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Syncrude's Aurora Soil Capping Study – Root Evaluation

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EXECUTIVE SUMMARY

A root assessment at select locations across the Aurora Soil Capping Study site was completed in October 2018 to determine if rooting patterns and distribution could be used to explain observed variation in above-ground tree growth. The variation in above-ground tree growth included patterns of growth along treatment boundaries that were better than in the adjacent treatments, and individual trees growing noticeably better than other trees within the same treatment. It was expected that observations from the root assessment would either provide supporting evidence for above-ground observations at the Aurora Soil Capping Study or suggest hypotheses for unexpected observations that could then lead to further avenues of research.

A total of 68 trembling aspen, jack pine and white spruce were assessed at 15 different locations. Trenches and/or test pits were excavated with mini-excavators and data collected at seven border locations and within eight treatments. Data were recorded as consistent as possible to allow for comparison of rooting patterns at borders between cells and within treatments. Measurements included parameters such as tree height and DBH, soil material type and depth, root orientation, direction and length of horizontal roots, and maximum and effective root depth.

Along borders, primary roots tended to grow in the direction of the treatments, rather than along the border, indicating that they may be utilizing varying resources to benefit tree growth; additionally, the largest diameter primary roots tended to grow towards peat coversoil treatments. Within treatments, roots tended to be evenly distributed around trees. In treatments containing a Bm horizon (three horizons versus two horizons) maximum rooting depth tended to be higher. When a blended B/C horizon was present, aspen roots, more so than pine or spruce, generally avoided rooting in this horizon. Treatments with an LFH coversoil tended to have a greater maximum rooting depth than treatments with a peat coversoil.

Trees tended to perform well when they had access to a variety of soil materials *(i.e.,* on borders where there was access to organic materials in adjacent treatments, and within treatments when a soil profile with multiple horizons was present). The distribution of roots tended to be greatest in organic materials. The roots of all species appeared to be present at the interface between different reclamation materials, especially when there were differences in the soil texture or organic matter content (e.g., peat coversoil vs subsoil). However, it's not certain whether the roots had a preference to remain in the above horizon or if there was a restriction to rooting in the underlying horizon. There was minimal rooting in the overburden. Roots were present above the overburden and occasionally made an abrupt turn on the overburden surface, suggesting there was either a root restriction (structure/consistence restriction) or preference to root in the above soil reclamation cover.

Trees appeared adaptable to varying conditions in terms of moisture and other soil resources (*i.e.,* nutrients). Material and landscape variability may provide benefits for root growth. The observations recorded in this report could prove valuable to informing future reclamation practices and avenues of future research.

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CITATION

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1.0 INTRODUCTION

1.1 BACKGROUND

In 2012 Syncrude Canada Ltd. began a comprehensive, multi-treatment soil reclamation cover design and revegetation experiment on a lean oil sands overburden landform at the Aurora North Mine site referred to as the Aurora Soil Capping Study (ASCS). As the initial phase of research was wrapping up through 2017 and 2018, there were a number of observations of unexpected growth patterns that could not be explained based on known site (soil) conditions or trends that could be evaluated from above-ground biometrics. In particular: (i) there were occasionally patterns of growth at treatment boundaries that were noticeably better than in either of the adjacent treatments on their own, and (ii) there were individual trees that were growing much better than the surrounding trees within the same treatment (Figures 1.1.1 to 1.1.3). It was speculated that access to below-ground resources was the likely cause of the differences, and that a root excavation study might provide evidence either to support current hypotheses or to suggest new ones. The purpose of this report is to document the outcomes of a root excavation study that was carried out in October 2018.

Figure 1.1.1. Increased tree height growth at border between Cell 19 (Treatment 12b) and Cell 20 (Treatment 5).

Figure 1.1.2. Increased tree height growth of aspen at border between Cell 31 (Treatment 5) and Cell 32 (Treatment 2).

Figure 1.1.3. Outstanding growth of individual aspen on the border between Cell 19 (Treatments 12a and 12b) relative to growth in the cell (in background).

1.2 AURORA SOIL CAPPING STUDY DESIGN

The Aurora Soil Capping Study (ASCS) research project was established in 2012 by Syncrude Canada Ltd. to: 1) quantify the risk of naturally-occurring petroleum hydrocarbons in soil cover and overburden materials, and 2) provide soil cover design and revegetation guidance for the re-establishment of locally common boreal forest vegetation. The study design included a range of soil reclamation cover designs, capping thickness treatments and revegetation strategies. The study was divided into cells, approximately one hectare (ha) in area and replicated in triplicate, where lean oil sands (LOS) was capped in winter 2011/12 with 1 of 13 treatments which were randomly assigned and consisted of varying depths of coversoil and subsoil. Coversoil materials consisted of peat and LFH (*i.e.*, upland surface soil - surface litter horizon (LFH), A horizon and potentially a portion of the B horizon). Subsoils varied depending on their salvage depth: 1) Subsoil (>1m) – mineral soil salvaged after upland surface soil salvage to a maximum salvage depth of approximately 2.5 m, 2) Blended B/C – subsoil salvage after Bm salvage (0.5 to 1.0m), 3) Upper Subsoil – Bm horizon salvage (approximately 0.15 to 0.5m) and 4) Upper Subsoil (Center Pit) – Bm horizon salvage (approximately 0.15 to 0.5m).

