equipment appropriate for the sample.

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 may be shipped frozen; at a minimum, samples must 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.

Needle 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.

Chain-of-custody documents for each sample set are to be prepared. A copy is to be retained by the Program Coordinator, and another 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 Program Coordinator.

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 acceptance of the samples as indicated on the chain-of-custody documents 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)**. The field-moist sample is for the analysis of available nitrogen and sulphur, which 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 sample archive. The chain-of-custody documents are to be signed and dated upon transfer of samples from the laboratory to the WBEA.

Prior to its placement in archive, each sample is to be inspected, and as required, actions taken to correct sample labelling and/or damage to sample containers. This inspection is to be conducted in a clean environment, under cool, shaded conditions, and by personnel wearing and using equipment appropriate for the sample.

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

Site information is required at site establishment and will include geographic information, hand-drawn plot diagrams and photos. This information is to be periodically confirmed to ensure no significant changes to the site prior to field sampling campaigns.

3.2 Jack Pine Monitoring Site Information

Site information for a new monitoring site is to be recorded using TEEM Form 01. 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 Form 01 Site Establishment: Site Information and Coordinates

Field Name	Required Information
Site	Four-digit site number
Year of Establishment	The 4-digit year of plot establishment (e.g., “2011”)
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”)
Personnel	Three fields are provided for the full names of the personnel involved
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”)
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”)
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”)
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 Name	Required Information
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
Location	UTM Coordinates and Remarks specific to those coordinates for each of the following key plot features: Reference stake, vegetation plot, off-plot tree area, Soil Plots 1-4, Soil Pit and Helipad
Remarks	Comments and information allowing for clearer understanding of the data and information
Site Remarks	Any notes of interest for that site (e.g., wildlife trails, quad tracks, nearby infrastructure)
Photos	Each cardinal direction listed should have a unique photo ID to keep track of photos for each site

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

3.3 Plot Diagram Sketch

TEEM Form 01b should be included along with TEEM Form 01. A sketch of the plot diagram with all the key features including soil plots with numbered subplots, soil plot sampling locations, soil pit, vegetation plot with numbered subplots, reference stake, bearings and directions to sampling locations, off-plot tree area and helipad. Depending on the site, other features may include the location of deposition equipment or any key landforms (e.g., game trails, cutlines, ecosystem boundaries).

3.4 Site Photographs

Photos of the site should be collected during each monitoring campaign to provide a visual record of the site. This is particularly useful for understanding natural changes in the forest ecosystem and the regeneration of fire-affected sites. TEEM Form 14 should be completed when photos are taken. The procedure includes four photos to be taken from the center of the vegetation plot towards the four cardinal directions and one canopy photo.

PROCEDURE #4
REFERENCE STAKE INSTALLATION & GEOREFERENCING

4.1 Background

Staking and georeferencing using a combination of GPS coordinates and ground measurements is required at each site. These coordinates and measurements permit the creation 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 accepted as the formal coordinates for the site, personnel should refrain 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.

All data collected from this procedure will be included on TEEM Form 01 and sketched out on TEEM Form 01b.

4.2 Coordinate Formats

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), and the Zone 12V projection.

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. Georeferencing the layout of site plots and equipment from this stake will allow re-establishment of the site after disturbance, such as wildlife damage to plot stakes, or a forest fire. Tying bright flagging tape to the protruding segment of rebar will make it visible from most locations within the site.

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 (with GPS averaging use, if available).

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 all other features relating to the monitoring program (e.g., helipad, monitoring tower), 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 using both tree paint and tree tags 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 Tree Labelling Procedures

A line 1.3 m above ground level is to be painted (using tree paint) around the entire 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 in the vegetation plot (e.g., “12”), or preceded with an “X” for off-plot trees (e.g., “X04”).

Trees selected for monitoring are to be labelled using numbered aluminum tags attached to the trunk at about eye level using a suitable non-rusting wire. The wire is to be wrapped tightly enough to prevent slipping of the tag, but loose enough to provide space for radial growth of the tree expected to occur between monitoring campaigns.

