

Forest Growth Organization of Western Canada
Foothills Pine Project Team

Regenerated Lodgepole Pine Trial

FIELD MANUAL
for
GROWTH PHASE TRANSITION
MEASUREMENTS AND MAINTENANCE

Version 5.3

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FOREST GROWTH
ORGANIZATION OF WESTERN CANADA

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1 General

This document is intended primarily for use by contractors engaged in ongoing measurement and maintenance of the Regenerated Lodgepole trial during the growth phase. For this purpose it replaces all previous versions as of July 1, 2017. It describes new procedures that are being implemented for measurements of installations that have reached the growth phase. Key changes to be implemented in the growth phase are summarized in Appendix 1.

The remainder of this section summarizes the ecological and treatment categories by which installations and plots are classified, and the layout of installations. Sections 2, 3 and 4 describe procedures for measurements, maintenance and quality control respectively.

Each installation is uniquely referenced by a sequence of 3 digital codes representing its eco-class (see Table 1), group (valid codes are 1 – 5), and planting density (Table 2). Treatment plots within each installation are further referenced by vegetation management treatment (Table 3).

Table 1. Eco-Classes

Code	Eco-class (and Edatope)
1	Bearberry / lichen / hairy wild rye (submesic / subxeric, medium – low)
2	Labrador tea – mesic (mesic – poor)
3	Billberry / cranberry / sarsaparilla / rhododendron (mesic / medium)
4	Honeysuckle / fern (subhygric – rich)
5	Labrador tea – hygric (hygric – poor)

Table 2. Installation Planting Densities

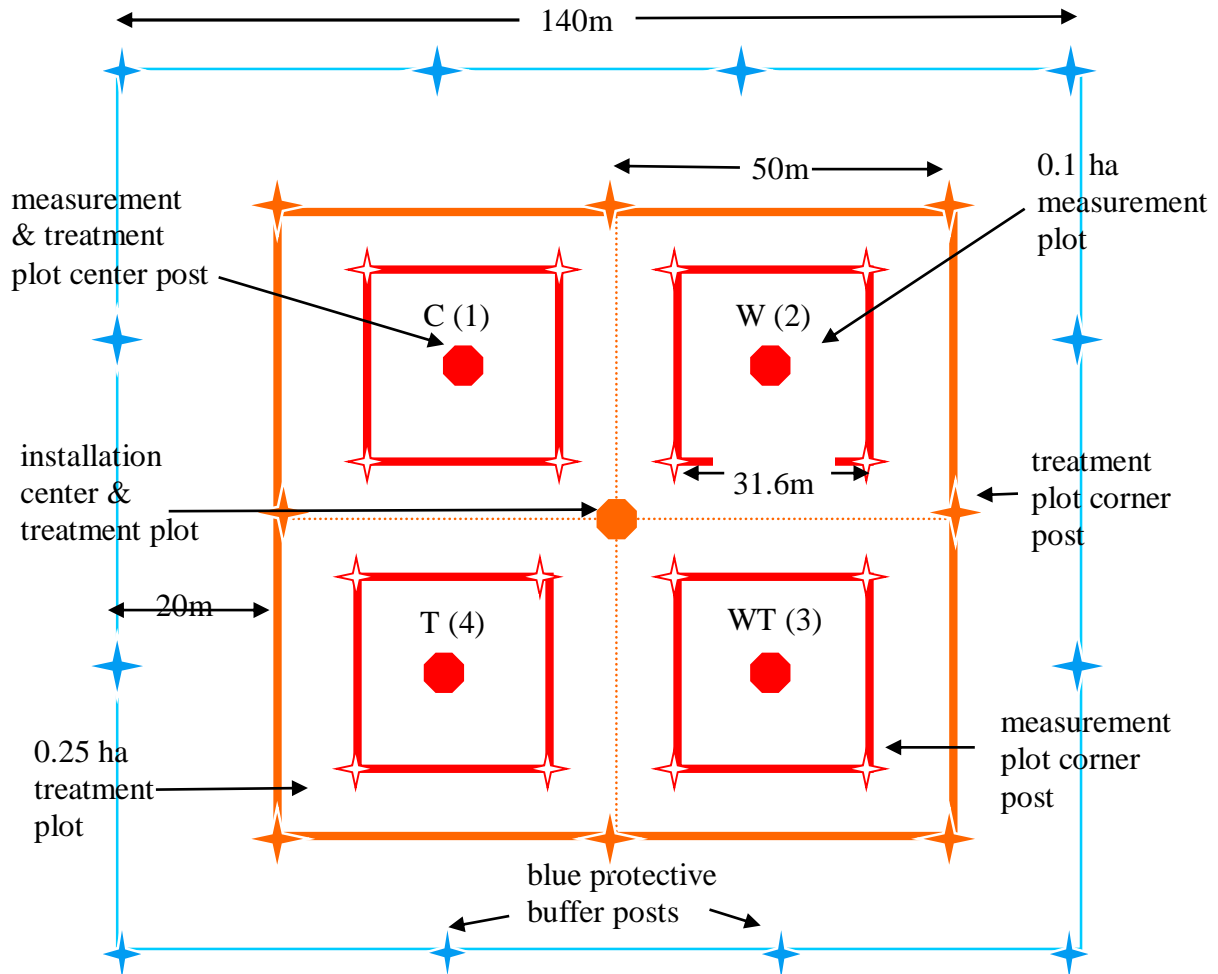
Code	Spacing (m ²)	Target Planting Density (stems/ha)	Target Trees/plot (0.25 ha/0.1 ha)
0 or 9	Control	0	0
816	3.5	816	204/82
1111	3.0	1111	278/111
1600	2.5	1600	400/160
2500	2.0	2500	625/250
4444	1.5	4444	1111/444

Table 3. Plot Vegetation Management Treatments

Code	Plot #	Treatment	Treatment Description
C	1	Control	No vegetation management treatments
W	2	Weeding	Remove competing vegetation
WT	3	Weeding & Thinning	Treatments 2 & 4
T	4	Thinning	Pre-commercially thin to target density

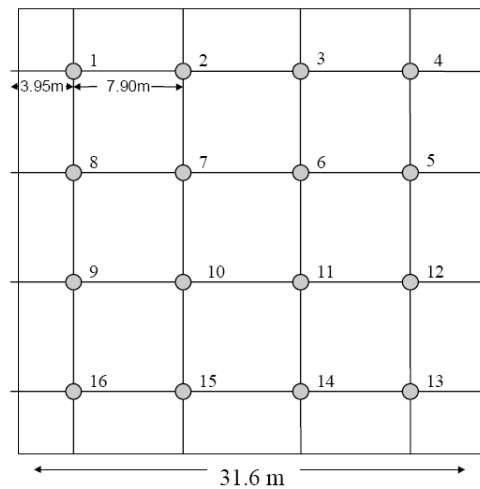
Figure 1 portrays a standard non-split installation. In some installations treatment plots have been re-aligned or separated to fit into the targeted site. Before carrying out any measurement on any plot, treatment plot post demarcation and field notes should be checked.