The soil cover design treatments consisted of the following:

Treatment 1: 0.3 m Peat/1.2 m Subsoil (>1m);

Treatment 2: 0.1 m LFH/1.4 m Subsoil (>1m);

Treatment 3: 0.1 m Peat/1.4 m Subsoil (>1 m);

Treatment 4: 0.3 m Peat/0.3 m Blended B/C;

Treatment 5: 0.3 m Peat;

Treatment 6: 0.3 m Peat/0.3 m Upper Subsoil/0.9 m Subsoil (>1m);

Treatment 7: 0.2 m LFH/1.3 m Subsoil (>1m);

Treatment 8: 0.2 m LFH/1.3 m Blended B/C;

Treatment 9: 0.2 m LFH/0.3 m Upper Subsoil/1.0 m Subsoil (>1m);

Treatment 10: 0.3 m Peat/1.2 m Blended B/C;

Treatment 11: 0.3 m Peat/0.7 m Blended B/C;

Treatment 12a: 1.5 m Upper Subsoil (Center Pit); and

Treatment 12b: 1.5 m Subsoil (>1m).

Each cell was divided into vegetation subplots (25 x 25m) and planted to white spruce (*Picea glauca*), trembling aspen (*Populus tremuloides*), jack pine (*Pinus banksiana*) and a mixture of all three species. Tree planting densities within the vegetation subplots were either 2,000 or 10,000 stems/ha, while the rest of the treatment cell was planted to a mix of all three tree species at a density of approximately 1,800 stems/ha.

The above-ground growth response has been monitored since planting, and as expected, a wide range of growth has been observed across the treatments. However, there has also been unexpected growth observations across the site: 1) there is a wide range in tree growth within some of the cell treatments, and 2) an increase in tree growth at some borders between treatments (compared to growth within the treatment) (Figures 1.1.1 to 1.1.3).

In the fall of 2018, InnoTech Alberta (ITA) was contracted to assess the root development at select locations across the study site to determine if rooting patterns and distribution could explain the observed variation in above-ground tree growth.

1.3 OBJECTIVES

The objective of the field investigation was to assess patterns of root development at select locations at ASCS to determine if variable above-ground growth could be explained by patterns of root development and access to resources necessary for growth. Root development and distribution were assessed along borders, within treatments, and among select treatments. Test-pits and/or trenches were established at these locations to collect data and photos describing rooting patterns relative to proximal and nearby soil media, soil media interfaces, soil layering and soil depth. The project was inductive in nature: it was expected that the observations would either (i) provide supporting evidence for observations in the controlled experiment of the ASCS, or (ii) suggest hypotheses for unexpected observations that could then lead to further deductive experiments.

1.4 REPORT ORGANIZATION

The data in the report are organized by location at the ASCS. Observations are provided for individual treatments and/or borders between treatments. Similarities and differences between tree species have been identified for each test pit and/or trench within cell/border, followed by a discussion of the findings.

2.0 METHODOLOGY

2.1 TREATMENT AND/OR CELL BORDER INVESTIGATION LOCATIONS

An initial site visit was conducted in September 2018 to identify inspection locations for the study. Considerations of inspection sites included equipment accessibility, proximity of trees to existing vegetation plots and infrastructure, relative tree size (in comparison to trees growing within the treatment and/or on either side of a border) and expected value of information for subsequent comparisons. Field activities were conducted over five days in October 2018, focusing on priority inspection locations with the highest level of interest:

Priority 1 – [Border locations generally consisting of transects with inspection points along the transect and individual pits as needed]

1. Cell 19b (Treatment 12b) and Cell 20 (Treatment 5);
2. Cell 5 (Treatment 5) and Cell 6 (Treatment 6);

3. Cell 36B (Treatment 12b) and Cell 13 (Treatment 3);
4. Cell 32 (Treatment 2) and Cell 31 (Treatment 5);
5. Cell 8 (Treatment 3) and Cell 9 (Treatment 1);
6. Cell 20 (Treatment 5) and Cell 21 (Treatment 9); and
7. Cell 19a (Treatment 12a) and Cell 19b (Treatment 12b).

Priority 2 – [Individual tree profile evaluations within select treatments to compare differences between Treatments 1, 6, 7 and 9; (Treatment 6 captured in above Border locations)]

8. Cell 9 (Treatment 1);
9. Cell 28 (Treatment 7); and
10. Cell 4 (Treatment 9).

Priority 3 – [Comparisons between Treatments 4, 5, 10 and 11 (Treatment 4 captured in Border locations)]

11. Cell 3 (Treatment 4);
12. Cell 30 (Treatment 10); and
13. Cell 7 (Treatment 11).

Tree growth characteristics were captured along the border between two treatments and within individual treatments. As many borders and treatments as possible were captured in the study. The investigation was not limited to only borders where tree growth along the transition between two treatments was more vigorous than in either treatment. When selecting trees along borders, areas were targeted that allowed evaluation of more than one tree along a trench; the sampling design was not intended to target individual trees. To help understand tree growth characteristics along borders, the distribution of roots towards each treatment was investigated, along with rooting depth in each treatment. The distribution of roots at soil horizon interfaces and the ability of roots to penetrate overburden were studied.

The treatments studied were not limited to those in which individual trees were growing better than the surrounding trees within the same treatment. Rather than selecting individual trees, trees with average growth for the treatment were targeted, while taking accessibility into account. Areas were targeted where more than one species could be captured within a trench. Within treatments, rooting depth, distribution of roots at soil horizon interfaces, and the ability of roots to penetrate overburden were studied.

2.2 Test-pit/Trench Locations and Soil Excavation

Field activities associated with the ASCS root evaluation were conducted from October 15 to 21, 2018. Two mini-excavators and associated operators from CBS Construction Ltd. completed the soil excavations of seven transects at three border locations and eight (8) individual pit excavations within treatments (Figure 2.3.1). Individual trees and/or a series of trees were identified in advance and equipment was directed for positioning to excavate soil from one side of the tree(s). Where possible, a trench was excavated to expose the roots from multiple trees to reduce the disturbance intensity on site and increase efficiency of sampling. The depth of the test-pit/trench was dependant on the treatment.