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 when off-plot trees are replaced.

5.3 Vegetation Plot

All standing trees (living and dead) of 10 cm DBH and larger, except for dead and standing trees whose tops do not reach into the canopy, are to be numbered. A three-digit number is required for each tree, in the format of “001”. This number is to be etched onto the aluminum tag attached to the tree.

5.4 Off-Plot Trees

Ten trees of similar height and morphological structure are to be chosen and labelled for off-plot measurements. The number assigned to off-plot trees is a two-digit number and preceded with an “X” (e.g., “X01”), painted onto the tree, and etched onto an aluminum tag attached to the tree.

PROCEDURE #7
SOIL DESCRIPTION

7.1 Background

A soil pit for soil classification is required only during stand site establishment. A soil pit is not required at edge 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 Name	Required Information
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”
Site	Four-digit site number
Assessment Date	The date, in the format YYYY-MM-DD (July 9, 2011 would be recorded as “2011-07-09”)
Personnel	Three fields are provided for the full names of the personnel involved
Location	UTM (Easting Northing) is to be provided for location of soil pit
Horizon	The horizons exposed in the soil pit are to be named according to Canadian terminology. Ensure horizons used for the fields on the first page match the horizons on the second page.
Depth: 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
Colour	The colour of the horizon is to be assigned using the Munsell notation, the colour name, and a note as to whether the soil is moist or dry at the time of examination
Texture	Soil texture by feel is to be recorded
Mottles	The presence of mottles in each horizon is to be noted in terms of colour, abundance, and contrast with the soil matrix
Consistency	By horizon, the resistance of the soil to deformation and the degree of cohesion/adhesion is to be noted
Roots	The abundance, size, orientation, distribution and depth of penetration of roots are to be recorded
Pores	The abundance, size, orientation, distribution and depth of penetration of pores are to be recorded

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

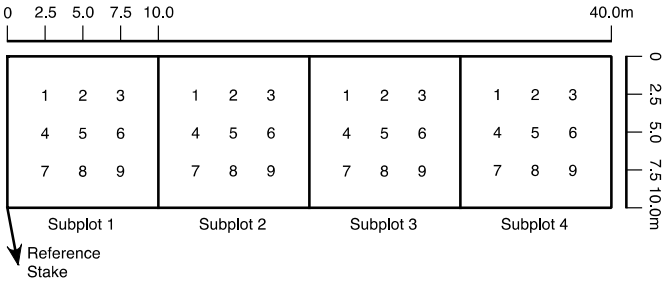
Field Name	Required Information
Structure	Horizon structure is to be noted by grade, distinctness, class, size, and type
Clay Films	Record the frequency, thickness, location and colour of clay films
Coarse Fragment Content	For the whole pit, provide an estimate in percent (v/v) of the coarse fragment content, and describe the shape, kind, size and name of coarse fragments
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
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

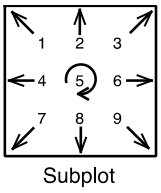
8.1 Soil Sample Location

Soil sampling by depth is required at monitoring sites during the 6-year monitoring cycle. Sampling locations are nine fixed points within standard soil subplots, as shown below. Sampling locations within the plots are not to be marked in the field. Locations are to be measured in the field and orientation of locations are noted on the Plot Diagrams.



Soil Sample Locations within each Soil Subplot

One sample locations in each selected soil subplots is to be sampled. In 2024, two subplots per plot (odd numbered subplots, 1 & 3) are to be sampled. A single number, from 1 to 9 is to be randomly selected for each subplot. This is done prior to the field campaign and can be found on the Site Information Sheet. 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. A location cannot be sampled more than once.



Soil Sample Location Adjustments

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 to be towards the perimeter of the subplot, except for location #5 which is to move in whatever direction that there is no longer a disturbance but not to interfere with the locations around the perimeter (see

figure above). Adjustments to soil sampling locations are to be measured, to the nearest 0.1 m, and recorded on TEEM Form 11.