Figure 1. Installation Diagram



In every measurement plot there are 16 circular regeneration sub-plots (radius 1.78m) marked with green plot centers. They are laid out on a 7.90 m square grid as shown in Figure 2.

Figure 2. Regeneration Plot Layout



2 Measurements

2.1 Numbering and Timing of Measurements

A unique and sequential measurement number will be assigned by the database manager to each scheduled measurement of a treatment plot. In the growth phase, there is only one measurement type. It will be conducted every two years until it is decided that a longer measurement interval will be sufficient to capture stand dynamics. Detailed measurement schedules will be provided annually. Measurements will be made between July 15 and October 15. Vegetation assessments must be completed in snow free conditions.

The regeneration phase sample type will be retained to allow continued identification of trees that were sample trees during the first 14 years. These regeneration phase sample trees will continue to be measured; regeneration phase crop trees will only be measured if they were also sample trees. Valid retained regeneration phase sample types are: R (sample tree in regeneration phase) or N (Not a sample tree in the regeneration phase). Table 4 shows how retained regeneration phase sample types are to be assigned.

Table 4. Retained Regeneration Phase Tree Sample Types

Code	Original Regeneration Phase Sample Type	Retained Regeneration Phase Sample Type
B	<u>B</u> oth crop and sample	R
S	<u>S</u> ample	R
C	<u>C</u> rop	N
N	<u>N</u> either	N
-	Not tagged in regen phase	N

Incorrect application of the above procedure has led to retained errors in sample type assignment. Commencing in 2019, the procedure will be simplified and improved by the pre-identification of baseline sample trees. Table 4 and the above paragraph can then be ignored.

Additional trees will be tagged as follows:

- All saplings $\geq 1.3\text{m}$ of any tree species occurring on the regeneration sub-plots will be tagged and measured. They will only be measured for dbh after they reach 2.0 m in height. Trees are considered inside the plot if the point of germination is inside the plot.

Details of required measurements are provided below. Quality control checks that must be passed before data are loaded into the master database are listed in Appendix 2.

2.2 Density of Coniferous Natural Regeneration (Coniferous “Ingress”)

- In each 1.78 metre radius regeneration plot (16), record the number of live naturally regenerated coniferous seedlings $>10.0\text{ cm}$ and $<1.3\text{ m}$ in height, by species. (Valid species codes are shown in Table 5.) **Do not include trees greater than 1.3m in height in ingress counts.**
- Partition the counts by height into $<30\text{cm}$ and $30\text{cm}+$.
- Trees are considered inside the plot if the point of germination is inside the plot.

Note: “height” is defined as the vertical distance between ground level and the tip of the terminal bud, as in Section 2.3.1.

For trees 30cm+ in height: If the count is less than or equal to 10, the exact number of trees should be recorded. However, if the stem count exceeds 10, an estimate (accurate to +/- 10%) is acceptable.

For trees <30cm in height: If the count is less than or equal to 10, the number of trees should be recorded to a required accuracy of +/- 2 trees. However, if the stem count exceeds 10, an estimate (accurate to +/- 20%) is acceptable.

Table 5. Coniferous Species Codes

Code	Species
Fa	Sub-alpine Fir
Fb	Balsam Fir
Lt	Tamarack (Larch)
Pj	Jack pine
Pl	Lodgepole Pine
Sb	Black Spruce
Se	Englemann Spruce
Sw	White Spruce

2.3 Size and Growth

The following trees will be assessed for size and growth at each measurement:

- All **previously tagged live** trees within regeneration plots, regardless of height
- All trees ≥ 1.3 m in regeneration plots
- All baseline sample trees

Stems ≥ 1.3 m in height of all species should be tagged and measured separately if forking occurs below 1.3m. Baseline sample trees if less than 1.3m should be left as tagged; but if forked below 1.3m and now over 1.3m, then the additional stem should be tagged separately.

The following information must be collected for all trees as listed above at each measurement.

2.3.1 Tree Height:

- Record the tree height from tree stem ground level to the tip of the bud. If identification of “stem ground level” is uncertain because of uneven slope, litter etc., measure on the side of the stem where the ground level appears closest to the germination point. Leaning trees are to be measured from the tip of the bud plumb to the ground level. E.g.; If a tree had an extreme lean of about 45° you would measure from the tip of the terminal bud straight down to the ground, in other words, you do not measure the *length* of the tree, only the *height* above ground level.
- Precision: record to nearest 0.1cm on trees < 2 m tall, trees over 2 m are recorded to nearest cm. Accuracy required for trees < 2 m to within +/- 1 cm or 1%, whichever is greater, and for trees > 2 m +/- 2%.
- Trees up to 5 m tall should be measured with a stiff tape or height pole. It is recommended that trees taller than 5 m should be measured using a vertex.

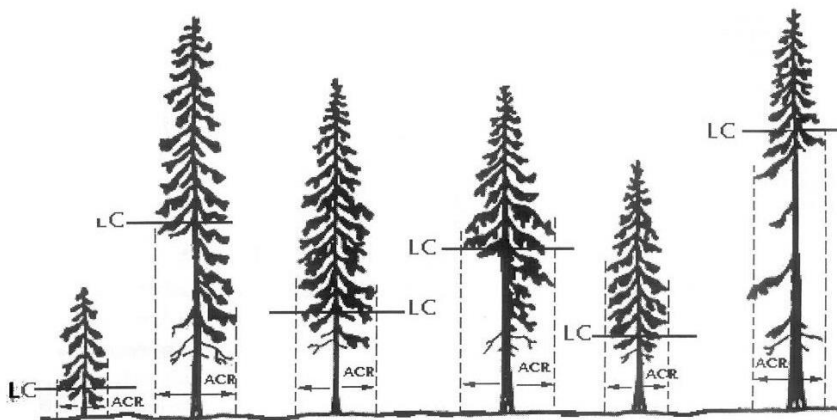
Any trees which have “shrunk” significantly in height since the last measurement should have a valid health code or comment explaining shrinkage. Contractors should have previous measurements available in data collectors or on tally forms to assist in identifying these trees.