Treatments with a soil cover capping thickness less than 1.5 m were generally excavated to the depth of the overburden (lean oil sand). Treatments where the overburden depth was greater than 1.5 m or greater were generally excavated to a maximum depth of 1.0 to 1.2 m. Occasionally, individual roots were hand exposed with shovels and hand trowels to deeper depths to identify the maximum rooting depth and length. Only 1 treatment was excavated with equipment to a depth of 1.5 m (Treatment 12b). Efforts were made to keep reclamation materials separate as they were removed from the test-pit/trench to ensure they could be returned in the same sequence when backfilled.

2.3 DATA COLLECTION

Observational and measured data were collected for individual trees within treatments. A minimum of one individual tree for each of white spruce, jack pine, and aspen were selected for destructive sampling and data collection within select treatments and in select borders between treatments. A total of 68 trees and their associated root profile were evaluated (Table 2.3.1).

Table 2.3.1. Number of trees sampled within treatments and borders between treatments[1].

Treatment 1 (Cell 9)	Treatment 2 (Cell 32)	Treatment 3 (Cells 8 and 13)	Treatment 4 (Cell 33)
• 1 jack pine (35) • 1 Spruce (36) • 2 Aspen (37, 38)	• Included in Border sites	• 1 jack pine (48) • 1 Spruce (47) • 1 Aspen (46)	• 2 jack pine (22, 23) • 2 Spruce (24, 25) • 2 Aspen (21,26)
Treatment 5 (Cells 5, 20, 31)	Treatment 6 (Cell 6)	Treatment 7 (Cell 28)	Treatment 8
• Included in Border sites	• 1 Aspen (34)	• 1 jack pine (41) • 1 Spruce (39) • 1 Aspen (40, 42)	• Not Assessed
Treatment 9 (Cell 4)	Treatment 10 (Cell 30)	Treatment 11 (Cell 7)	Treatment 12b (Cells 36b, 19b)
• 2 jack pine (16, 19) • 1 Spruce (18) • 2 Aspen (17, 20)	• 1 jack pine (51) • 1 Spruce (49) • 3 Aspen (50, +2 Additional)	• 1 jack pine (44) • 1 Spruce (43) • 1 Aspen (45)	• Included in Border sites
Treatments 2/5 Border (Cells 32 and 31)	Treatments 3/1 Border (Cells 8 and 9)	Treatments 3/12b Border (Cells 13 and 36b)	Treatments 5/6 Border (Cells 5 and 6)
• 1 jack pine (63) • 3 Spruce (59, 60, 62) • 1 Aspen (61)	• 4 Spruce (64, 65, 66, 67)	• 2 jack pine (11, 13) • 2 Spruce (10, 15) • 2 Aspen (12, 14)	• 1 jack pine (27) • 4 Spruce (28, 30, 32, 33) • 2 Aspen (29, 31)
Treatments 5/9 Border (Cells 20 and 21)	Treatments 5/12b Border (Cells 5 and 19b)	Treatments 12A/12b Border (Cells 19a and 19b)	
• 3 jack pine (53, 54, 56) • 2 Spruce (57, 55) • 2 Aspen (52, 58)	• 4 jack pine (2, 3, 8, 9) • 2 Spruce (6, 7) • 3 Aspen (1, 4, 5)	• 1 Aspen (68)	

[1]Numbers in brackets are corresponding tree numbers assigned during investigation.

Following soil excavation, the soil profile directly below individual trees was cleaned with hand tools to expose roots for a minimum of 50 cm on either side of the base of the tree and to various depths depending on the treatment and soil materials. Photographs of the roots for each tree were obtained from multiple angles for future reference. Tree locations were then geo-referenced and above-ground tree data was recorded. Observational data collected at each individual tree varied somewhat based on rooting patterns and distribution; however, a list of tree, soil, and root parameters assessed at each tree is provided in Table 2.3.2. Definitions for key root parameters relevant to this project are provided in Table 2.3.3. Detailed field methodology and an example data sheet is provided in Appendix A.

Table 2.3.2. Tree, soil, and root parameters measured in the ASCS root evaluation study.

General Site and Tree Parameters	Soil/Profile Parameters	Root Parameters
• Treatment • GPS Location • Tree Species • DBH • Basal diameter • Tree height • Surface roots • Tree proximity within a cell	• Soil material type and depths • Soil capping thickness depth • Moisture anomalies • Total depth of pit/trench • Anomalies (oil sand materials, etc.)	• Number of primary roots at the base of the tree • Direction of growth of horizontal roots • Orientation • Root distribution around the tree • Abundance and size of primary and secondary roots • Maximum observed root length • Diameter of exposed root at tree and at the end; average depth of exposed root • % roots within soil material • Maximum rooting depth • Presence/absence of tap root • Effective rooting depth

Table 2.3.3. Definitions of key root system parameters within the context of this project and justification for measurement (modified from Atkinson, 2000).

Root Parameter	Definition
Primary Roots (1°)	The main roots that emerge from stem tissue and so includes both seedling (tap, radical seminal) roots and adventitious (nodal) roots
Secondary Roots (2°)	Roots emerging from a primary root
Tertiary Roots (3°)	A root emerging from secondary roots and bearing quaternary roots (4°) which may bear quinary roots (5°)
Root Number	Total number of individual 1° roots
Root Distribution	Relative pattern of soil exploitation strategy around the tree
Primary direction of growth of horizontal roots	Relative pattern of soil exploitation in any given direction.
Root orientation	Primary direction root is growing within the soil: horizontal, oblique, vertical
Root Size and abundance	Average number and size of roots within a square decimeter (10 x10 cm) according to the table provided in Appendix A.
Maximum observed root length	Measure length of root from base of tree to as near to the root end as possible
Maximum observed rooting depth	The depth of the deepest root found on a plant root system. Maximum rooting depth (MRD) is very difficult to define in the field. For the purposes of this evaluation, observed MRD was only recorded for roots growing w/in 1 m of the base of the tree.
Effective rooting depth	A semi-quantitative estimate of the use of the depth of soil available to the plant. The depth within which 80% of roots are found. For the purposes of this evaluation, effective rooting depth was recorded for roots growing within 1 m of the base of the tree and was much more difficult to estimate for trees growing on borders.
Above ground tree height/ **max** root depth ratio	Tree height (m) divided by the maximum observed root depth (MRD) (m); a height to MRD ratio of 1 indicates equal above and below ground height/depth; a height to MRD ratio of less than 1 indicates deeper roots compared to the associated above ground tree height; a height to MRD ratio greater than 1 indicates the tree height is greater than the MRD.
Above ground tree height/ **effective** root depth ratio	Tree height (m) divided by the effective observed root depth (ERD) (m).