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 Name	Required Information
Page _ of _	Complete after collecting the last subplot soil sample
Site	Four-digit site number
Assessment Date	Date as YYYY-MMM-DD (July 9, 2011 would be recorded as “2011-JUL-09”)
Personnel	Three fields are provided for the full name(s) of the personnel conducting the assessment
Plot	The 1-digit soil plot number (1 to 4)
Subplot	The 1-digit soil subplot number (1 to 4). This applies to the field duplicate sample as well
Location	The 1-digit random number used to select the sampling location.
Duplicate	Indicate with a “D” whether the sample has a duplicate
Depth	Indicate depth of the sample. Labelled as: LFH, 0-5, 5-15, or 15-30
Adjustment	If any adjustment to sample location is required, enter the distance and direction of the adjustment. Measures to the nearest 0.1m. Example: 1.5m NW, 0.5m S
Remarks	Enter general remarks about soil sampling. If an adjustment is made, explain reason behind the adjustment.
Stored at WBEA (Date)	Provide the date that the sample was dropped off at the WBEA Centre. Labels and seals should all be checked.
Initials	Personnel should initial the form once the sample has been reviewed and properly stored at the WBEA Centre.

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 site establishment and the 6-year monitoring cycle in its current configuration is presented below.

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	2	8	45
0 to 5 cm	4	2	8	
5 to 15 cm	4	2	8	
15 to 30 cm	4	2	8	
30 to 50 cm	4	2	8	
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	2	8	36
0 to 5 cm	4	2	8	
5 to 15 cm	4	2	8	
15 to 30 cm	4	2	8	
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, excess may be stored frozen as supplemental material in the event repeat analysis on fresh material is required. Alternatively, excess fresh material may be combined with the dried LFH and milled per 9.1.2.

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 high-speed centrifugal rotor or hammer mill equipped with wear resistant rotor or hammers. 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 a 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 5 g, weighed to ±0.0001g precision) is to be taken and dried in an oven set to 105°C, for 24 to 48 hours. Upon removal from the oven, is to be placed in a desiccator, and cooled and weighed to the same level of precision (±0.0001g). 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 centrifugate 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]) using an automated vacuum extraction system.

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.

[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 a sample tube as described below.

For mineral horizons, weigh approximately 2.50 g (weighed to ±0.01 g precision) of air-dried, 2 mm mineral soil into a sample tube as described below.

13.5 NH_4Cl Extraction for Exchangeable Cations

1. Place a filter pad on top of the filter frit and holder, firmly connect to bottom of sample tube (sample tube assembly).
2. Tare sample tube assembly on the balance and weigh appropriate amount of sample into the tube onto the filter pad, levelling if necessary, and record sample weight.
3. Connect sample tube to upper disk section of the extractor.
4. Weigh lower collection syringe and plunger assembly (weighed to ±0.01 g precision) and connect assembly to lower disk section of the 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 an inert gas (helium or argon) 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. However, instruments capable of performing one analysis alone, or two of the analyses simultaneously, are acceptable.

In the case of samples containing very low levels of sulphur (i.e., sandy mineral soil), it may be preferable to use a dedicated high temperature sulphur (or combination carbon/sulphur) analyzer capable of accommodating 500mg or more of sample (macro-analyzer).

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. For analysis on micro-analyzer, weigh (using a microbalance) into a tin combustion capsule an appropriate amount of finely ground (100 mesh) sample material.
2. For analysis on macro-analyzer, weigh (in g, to 3 decimals) 2mm sieved sample into a ceramic crucible.
3. Where required, add catalyst to the sample.
4. Follow instrument procedures for combustion and analysis.

[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

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.

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 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.

[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

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).
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 ICP-OES or ICP-MS instrument.

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 161-179

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 nitrate (NO_3^-) and ammonium (NH_4^+) 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.