2.3.2 Stump Diameter / Breast-Height Diameter:

- Stump diameter is to be recorded for all measured trees.
- Breast-height diameter is to be recorded for all measured that have reached 2m in height.
- Precision: record all diameters to the nearest 0.1cm, accurate to within +/- 0.2cm or 2%, whichever is greater.
- Diameters greater than 3.0 cm should be measured using a D-tape. Smaller diameters should be measured using calipers.

2.3.3 Height to Live Crown:

- For each sample tree, record the height to live crown from the ground to the base of the continuous live crown in cm.
- The measurement is made to the point where the branch connects to the main bole.
- As a rule, the continuous live crown ends where two consecutive “dead” whorls are found. To be considered “live”, a whorl must have more than two branches with green leaves. The live crown may not include isolated or sparse live branches. The figure below provides examples of where the measurement to live crown (LC) should be made.



- Precision: record to the nearest cm. Accuracy required for trees < 2 m to within +/- 1 cm or 1%, whichever is greater, and for trees > 2 m +/- 2%.

2.3.4 Crown Class:

Crown class refers to the relative position of the tree crown within the entire canopy of a stand. It is often defined by the height of the tree crown in relation to its neighbours or competitors.

- D— Dominant, crown extends above the general canopy level
- C— Co-dominant, crown forms the general canopy level
- I— Intermediate, crown below but extends into the bottom of the general canopy level
- S— Suppressed, crown entirely below the general canopy level
- N— No crown class (e.g., tree with severe lean, broken top, broken stem, dead, standing dead)

2.4 Health

Health assessments are required on all tagged trees at each measurement, **including trees that were not sample trees in the regeneration phase**. For each tagged tree within the measurement plot, record up to two of the valid health codes listed in Table 6. If no health issues are apparent, record “NONE” for the first health code.

Table 6. Health Codes

Code	Description	Code	Description	Code	Description
AB	Fire	DEG	Grey Mold	IDC	Cankerworms General
AC	Chemical Pollutants (not pesticides)	DEM	Powdery Mildew	IE	Engravers/IPS
AD	Drought	DF	Needle Diseases	IM	Seed and Cone Insects
AE	Winter Damage	DFB	Needle Cast General	IMD	Coneworms
AES	Snow or Ice	DFE	Needle Rusts General	IME	Eastern Pine Seedworm
AEW	Winter Desiccation	DM	Lodgepole Pine Dwarf Mistletoe	IMS	Cone Maggots
AF	Frost	DRA	Armillaria Root Disease	IP	Pitch Blister Moths
AFC	Frost Crack	DS	Stem Diseases	IR	Wood Borers
AFH	Frost Heaved	DSA	Atropellis Canker	IRF	Flathead Borers
AFK	Shoot/Bud Frost Damage	DSB	White Pine Blister Rust	IRM	Clearwing Moth
AHM	Hail-main stem	DSC	Comandra Blister Rust	IRW	White Spotted Sawyer Beetle
AHL	Hail-lateral	DSD	Sphaeropsis (Diplodia) Blight	IRY	Northeastern Sawyer Beetle
AL	Lightning	DSF	Sweet Fern Blister Rust	ITS	White Pine Weevil
AO	Flooding	DSG	Scleroderris Canker	ITT	Lodgepole Terminal Weevils
AR	Redbelt	DSH	Hypoxylon Canker	IW	Root Weevils
AWS	Soil Failure	DSR	Diplodia Gall and Rough Bark	IWA	Northern Pine Weevil
AWT	Treatment or Harvesting Related	DSS	Stalactiform Blister Rust	IWP	Couper Collar Weevil
AX	Scarring/Rubbing	DSW	Western Gall Rust*	IWS	Yosemite Bark Weevil
CL	Condition - Leaning	DSW50	DSW, gall encircles >%50 of stem	IWW	Warren Root Collar Weevil
CCK	Crook	IAG	Gall Forming Aphids	TC	Chemical
CDT	Dead Top	IAO	Open feeding Aphids and Adelgids	TL	Logging
CFT	Fork Top	IAP	Pine Needle Scale	TM	Mechanical
CNL	New Leader	IB	Bark Beetles	TP	Planting
CSP	Sweep	IBA	Ambrosia Beetles	TPJ	J Root
CSM	Settling Mound (microsite)	IBL	Lodgepole Pine Beetle	TPM	Poor Planting Microsite
DB	Broom Rusts	IC	Defoliators – Coniferous	<u>UNS</u>	<u>Seedling Shrinkage – Unexplained</u>
DD	Stem Decays	ICA	Needle Miners General	VP	Vegetation Press
DDP	Red Ring Rot	ICG	Black Army Cutworm	WB	Browsing Damage
DED	Damping off Disease	ICN	Sawflies General		

* NOTE alternative code added 2011: If the gall encircles more than 50% of the main stem, enter the code “DSW50” instead of “DSW”

Pay particular attention to the codes listed in Table 6 that are bolded. These are factors that are known or expected to be significant causes of mortality or damage that could pre-dispose tree to other mortality factors in young lodgepole pine growing in west-central Alberta, and differentiation of which might lead to different management interpretations. Identification aids for these “key” factors are provided under separate cover.¹ If cause of death is not apparent, dig up dead trees to determine if they were affected by IWW or DRA.

In cases where **live** trees are affected by more than two coded health factors, record the two highest priority codes according to the following priority rules.

1. If any are present, record pests or health factors which are likely to cause mortality in the short term: DRA, DSW50, IWW, or AHM.
2. Record pests or health factors that reduce vigour but which will not cause mortality in the short term. This includes the remainder of the bolded items in Table 6.
3. Record non-bolded items in Table 6 last.