Figure 2.3.1. Syncrude Aurora Soil Capping Study root investigation locations.

3.0 RESULTS

The measured tree, root, and soil characteristics for select borders and select treatments are described in Section 3.0. Results include parameters such as tree height, soil horizons and depths, root depth, root distribution around individual trees, the distribution of roots at soil horizon interfaces, and the ability of roots to penetrate overburden material. For further information, refer to the data tables in Appendix B.

3.1 SELECT BORDERS BETWEEN TREATMENTS

3.1.1 **Treatments 2 (10 cm LFH/140 cm Subsoil (>1 m)) and 5 (30 cm Peat) border**

- Photos are provided; see Figure 3.1.1 to 3.1.9.
- All tree species along the border were considerably larger than those within Treatment 5 and similar in size to trees within Treatment 2.
- Overburden consistency was variable when within the rooting zone (harder in some sampling locations, more friable in others).
- Roots generally avoided the overburden (Figure 3.1.10; Table B.1.1). When roots did penetrate the overburden it was only for 1 to 2 cm, and then they were observed to angle back towards the overlying material and grow along the transition.
- Majority of primary roots were horizontal and grew along interfaces between materials in north and south directions (*i.e.*, unevenly distributed around tree and directly into treatments).
- Tree roots at the border showed no obvious preference between Treatment 5 and Treatment 2 (*i.e.*, equal number of roots growing south towards Treatment 5 and north towards Treatment 2 for all species, with the exception of Spruce (59) which was growing within the peat directly on the border and had the majority of its roots growing in the direction of Treatment 2.
- Observed root length was generally longer for roots growing into Treatment 5 and east-west along the border than for roots growing into Treatment 2.
- More secondary branching in Treatment 2 (LFH) than Treatment 5 (Peat).