[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 Type I water.
    2. Add 200 mL 1.0 *N* HCL.
    3. Dilute to 8 L using Type I water.
    4. Confirm pH of 2.60 (±0.05).
3. Stock Colour Reagent (A):
    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 of 54% H_2SO_4.
    4. Bring to 1 L with water.
4. Working Colour Reagent (B)
    1. Just prior to use, add 2.0 g ascorbic acid (ACS) per litre of reagent (A) and mix well

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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

5. 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.

22.3 QA/QC

1. 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.
2. 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.
3. Blank (1 per batch): a polypropylene tube without soil material.
4. Replicate (1 per batch): from one randomly selected sample within the batch.

22.4 Soil Sample Preparation

4. 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

1. Add 25 mL of Bray-1 extracting solution to centrifuge tube.
2. Place tube on shaker, shake for 15 min at medium speed.
3. 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.

4. If analysis cannot take place within 24 hr after extraction, refrigerate (4°C) clarified samples until analysis can be completed.
5. Dilute 0.15 mL sample (supernatant) with 3.6 mL of colour reagent using a digital dilutor
6. Completely mix the sample and colour reagent.
7. Allow 30 min for colour development.
8. 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 the vegetation plot is to be mapped relative to the plot centre. These measurements will be used to prepare a map of trees within the plot. The mapping distances are done when a new tree is selected, or on a as needed basis.

24.2 Tree Species Codes

The codes to be used to identify tree species on TEEM Form 02 are as follows:

Tree Species Codes for TEEM Form 02

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 Vegetation Plot Tree Map

Each tree within the stand interior vegetation plot is to be mapped as a function of distance from the plot center. 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 Name	Required Information
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
Site	Four-digit site designation
Year of Establishment	The 4-digit year of plot establishment

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”)
Personnel	The full names of field personnel collecting the plot map data
Tree Number	A 3-digit number, such that the 26th mapped tree would be recorded as “026”
Tree Species	The 2-character code representing the species
Status	“A“= alive and “D” = dead
Distance Along Centre Line (X)	The centre of each tree bole, measured from the plot centre (“0,0”). Distances along the X axis are measured from 0 to 5.0 m (±0.1 m). Include direction (+ or -)
Distance Along Reference Line (Y)	The centre of each tree bole, measured from the plot centre (“0,0”). Distances along the Reference Line (Y axis) are measured from 0 to 20.0 m (±0.1 m). Include direction (+ or -)
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 and growth rate. During site establishment, cores are to be obtained from off-plot trees at each sites. Cores are also to be obtained from off-plot replacement trees at the time of their selection and/or on an as needed basis to confirm the tree age.

At no time are cores to be obtained from trees within the vegetation or soil plots.

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. If the tree is not round, obtain the core from the narrow width.

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 and should not be placed in the cooler with other field samples during transport.

Data indicating which trees were cored should be entered into TEEM Form X03 in the Tree Core Taken column (Field 39 & 40). If a tree core is taken, record "TC" in the field and if no tree core is taken record "No".

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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, as follows:

TEEM Form X05 – Off-Plot Tree Growth Ring Analysis

Field Name	Required Information
Page _ of _	Complete as appropriate. If tree growth ring data are collected on different days, complete a separate form for each day.
Site	Four-digit site number
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")
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")
Cores Acquired By	Three fields are provided for the full name(s) of the personnel taking the tree core samples
Cores Measured By	Two fields are provided for the full name(s) of the personnel measuring the tree core samples
Off-Plot Tree Numbers	The 3-character tree number for each tree measured, in the form "X10"
Tree Species	Code pre-entered for Jack Pine (Pj)
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
Pith	Whether the pith was reached for the sample. Indicate with Y or N.
Years to Breast Height	Pre-entered as 10 and accounts for the number of years required for the tree to grow to breast height
Tree age	The age of the tree is to be determined by counting the number of growth rings, and adding 10 (Years to Breast Height)
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 and DBH reference marks are to be checked and as required, repaired or replaced (**TREE NUMBERING & LABELLING PROCEDURE (#5)**), including any tags and wires that are at risk of girdling the tree.