When choosing between pests within the same priority rule, choose the one that appears to be having the greatest impact on the tree's health. If a tree is **dead**, record the health factor that is most likely to have caused mortality. If a condition is observed which is not listed in Table 6, record as a comment and notify the Project Coordinator.

2.5 Vigour and Source

Assessment of vigour is required during scheduled measurements. For each tagged tree within the measurement plot, record one of the six vigour codes indicated in Table 7.

Table 7. Vigour Classes

Code	Description
AL	Alive and likely to survive
AU	Alive but unlikely to survive
D	Dead
M	Missing
MD	Missing, assumed dead.
MT	Mechanically thinned (i.e. removed by thinning)

Trees confirmed as missing for 2 consecutive years will be assumed as Dead (MD). It is very important that every effort is made to locate missing trees before this re-assignment is made.

All trees recorded for vigour must be correctly differentiated by source: “P” for Planted and “N” for Natural.

¹ (a) Alberta Sustainable Resource Development, 2009. *Pest ID Cards 2009*. Unpublished. Edmonton, Alberta.

2.6 Competition Assessment

Assessment of competition from deciduous trees and from non-tree vegetation is required at each measurement.

2.6.1 Deciduous Competition

Deciduous trees $\geq 1.3\text{m}$ in height are already accounted for in Section 2.3. In addition:

- Record for each deciduous species the number of stems $\geq 30\text{cm}$ and $< 1.3\text{m}$ in height within 1.78 m of the regeneration plot centre. Trees are considered inside the plot if the point of germination is inside the plot.
- If the number of deciduous trees $< 1.3\text{m}$ in the plot is less than or equal to 10, the exact number of trees should be recorded. However, if the stem count exceeds 10, an estimate ($\pm 10\%$) is acceptable. This may be obtained by estimation from a representative segment of the circular plot (e.g. counting trees in a $\frac{1}{4}$ segment, and multiplying by 4 to obtain the estimate for the plot).

Suckered deciduous stems are counted as individuals if the suckering has occurred under ground and is not visible. A “group” of stems visibly suckered and/or originating above ground may be counted as a single stem. Note that this applies only to counts of stems $< 1.3\text{m}$ in height.

2.6.2 Shrub and Herb Competition

In each regeneration plot record, to the nearest 5%, the percentage of the ground that is covered by each of the following:

- Shrubs: All shrubs (including tall, low and ground level). Shrub stems may be inside or outside the regen plot. The maximum value is 100 percent.
- Herbs/Forbs: All herbs and forbs.
- Grass: All species of grasses and sedges.
- Moss/Lichen: all moss/lichen species. Moss coverage on logs or debris elevated above the ground should not be included in the estimation.

Table 8. Dimensions for Cover Percentages of a Regeneration Plot

Percent Cover	Area (cm ²)	Radius (cm)	Diameter (cm)	Side of square (cm)
1	1,000	18	36	32
5	5,000	40	80	71
10	10,000	56	113	100
20	20,000	80	160	141
30	30,000	98	195	173
40	40,000	113	226	200
50	50,000	126	252	224
60	60,000	138	276	245
70	70,000	149	299	
80	80,000	160	319	
90	90,000	169	339	
100	100,000	178	357	

Note: where cover is $\leq 5\%$ record to the nearest 1%.

- Precision: Record percent cover to the nearest 1% where cover is <5% and to the nearest 5% when cover is >= 5%.
- Required accuracies: Percent covers: +/- 10%

2.7 Photographs

Now that all installations are established, the taking of photographs will be optional (at the discretion of the plot owner), unless specifically requested for defined research or demonstration purposes. If the option is selected, the following methodology applies:

At each treatment plot center (4 per installation), take one landscape orientated photo toward each treatment plot corner. This will give four photos per treatment plot and therefore 16 photos per installation. Photographs should be digital and labeled accurately. Contractors will confirm the photograph submission format and protocol with the database manager prior to any collection of data.

2.8 Stocking of Regeneration Plots by Tagged Trees

Stocking of regeneration plots by natural regeneration can be computed from the regeneration plot data collected as described in Section 2.2. It is important that, in addition to determining whether each regeneration plot is stocked with natural regeneration (ingress), a record is made of whether the plot is stocked with any tagged tree or sapling. This is the purpose of the “Regen Plot Number” field in the Tree Information Table. If a tagged tree or sapling is INSIDE a regeneration plot, record the plot number in this field. If a tagged tree or sapling is outside a regeneration plot, record “0” in this field. Blanks are not acceptable. **Contractors are asked to pay particular attention to checking that the correct information is entered in this field at every measurement, since some inconsistencies have been observed in the data from previous years.**

2.9 Closest Regeneration Plot

The field “Closest Regen Plot” will be retained in the database, but populating the field is no longer required.

2.10 Top Height

Top height will be assessed using the RSA method. In 2015 only, top height was also assessed utilizing the 10-largest diameter tree method.

2.10.1 RSA Method

In order to emulate assessment of top height in RSA (Reforestation Standard of Alberta) performance surveys, tag and measure the largest diameter at breast-height live (AL or AU) tree, by species group, within 5.64m of the centre post of each of the following regeneration plots: 1, 4, 13, 16. Within the Pine, White spruce, and Black spruce species groups if there are no trees that have reached breast height, the largest tree in each species group that is greater than 30cm in height must be selected.

Follow RSA tree selection and measurement procedures as quoted in Appendix 3, treating the above 4 centre posts as the centres of RSA detailed performance survey plots.

If the selected tree already is tagged, use the existing tree number; otherwise tag the tree with a new number, series 4000. Selected RSA top height trees should be flagged with orange and blue ribbon. Record for each tree:

- Regeneration plot number: 1, 4, 13 or 16;
- Health (do not select any tree with a broken top that has not been replaced by a new leader, or a tree whose main stem is more than 50% encircled by western gall rust);
- Species (note that if more than one species group is present within the 5.64 m plot radius, one tree for each group should be measured);
- Source (note that age need not be measured if the tree was planted);
- Top height (this is height to the top of the terminal bud, as in RSA protocols);
- **DBH;**
- Total age: if the selected tree is naturally regenerated, follow the RSA procedure for estimating total age (see Appendix 3);
- Distance to the regeneration plot centre;
- Azimuth from the regeneration plot centre;
- Whether the tree falls outside the 0.1 ha staked measurement plot.