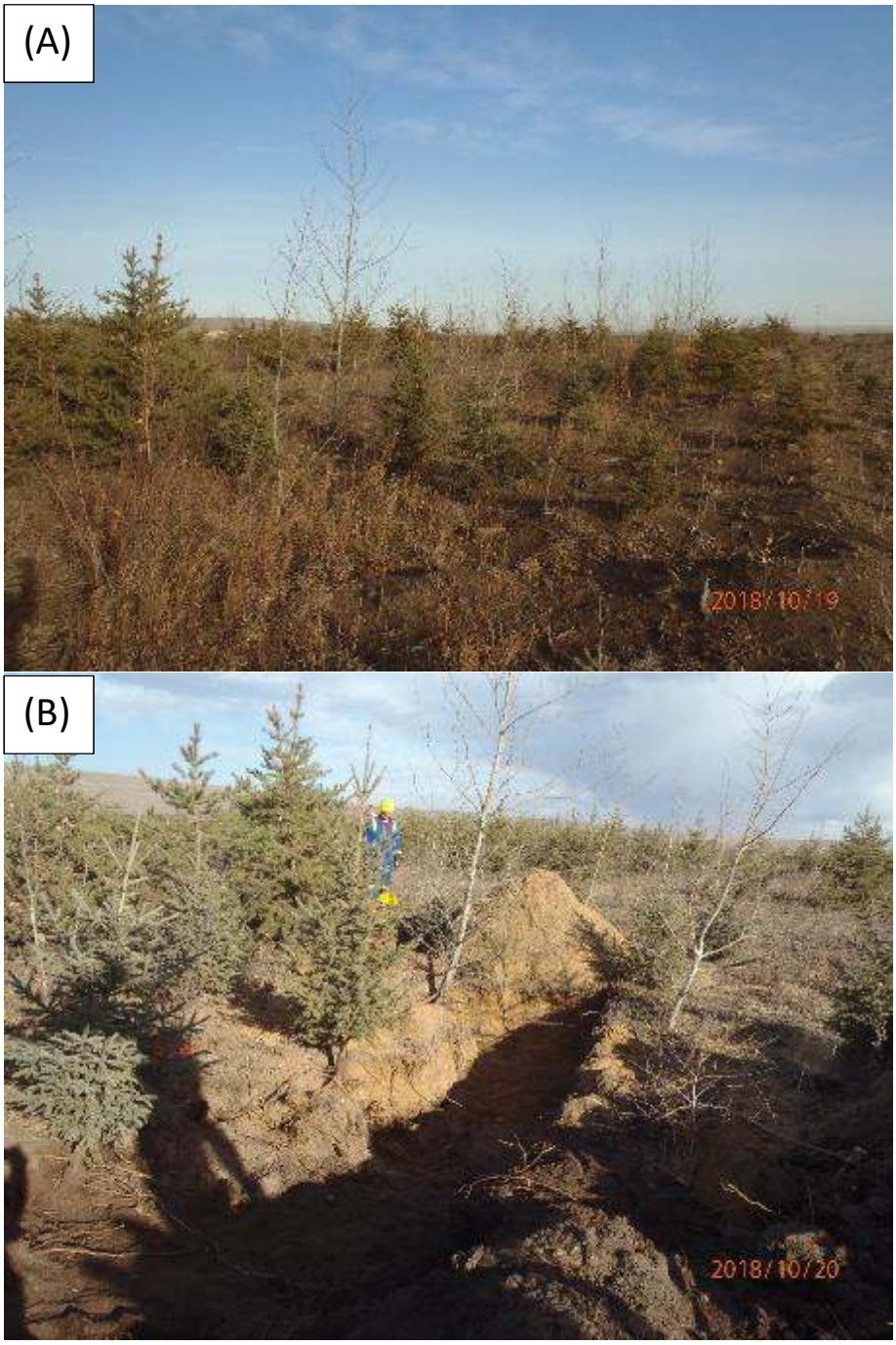

Figure 3.1.1. Treatments 2 and 5 Border inspection location area; both (A) and (B) show general site photos.

(A)

(B)

Figure 3.1.2. Treatment 2 and 5 Border inspection area; both (A) and (B) show Tree 59 (spruce).

Figure 3.1.3. Treatment 2 and 5 inspection location (Tree 60 (spruce)).

Figure 3.1.4. Treatment 2 and 5 inspection area (Tree 60 (spruce)).

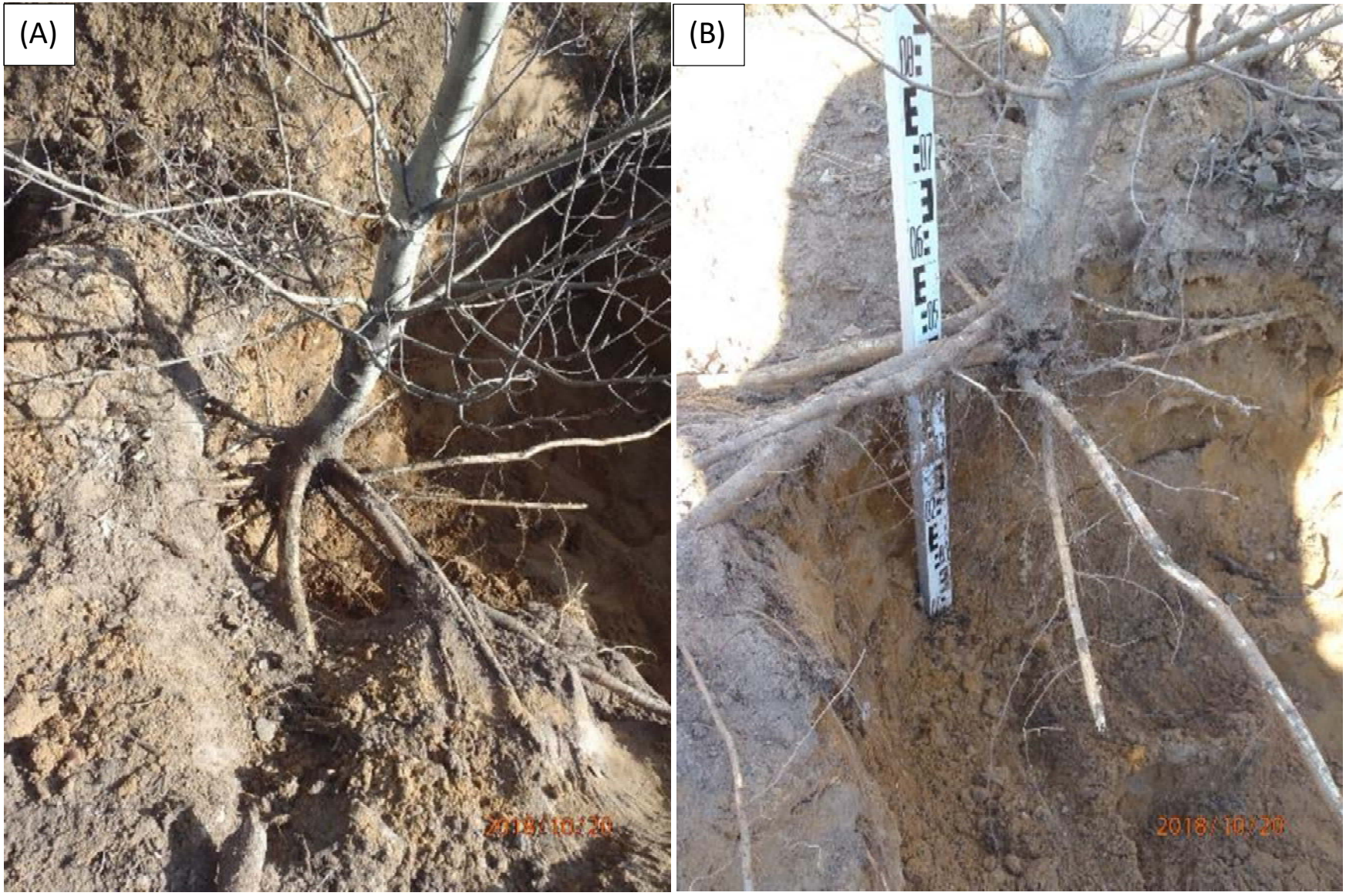

Figure 3.1.5. Treatment 2 and 5 Border inspection area; both (A) and (B) show Tree 61 (aspen).

Figure 3.1.6. Treatment 2 and 5 Border inspection location area (Tree 61 (aspen)).

Figure 3.1.7. Treatment 2 and 5 Border inspection location area (Tree 62 (spruce)).

Figure 3.1.8. Treatment 2 and 5 Border inspection location area (Tree 62 (spruce)).