28.2 Common Procedures

28.2.1 Tree Species Codes

Where required, the tree species are to be identified and entered into TEEM Form 03 (Vegetation Plot) 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. 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 using 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.

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.

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.

28.2.7 Tree Core Taken (TEEM Form X03 ONLY)

Tree cores are to be obtained using **TREE CORING PROCEDURE (#25).** Whether a tree from the off-plot has been cored should be indicated on TEEM Form X03. A “TC” should be recorded if a tree core is taken, and a “No” should be recorded if a tree core was not taken from that tree.

28.2.8 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) and X03 (stand interior off-plot trees) as follows:

TEEM Forms 03 and X03 –Tree Data

Field Name	Required Information
Page _ of _	Complete after collecting the data from the last plot tree
Site	Four-digit site number
Assessment Date	Date as YYYY-MMM-DD (July 9, 2011 would be recorded as “2011-07-09”)
Personnel	Three fields are provided for the full names of the personnel involved
Tree Number	A 3-digit number, such that the 26th mapped tree would be recorded as “026”
Tree Species	Tree species 2-character code
Dominance	Dominance of each numbered tree is coded according to Section 21.2.1 (above)
DBH	The diameter of the tree at breast height is to be measured according to Section 21.2.2 (above)
Crown Closure	Crown closure described according to Section 21.2.3 (above)
Stem Form	Stem form described according to Section 21.2.4 (above)
Total Height	Total tree height measured according to Section 21.2.5 (above)
Height to Top of Live Crown	Height to top of live crown measured according to Section 21.2.5 (above)
Height to Base of Crown	Height to base of live crown measured according to Section 21.2.5 (above)
Tree Core Taken	(Form X03 only) Indicate whether a tree core was taken (TC) or no tree core taken (NO)
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.

29.2 Internode Measurement

The length of each internode on each of the five selected branches is to be measured (in cm, to the nearest 0.1 cm) using a ruler or calipers and recorded on TEEM Form X06.

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. The data are recorded on TEEM Form X06 in the Defoliation column. 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

29.4 Off-Plot Tree Shoot Data

TEEM Forms X06 are to be completed as follows:

TEEM Form X06 – Off-Plot Tree Shoot Data

Field Name	Required Information
Page _ of _	Complete as appropriate
Site	Four-digit site number
Assessment Date	The date, in the format YYYY-MM-DD (July 9, 2011 would be recorded as "2011-07-09")
Personnel	Three fields are provided for the full names of the personnel involved
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")
Tree Numbers	A 2-digit off-plot tree number, following the "X" that is pre-entered on the form. The 10th tree would be recorded as "X10"
Tree Species	Pre-entered tree species code for Jack Pine
Current Year Internode Defoliation	The extent of defoliation in the current year internode
Current Year Internode Length	The length of the current year internode
1 Year Old Internode Defoliation	The extent of defoliation in the 1-year-old internode
1 Year Old Internode Length	The length of the 1-year-old internode
2 Year Old Internode Defoliation	The extent of defoliation in the 2-year-old internode
2 Year Old Internode Length	The length of the 2-year-old internode
3 Year Old Internode Defoliation	The extent of defoliation in the 3-year-old internode
3 Year Old Internode Length	The length of the 3-year-old internode
4 Year Old Internode Defoliation	The extent of defoliation in the 4-year-old internode
4 Year Old Internode Length	The length of the 4-year-old internode
5 Year Old Internode Defoliation	The extent of defoliation in the 5-year-old internode
5 Year Old Internode Length	The length of the 5-year-old internode
6 Year Old Internode Defoliation	The extent of defoliation in the 6-year-old internode
6 Year Old Internode Length	The length of the 6-year-old internode
7 Year Old Internode Defoliation	The extent of defoliation in the 7-year-old internode
7 Year Old Internode Length	The length of the 7-year-old internode
Remarks	Observations of interest unrelated to the internode measurements or defoliation estimates
Photo. No.	The branch photograph number