3 Maintenance

The items indicated in Table 9 must be checked at each plot measurement visit, and the listed requirements met. Unlike in measurements, where errors are tolerated within specified limits, no errors or omissions are acceptable in installation and plot maintenance.

Table 9. Installation and Plot Maintenance Requirements

Item	Requirement
Access Maps	Accurate, and updated if access has changed.
Installation Tie-point	Clearly visible. Marked with the azimuth and distance to installation center.
Installation Buffer	Clearly visible around the entire installation. Conduit poles pounded securely into the ground and blue paint refreshed as required. As trees begin to approach 2m tall, blue ribbon should be tied to the lateral branches (never to the main stem!) of regenerating trees to make the buffer easier to see.
Installation Centre Post	Pounded securely into ground. Orange paint clearly visible. Flagged with orange ribbon. As neighbouring trees reach 2m tall, witness trees should be flagged on lateral branches only. Tagged with the installation number.
Treatment Boundary Corner Posts	Pounded securely into ground. Orange paint clearly visible. As neighbouring trees reach 2m tall, witness trees should be flagged (when possible) on lateral branches only.
Measurement Boundary Corner Posts	Pounded securely into ground. Red paint clearly visible. As neighbouring trees reach 2m tall, witness trees should be flagged on lateral branches only.
Measurement and Treatment Plot Centre Post	Pounded securely into ground. Red paint clearly visible. Tagged with the installation number and treatment type.
Regeneration Plot Centre Post	Every measurement plot must contain 16 green regeneration plot centre posts properly positioned and securely pounded into ground.
Tree Demarcation	<p>Number on tags is clear & legible and clearly displayed (i.e. off the ground). Pigtails are utilized ONLY until trees are robust enough to allow for either:</p> <ul style="list-style-type: none"> • Placement of a big-loop-tag to the main stem (providing a minimum of 4 inches of diameter slack to allow for growth) or • Tagging a lateral branch <p>Trees tagged with a big-loop or tagged on lateral branch will be flagged appropriately on a lateral branch. The only required flagging is:</p> <ul style="list-style-type: none"> • Any trees tagged for RSA top height assessment (Section 2.10) will be flagged orange and blue. <p>If utilized, pigtails are placed 20cm North of their assigned tree. If pigtails are utilized and there is <u>ANY</u> doubt as to which tree is represented, the tree itself may be flagged with the appropriate color and/or tagged (flagging and/or tagging tree stem must be done in a non-restrictive manner, and, will be only utilized until transfer to main stem big loop tag or lateral branch demarcation</p>

4 Quality Control

4.1 Measurements and Maintenance

Required accuracies of measurements are specified in Section 2. Note the distinction made between precision and accuracy. “Precision” refers to how the data should be recorded. Quality control audits will be made to check whether measurements are within the “required accuracy” (i.e. acceptable error limit) specified for each variable. No errors or omissions are acceptable in plot maintenance.

Field contractors are encouraged to submit completed data to the Project Coordinator as soon as possible to allow for quick audits. Submitted data will have a data audit completed by the PC to identify if there are any installations that require the FA to confirm data abnormalities or discrepancies in data. Installation maintenance and measurements will be checked by the Field Auditor in consultation with the applicable company technical representative. Failures will be placed in one of 3 categories:

1. Minor outage: an issue that can be rectified during the next regularly scheduled field visit.
2. Moderate outage: an issue that can be rectified during the next regularly scheduled field visit; however additional measurements may need to be taken.
3. Major outage: an issue that cannot be fixed at the next regularly scheduled field visit.

Identified outages will be regarded as potentially applying to all plots measured by the contractor within the sample year. The Project Coordinator will discuss observed problems with the respective company technical representative and notify the field contractor of any required remedial action. Major outages (and some systemic moderate outages) will require the field contractor to ensure that all plots visited for that sample year have been fixed. The Field Auditor will re-audit corrected plots, and the Project Coordinator will provide a recommendation for payment to member companies only when satisfied that all quality control issues have been addressed.

4.2 Data Loading

All data must be submitted using the Contractor Loading Database (CLDB). The CLDB is a Microsoft Access database provided to each of the contractors engaged to undertake measurements. Contractors receive a personalized version of the database that contains all the installations they are scheduled to measure. It includes previous measurement data and error-checking routines.

Regardless of how data is collected in the field, it must be loaded into this database. Prior to submission of data, all error checking routines must be run and any problems identified must be corrected. On receipt of the data, the database manager and / or Project Coordinator will verify whether the data passes the quality control checks, and will notify the contractor and company representative to this effect within 2 weeks of receiving the data.

The error checks incorporated into the CLDB and applicable for the 2016 field season are described in Appendix 2.

4.3 Field Audit Procedures

Field audit procedures are described in Appendix 4.

Appendix 1. Latest Amendments

The following changes and additions have been made since 2014 (version 4.3 of this Manual). Contractors must ensure that they have noted and understood the revised manual sections referenced below before commencing field work.

1. Measurements will be conducted every two years.
2. All saplings $\geq 1.3\text{m}$ occurring on the regeneration sub-plots will be tagged and measured for height, DBH and condition.
3. Only tagged sample trees outside the regeneration sub-plots will be measured for height, dbh and condition.
4. Dropped Crop Tree assessment.
5. Height (Section 2.3.1) will be measured to the tip of the bud.
6. Dropped requirement to measure Ground Line Diameter (Section 2.3.2).
7. Dropped measurement of Crown Diameter.
8. Add Crown Class Assessment (Section 2.3.4).
9. Protocol for assessing Deciduous Competition (Section 2.6.1) has been simplified Number of Stems $>30\text{cm}$ in Height, by Species
10. Vegetation assessment (Section 2.6.2) simplified to be consistent with Provincial Growth and Yield Initiative protocols.
11. The “Regen Plot Number” field (Section 2.8) is now used to track if trees are inside a regen plot. Any trees not within a Regen Plot must be assigned a value of 0. Blanks are not permitted.
12. “Closest Regen Plot” field is now optional.
13. Top height (Section 2.10) will be collected only using the RSA method.
14. Change to protocol for tree flagging (Table 9).
15. The Project Coordinator will pre-screen data submitted prior to field auditing, to address any potential data discrepancies and direct field audits to confirm/address issues.
16. Introduction of baseline sample tree concept in Section 2.1.
17. Clarification of tagging procedures for trees $>1.3\text{m}$ in height in Section 2.3.
18. Clarification of deciduous ingress counting procedures in Section 2.6.1