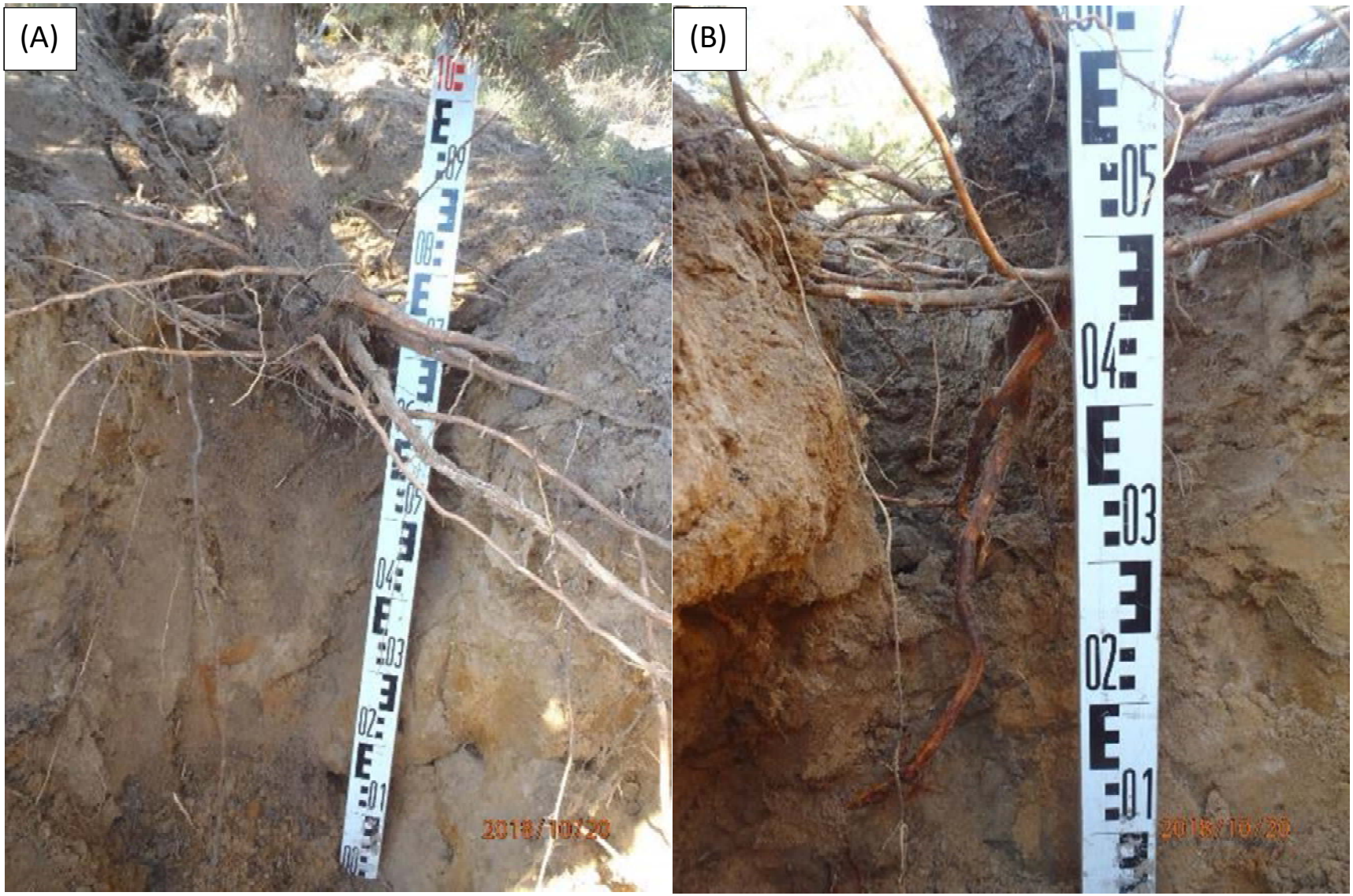

Figure 3.1.9. Treatment 2 and 5 Border inspection location area; both (A) and (B) show Tree 63 (pine).