PROCEDURE #30
FOLIAR SAMPLE COLLECTION & CHECKLIST

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 needle (Age-1) and 2-year-old needle (Age-2) samples are to be separately sampled from each of the five off-plot tree branches. 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. If needle material is limited, a second branch may be obtained from the same off-plot tree to obtain the required 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 not to 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**

Samples are to be recorded on TEEM Form X06 to record that all samples were collected at each site and properly stored at the WBEA. Field personnel will check off that each sample was collected, and then provide the date when the sample was brought to the WBEA and provide final hand-off initials.

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 (i.e., 40 ml precleaned EPA vials), 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 archive at the WBEA Centre. 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., vortexing sample several times throughout the process.
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 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 if available, 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 Closed Vessel Microwave Digestion

Control of digestion conditions in a traditional carousel based closed vessel digestion system 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.

Alternative digestion systems using a single pressurized digest vessel equipped with a rack of individual sample digest tubes provides a simplified and efficient means of digestion while treating all samples identically, thus eliminating uncertainties associated with inter-vessel variations in temperature and pressure while using the carousel system. Additionally, single reactor systems permit the use of smaller quartz, Teflon and even pre-cleaned disposable glass sample vessels.

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 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.

The vegetation plots are numbered clockwise starting with Medium Plot #1 in the SW corner. This corner is indicated on the plot diagrams with VEG. If the Medium Plot #1 is not in the corner as indicated on the plot diagram, make note on TEEM Form 08c so the plot diagram can be properly updated.

38.2 Absolute Cover Assessment

For consistency within a single monitoring cycle, the assessment is to be performed at all sites by the same qualified vegetation ecologist or by vegetation ecologists that have standardized methods amongst themselves prior to the field season. 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 prior to vegetation beginning senescence.

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 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.

TEEM Form 08b

Field Name	Required Information
Page _ of _	Complete after collecting the data from the last plot tree
Site	Four-digit site number
Assessment Date	Date as YYYY-MMM-DD (July 9, 2011 would be recorded as “2011-07-09”)

Field Name	Required Information
Personnel	Three fields are provided for the full names of the personnel involved
Species Code	Enter each species present in the subplot on a separate line
Small Subplot	Enter the estimated % cover for each species in each small subplot
Medium Subplot	Enter the estimated % cover for each species in each medium subplot
Large Subplot	Enter the estimated % cover for each species in the large subplot
Remarks	Enter observations, difficulties and any other information that may be useful in guiding the interpretation of the data

38.3 Standard Random Walk/Comprehensive Species List

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.

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.

The comprehensive species list will be completed on TEEM Form 13. All species present (latin name) will be recorded along with a distribution (Abundant = Observed constantly within stand >10%, Common = Observed in patched or not a uniform distribution 1-10% cover, Few = observed in a single location or occasional plants scattered across stand). Any additional remarks on plant health, disease, or interesting information will be provided in remarks.

38.4 Vegetation Plot Sketch

To ensure consistency of numbering and sampling for vegetation subplots, TEEM Form 08c will be completed showing a hand drawn sketch of the vegetation plot. It is essential to include the following on the sketch: small, medium and large plot location and numbers, direction of North, and indicate the corner of the plot that has the arrow from the reference stake on the plot diagram.

38.5 Site Photographs

Site photographs are to be taken each monitoring campaign to provide a visual reference to changes in the site. Standing at the vegetation plot centre, one photo is taken in each of the cardinal directions (N, E, S, W) and one photo is taken looking directly up at the sky of the canopy. Ensure all photos are clear and in focus. Information is to be entered into TEEM Form 14. Photos are to provided to the WBEA along with the form and should be labelled as "SiteNumber_Date_Direction/Canopy".