Appendix 2. Quality Control Checks for Loading Data – 2017

Measurement Plot Information

Error ID	Error Description	Minimum Value	Maximum Value	Tolerance Percent	Tolerance Absolute	Criteria
2	Missing or Invalid Plot Measurement Type			0	0	
3	Missing / Invalid Start Date	15/07/2017	15/10/2017	0	0	
4	Missing / Invalid End Date	15/07/2017	15/10/2017	0	0	
5	Missing Contractor			0	0	
6	Missing Crew Initial			0	0	
7	Excessive Days Between Start and End (warning)			0	10	

Regeneration Plot Information

Error ID	Error Description	Minimum Value	Maximum Value	Tolerance Percent	Tolerance Absolute	Criteria
9	Invalid Ingress Species 1			0	0	
10	Invalid Ingress Species 2			0	0	
11	Invalid Ingress Species 3			0	0	
35	Missing / Invalid Start Date	15/07/2017	15/10/2017	0	15	
36	Missing / Invalid End Date	15/07/2017	15/10/2017	0	15	
37	Invalid Contractor			0	0	
38	Excessive Days Between Start and End (warning)			0	20	
39	Missing IngressCount1_LT30	0		0	0	
40	Missing IngressCount1_GT30	0		0	0	
41	Missing IngressCount2_LT30	0		0	0	
42	Missing IngressCount2_GT30	0		0	0	
43	Missing IngressCount3_LT30	0		0	0	
44	Missing IngressCount3_GT30	0		0	0	
61	IngressCount1_LT30 > 25 (warning)	0	25	0	0	
62	IngressCount2_LT30 > 25 (warning)	0	25	0	0	
63	IngressCount3_LT30 > 25 (warning)	0	25	0	0	
64	IngressCount1_GT30 > 25 (warning)	0	25	0	0	
65	IngressCount2_GT30 > 25 (warning)	0	25	0	0	
66	IngressCount3_GT30 > 25 (warning)	0	25	0	0	
67	Invalid Shrub percent cover	0	100	0	0	PC_Shrub >= 0
68	Invalid Herb/Forb percent cover	0	100	0	0	PC_HerbForb >=0
69	Invalid Grass percent cover	0	100	0	0	PC_Grass >= 0
70	Invalid Moss/Lichen percent cover	0	100	0	0	PC_MossLichen >=0

Regeneration Plot Information (Deciduous)

Error ID	Error Description	Minimum Value	Maximum Value	Tolerance Percent	Tolerance Absolute	Criteria
1	InValid Decid Species 1			0	0	
2	InValid Decid Species 2			0	0	
3	InValid Decid Species 3			0	0	
4	Missing / Invalid Start Date	15/07/2017	15/10/2017	0	15	
5	Missing / Invalid End Date	15/07/2017	15/10/2017	0	17	
6	Too Long Between Start and End (warning)			0	10	
7	Missing DecidCount1	0		0	0	
8	Missing DecidCount2	0		0	0	
9	Missing DecidCount3	0		0	0	
34	Ingress Count1 > 50 (warning)	0	50	0	0	
35	Ingress Count2 > 50 (warning)	0	50	0	0	
36	Ingress Count3 > 50 (warning)	0	50	0	0	

Tree Information

Error ID	Error Description	Minimum Value	Maximum Value	Tolerance Percent	Tolerance Absolute	Criteria
1	Missing Species or Change			0	0	
2	Missing/invalid Height	0.1	1050	0	0	
3	Shrinking Height (warning)			0	10	
6	Missing/invalid DBH	0.1	20	0	0	Height >= 200
7	Shrinking DBH (warning)			0	0.1	
8	Suspect DBH/Ht Ratio (warning)	0.002	0.04	0	0	
10	Shrinking Height to Live Crown (warning)			0.05	0	
27	Dead to Live			0	0	
28	Missing Vigour/Health Code Information			0	0	
29	Invalid Tree Species			0	0	
30	Missing/Invalid Height to Live Crown	0.1	1000	0	0	
32	Height to Live Crown > Height (warning)	0	0	0.1	10	
33	Invalid SampleType Code			0	0	
34	Invalid Source Code			0	0	
35	Invalid Vigour Code			0	0	
36	Invalid Health Code 1			0	0	
37	Invalid Health Code 2			0	0	
38	Missing Regen Plot Number			0	0	
39	Missing DSH	0.1		0	0	Height >= 30 AND < 200
40	Missing/ Invalid Stem Map Information (warning)			0	0	
42	DBH > Stump Diameter (warning)			0	0	
43	Missing or Changed Source			0	0	
45	Suspect DSH/Ht Ratio (warning)	0.002	0.04	0	0	
46	Missing or Changed SampleTree Code			0	0	
47	Regen Plot Number Change			0	0	
48	Missing/Invalid Crown Class Code			0	0	
49	Height Base > Height Top			0	0	
50	Missing top height tree age (< 10 trees)					

Top Height Information

Error ID	Error Description	Minimum Value	Maximum Value	Tolerance Percent	Tolerance Absolute	Criteria
1	Missing Species			0	0	
2	Missing/invalid Height	0.1	1300	0	0	
3	Missing/invalid Top Height	0.1	1300	0	0	
4	Missing/invalid DBH	0.1	20	0	0	
5	Invalid Health Code			0	0	
6	Missing/invalid Age			0	0	
7	Invalid Regen Plot Number			0	0	
8	Suspect DBH/Ht Ratio (warning)	0.002	0.04	0	0	
9	InValid Tree Species			0	0	
10	Missing Stem Map			0	0	
11	Height > Top Height			0	0	
12	Age Not Required (Planted)			0	0	

Appendix 3. Extracts from Reforestation Standard of Alberta

(Government of Alberta Publication T/245, May 2011)

Top Height

A top height tree is the largest diameter at breast height (DBH) tree by species group present within the 5.64 m radius Detailed plot.