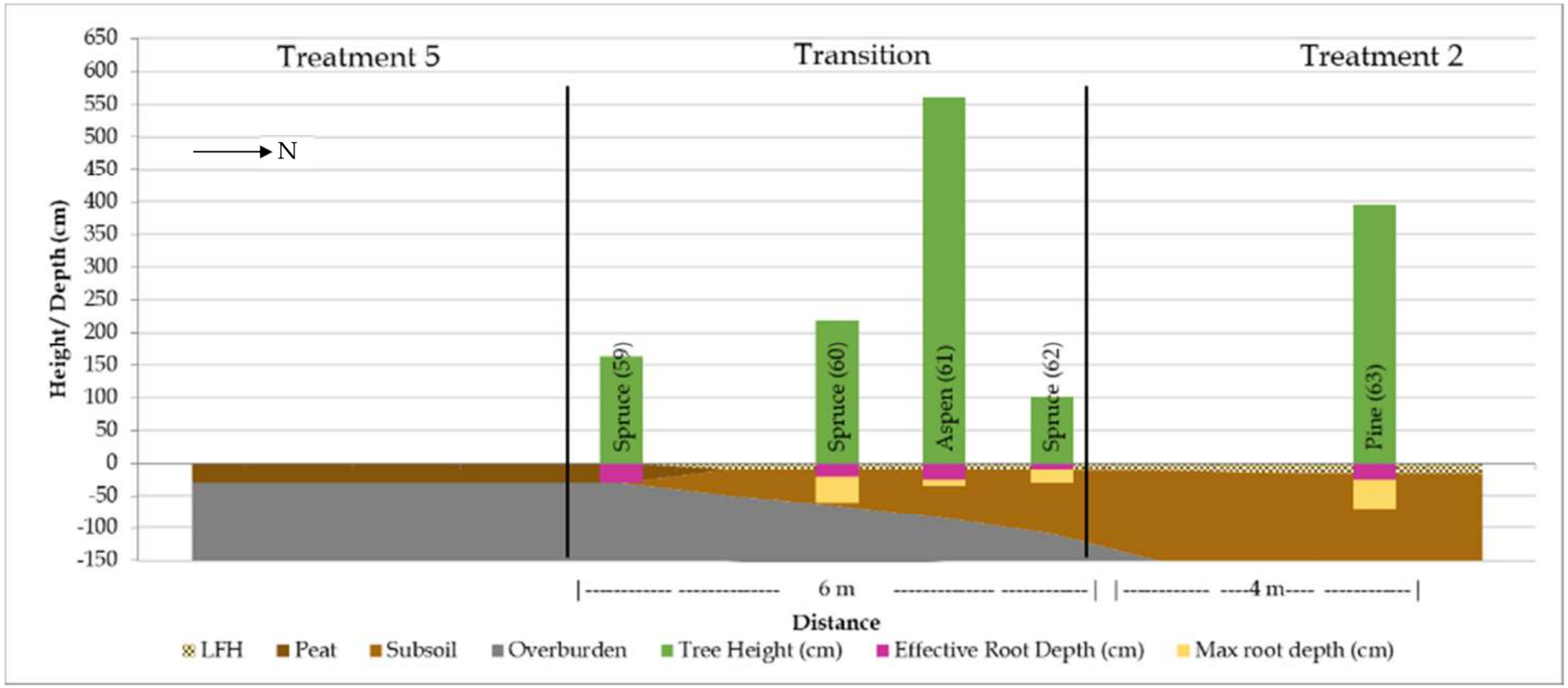

Figure 3.1.10. Tree height, maximum and effective root depth for the border between Treatment 5 (30 cm peat) and Treatment 2 (10 cm LFH/140 cm Subsoil (>1 m)).
Bars represent individual trees measured on site with the tree number displayed in parentheses within the bar. Data used to develop this figure can be found in Appendix B.

3.1.2 **Treatments 1 (30 cm Peat/120 m Subsoil (>1m)) and 3 (10 cm Peat/140 cm Subsoil (>1m)) border**

- Photos are provided; see Figure 3.1.11 to 3.1.13.
- Only spruce were evaluated (Figure 3.1.14; Table B.1.2).
- No trenches were dug across the Treatment 1/3 border. Spruce trees with exceptional leader growth were observed on the western side of Cells 8 and 9, between Treatment 1 and 3, and it was determined that we would investigate individual trees by digging test pits. Spruce trees along the border and within Treatment 1 were also investigated by digging test pits.
- The two spruce evaluated in Treatment 3 had exceptional leaders (>30 cm) and also demonstrated deeper maximum rooting depths.
- The two spruce evaluated on the border between Treatments 3 and 1 (22 and 28 cm of peat) had deeper effective rooting depths and shallower maximum rooting depths than the spruce growing completely within Treatment 3 (10 and 12 cm of peat).
- The number of primary roots was similar amongst all 4 trees, however the spruce growing in Treatment 3 developed coarse roots with small and medium secondary roots within 1 meter of the tree, while the spruce growing on the border only had medium primary roots with fewer secondary roots.
- Root orientation was vertical within the subsoil below the peat in Treatment 3 whereas root orientation on the border and Treatment 1 (deeper peat) was primarily horizontal.