PROCEDURE #40
REGENERATION AND SAPLING SURVEY

40.1 Background

This procedure applies to the vegetation plot at 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 (excluding shrub species) that are at least 2 m tall, with a DBH <10cm. Tree species codes for use in completing TEEM Form 12 are as follows:

Tree Species Codes for TEEM Form 12

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

Seedling surveys are only conducted in small and medium subplots.

Within each small and medium subplot, 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

[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.

determine which seedlings are to be counted (tallied) within each of the eight height classes. Data are to be recorded on TEEM Form 12 as indicated in the table below.

40.3 Sapling Survey

Sapling survey is conducted in each small, medium and large subplots.

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 as follows:

TEEM Form 12 – Regeneration and Sapling Survey

Field Name	Required Information
Page _ of _	Complete after collecting the data from the last plot at the site
Site	Four-digit site number
Assessment Date	Date as YYYY-MMM-DD (July 9, 2018 would be recorded as “2018-07-09”)
Personnel	Three fields are provided for the full names of the personnel involved
Subplot Size	Enter “S” (small), “M” (medium), or “L” (large)
Subplot No.	Enter the number of the subplot (“1” to “10” for Small plots, “1” or “2” for Medium plots, “1” for Large)
Tree Species	Enter the code for each species (see table above) present in each subplot on a separate line
16-35	Enter the number (count) of regenerating trees that are 16 to 35 cm tall
36-55	Enter the number (count) of regenerating trees that are 36 to 55 cm tall
56-75	Enter the number (count) of regenerating trees that are 56 to 75 cm tall
76-95	Enter the number (count) of regenerating trees that are 76 to 95 cm tall
96-115	Enter the number (count) of regenerating trees that are 96 to 115 cm tall
116-135	Enter the number (count) of regenerating trees that are 116 to 135 cm tall
136-155	Enter the number (count) of regenerating trees that are 136 to 155 cm tall
156-200	Enter the number (count) of regenerating trees that are 156 to 200 cm tall
Total Regeneration	Enter the total number of regenerating trees in the subplot (total of fields 23 to 30)
Sapling Survey Count	Enter the total number of saplings (trees >200 cm, <10 cm DBH) in the subplot
Remarks	Enter observations, difficulties and any other information that may be useful in guiding the interpretation of the data

PROCEDURE #41
CANOPY COVER USING CONVEX DENSIOMETER

41.1 Background

The spherical densiometer is an instrument used in permanent-plot estimates of relative canopy closure or density. It is a compact and simple device with a curved reflecting surface that allows observations from overhead and lateral positions (Strickler 1959). Measurements consist of the densiometer being held horizontally while the observer counts how many of the corners of each square intercept with the reflection of the canopy. Strickler (1959) proposed a modification of the original densiometer method to remove overlap from measurements. In the modified method, a wedge-shaped area of the densiometer including 17 points is used, instead of the whole area (Figure 1). The current procedure will use Strickler's wedge-shared area method. Wedge-shaped area can be created with tape (Figure 2).

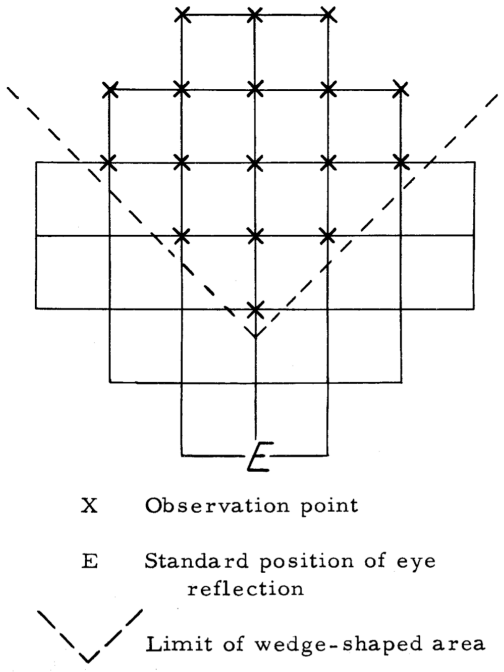

Figure 1. Spherical densiometer grid showing the 17 points of observation and the position of eye reflection when a directional reading is made. Canopy reflected in the wedge area within the dotted lines is not duplicated in subsequent directional readings. Image from: Strickler (1959).