The species groups are:

- $A_w = A_w + P_b$;
- $P_l = P_l + P_j + L_t$;
- $S_w = S_w + S_e + F_b + F_a$; and,
- $S_b = S_b$.

Top height trees shall be selected based on the rules outlined below:

Primary tree species to select	Secondary tree species to select (if primary tree species is absent from the 5.64m radius plot)
Aspen	Balsam poplar
Pine	Larch
White spruce	Engelmann spruce, then fir species
Black spruce	None

If the largest DBH tree has a lost or broken top that has not yet been replaced by a new leader, then the next largest DBH tree of that species shall be selected.

ADV trees and SDL trees classified as having western gall rust ($\geq 50\%$ of the stem encircled by gall) are not eligible as top height trees.

If there are no coniferous trees taller than breast height (130 cm) within the Pine, White spruce, and Black spruce species groups, then select and measure the height of the tallest tree below breast height to a minimum height of 30 cm.

The minimum height for deciduous trees is 130 cm. Thus, if there are no deciduous trees taller than breast height (130 cm) within the Aspen species group, then no deciduous top height trees shall be selected.

Total Age

Total age is the number of years since germination. To field-age a tree:

- Count the number of branch whorls on coniferous trees or bud scars on deciduous trees from the current season's growth (i.e., terminal leader) down to the root collar node;
- Add one year (germination to cotyledon); and,
- Record age.

Appendix 4. Field Audit Procedures

The Project Coordinator (PC) has the lead responsibility to ensure that the field installations have been properly maintained and measured. She will be assisted by a Field Auditor (FA). Company technical representatives are encouraged to be actively involved in maintaining the integrity of the data collected within their respective FMA areas. This can be done by visiting installations (with the FA or independently) and alerting the PC of any suspected problems.

The FA will annually audit 10% of the full measurement installations. Selection of the installations to be audited will be done by the PC, and may be targeted as a result of a data audit prior to field audit. Each year a representative sample should be audited on each of the participant FMA areas. The FA will attempt to visit each contractor early in the season, in a mentoring/audit role. Subsequently, most of the installations to be audited should be randomly selected each field season, but this may be modified for logistical purposes. The PC may also select sample locations to improve access efficiencies; however this must be done carefully to ensure that predictable auditing does not occur.

The PC may also select installations for audit by the FA that have not been QC'd for an extended period or to ensure that locations (or contractors) with potential problems are given emphasis.

QC audits must examine:

- installation maintenance;
- measurement plot data (one measurement plot will be randomly selected within each audited installation), and;
- regeneration plot data (2 out of 16 regeneration plots will be randomly selected within each audited measurement plot).

Table 10 lists the sampling intensities and permitted measurement thresholds that the FA will reference. Where the FA finds measurements and maintenance outside the acceptable thresholds, he will conduct additional checks within the plot to determine if the issue is isolated or extends throughout the plot. If necessary, additional checks will be conducted on the rest of the installation or on additional installations measured by the same contractor to determine the extent of the problem.

Figure 3 provides a schematic for the field auditing process.

Table 10. Field audit sampling intensity and accuracy targets

Measurement / Maintenance Item	Sampling Intensity	Target Accuracy Standard*	Maximum Permitted Deviation †
Installation Maintenance Audit			
Access Maps	Check for all audited	Must be 100% accurate	None
Installation Tie-point	Check on audited installations	All Tie-points must: <ul style="list-style-type: none"> • be clearly visible • be marked with the azimuth and distance to installation center 	None
Installation Buffer	Thoroughly examine one side of the buffer	The blue buffer must be well maintained and clearly visible around the entire installation. Conduit poles should be pounded securely into the ground and the blue paint refreshed as required. As trees begin to approach 2m tall, blue ribbon should be tied to the lateral branches (never to the main stem!) of regenerating trees to make the buffer easier to see.	None
Installation Centre Post	Check on audited installations	Centre post must be: <ul style="list-style-type: none"> • pounded securely into the ground • painted orange • flagged with orange ribbon. As neighbouring trees reach 2m tall, witness trees should be flagged (when possible) on lateral branches only. • tagged with the installation number 	None
Treatment Boundary Corner Posts	Thoroughly examine posts for at least one treatment zone	Corner posts must be: <ul style="list-style-type: none"> • pounded securely into the ground • painted orange. • as neighbouring trees reach 2m tall, witness trees should be flagged (when possible) on lateral branches only. 	None
Measurement Boundary Corner Posts	Thoroughly examine posts for at least one measurement plot	Corner posts must be: <ul style="list-style-type: none"> • pounded securely into the ground • painted red. • as neighbouring trees reach 2m tall, witness trees should be flagged (when possible) on lateral branches only. 	None
Measurement and Treatment Plot Centre Post	Check on audited plots.	Centre post must be: <ul style="list-style-type: none"> • securely pounded into the ground • clearly painted red • tagged with the installation number and treatment type 	None

Measurement / Maintenance Item	Sampling Intensity	Target Accuracy Standard*	Maximum Permitted Deviation †
Tree Tags	Check tags on trees checked as described below.	<p>The tags should be:</p> <ul style="list-style-type: none"> • legible • clearly displayed (i.e. off the ground) • located 20cm to the north of their assigned tree (if possible) when pigtailed are used <p>Trees 2m+ tall should be tagged either by affixing a tag to a lateral branch or if the tree is less than 4m tall the tag can be affixed to the main stem by a big-loop-tag that provides a minimum of 4 inches of diameter slack to allow for growth.</p>	None
Saplings and trees tagged >= 1.3m	Checked on 4 regen plots of audited installations.	All must be correct and correctly assigned to regeneration plot	None
Eco-Class	Check on audited installations.	Field Auditor must agree that the assessment is plausible.	None
Audit 1 of the 4 Measurement Plots (Randomly Selected)			
Dead and Missing Trees [vigour code = 'D' or 'M']	5 trees	Confirm the status of trees that have been identified as either dead or missing during the last measurement (to a maximum of 10 trees).	No errors allowed
Dead Tree Causal Agent	5 trees	Confirm the causal agent for trees that have been identified as dead during the last measurement (to a maximum of 10 trees).	A maximum of 20% of the measurements are allowed to be outside the target standard.
Health Assessment	10 trees	Field Auditor must agree that the assessment is plausible.	A maximum of 20% of the measurements are allowed to be outside the target standard.