Figure 2. Example of how wedge-shaped area can be created with tape. Image from: www.flickr.com/photos/silentscott/9895076415

41.2 Cover Assessments

This method requires the following equipment: compass, convex spherical densiometer, and tripod to sit the densiometer on.

At the center of the vegetation plot (origin, 0.0) use the compass and a convex spherical densiometer to estimate canopy cover. While standing at the center of the plot, level the bubble and record how many of the 17 cross hairs are intercepted by cover (Figure 3). In the example of Figure 3 there are 10, so cover is 10/17 = 58.8%. Record for each of the 4 Cardinal (N, S, E, W) directions. It may be easier in high cover situations to measure the gaps (i.e., A-G below and then subtract that value from 17 to get the cover value). To get the total estimate of canopy cover add up the cover values for each of the four directions and then divide by 68.

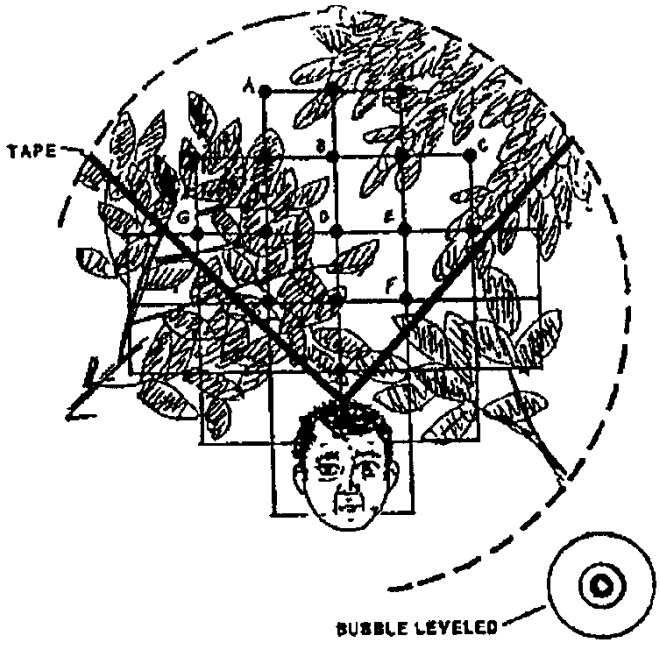

Figure 3. A visual demonstration of how to measure canopy cover using a spherical densitometer taken from Strickler (1959).

TEEM Form 15 – Canopy Cover (Using Densiometer)

Field Name	Required Information
Page _ of _	Complete after collecting the data from the last plot at the site
Site	Four-digit site number
Assessment Date	Date as YYYY-MMM-DD (July 9, 2018 would be recorded as “2018-07-09”)
Personnel	Three fields are provided for the full names of the personnel involved
# Cross Hairs Intercepted by Cover	Count of the number of cross hairs that are intercepted by cover
Total # of Cross Hairs	Record how many cross hairs in total are visible on the densiometer
Canopy Cover	Percent cover for each direction calculated by dividing the # cross hairs intercepted by cover by total # of cross hairs
Total Canopy Cover	Add up the cover values for each of the four directions. Divide the sum of the # cross hairs intercepted by cover by the sum of the total # of cross-hairs.
Remarks	Enter observations, difficulties and any other information that may be useful in guiding the interpretation of the data

Strickler GS. 1959. Use of the densiometer to estimate density of forest canopy on permanent sample plots. U.S. Department of Agriculture. Forest Service. Pacific Northwest Forest and Range Experiment Station. Research Note. Number 180. Portland, Oregon. 5 pp.