Measurement / Maintenance Item	Sampling Intensity	Target Accuracy Standard*	Maximum Permitted Deviation †
Sample Tree Height	10	For trees <2m tall: within 1cm or 1% whichever is higher For trees >2m tall: within 2%. Shrinking trees must have a health code/comment to explain the cause.	A maximum of 10% of the measurements are allowed to be outside the target standard.
Sample Tree Diameter	10	Within 0.2cm or 2% whichever is higher	A maximum of 10% of the measurements are allowed to be outside the target standard.
Sample Tree Height to Live crown	10	For trees <2m tall: within 1cm or 1% whichever is higher For trees >2m tall: within 2%.	A maximum of 20% of the measurements are allowed to be outside the target standard.
Sample Tree Species Code	10	All must be correct.	None
Sample Tree Planted / Natural	10	All must be correct.	None
Crown class	10	Field Auditor must agree that the assessment is plausible.	None
Audit 3 of the 16 Regeneration Plots (Randomly Selected)			
Shrub and Herb Percent Cover	Check for each category	Within 10%	None
Density of Coniferous Natural Regeneration (Ingress)	Count all stems within regeneration plot. Stratified by species	For trees <1.3m and >=30cm tall: If there are 10 or less trees– the exact number If there are more than 10 trees total – within 10% For trees <30cm tall: If there are 10 or less trees– within 2 stems If there are more than 10 trees total – within 20%	None
Density of Deciduous Competition Trees >= 30cm	Count all stems within regeneration plot. Stratified by species	For trees >=30cm tall: If there are 10 or less trees – the exact number If there are more than 10 trees total – within 10%	None
Top Height	For each species on regen plot	Protocol for top height tree selection and measurement as described in Section 2.10 of the manual are followed.	None

* - Deviation is calculated from true measurement: for example a tree height measurement of 2.50m (10% deviation allowed) would have an acceptable measurement tolerance of 2.25m to 2.75m.

† - "Maximum Permitted Deviation" is the maximum amount of field measurements that are permitted to not comply with the "target standard". The total observed deviation is calculated for each measurement/maintenance item on each plot by dividing the total number of QC measurements by the total number of QC samples taken (for that specific item).

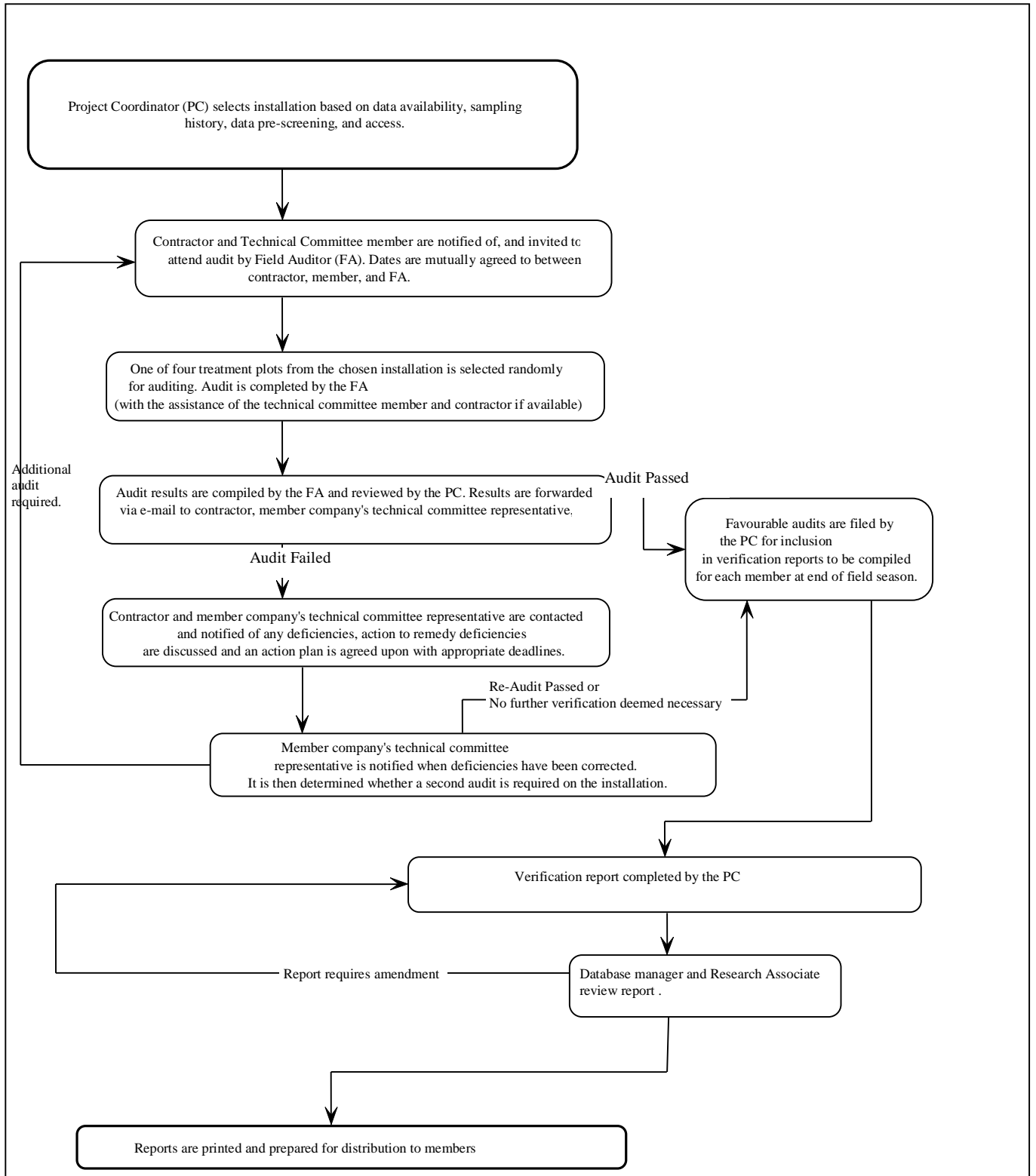


Figure 3. Field Audit Flow Chart