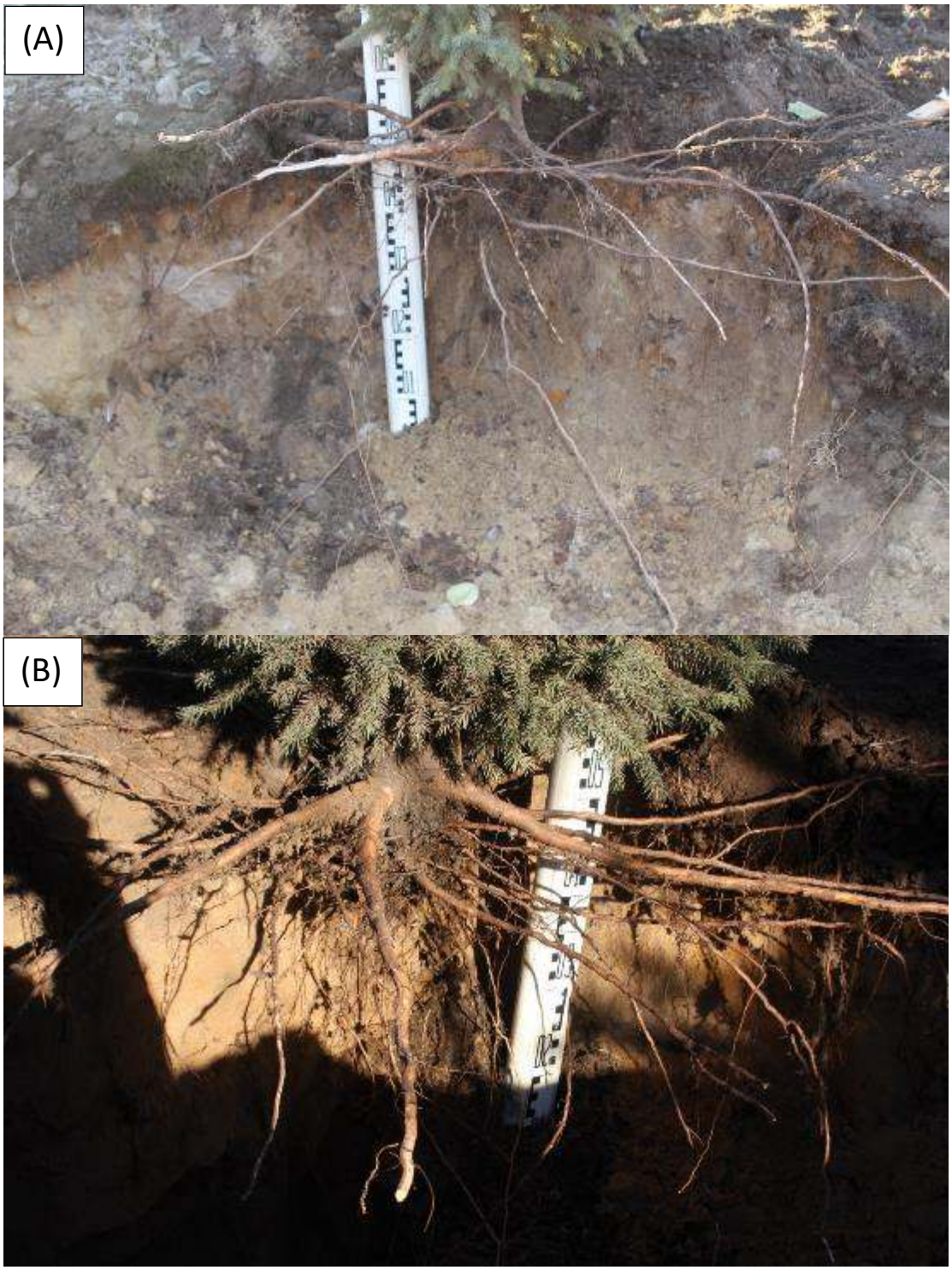

Figure 3.1.11. Treatment 3 and 1 Border inspection location area; (A) Tree 64 (spruce) and (B) Tree 65 (spruce).

Figure 3.1.12. Treatment 3 and 1 Border inspection location area (Tree 66 (spruce)).

Figure 3.1.13. Treatment 3 and 1 Border inspection location area; both (A) and (B) show Tree 67 (spruce).

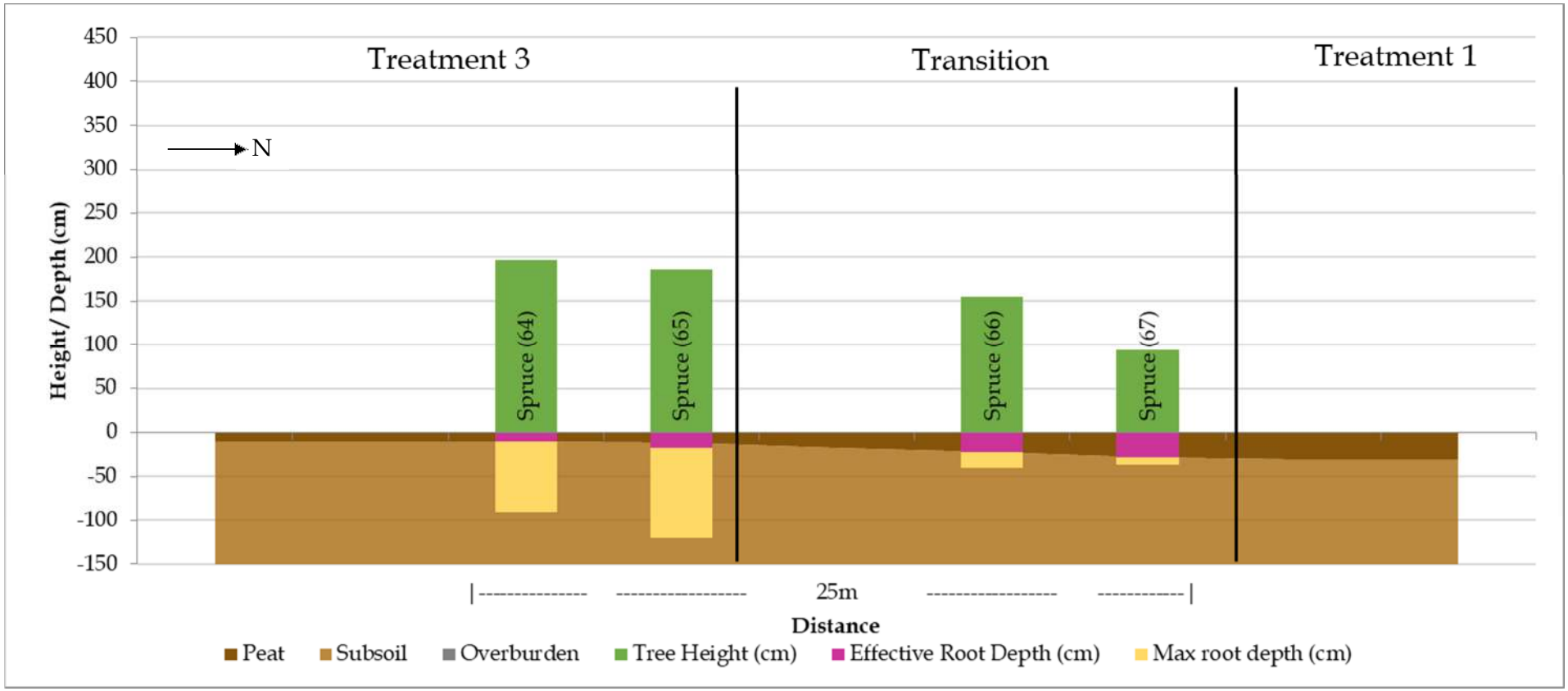

Figure 3.1.14. Tree height, maximum and effective root depth for the border between Treatment 1 (30 cm Peat/120 cm Subsoil (>1m)) and Treatment 3 (10 cm Peat/140 cm Subsoil (>1m)).

Bars represent individual trees measured on site with the tree number displayed in parentheses within the bar. Data used to develop this figure can be found in Appendix B.

3.1.3 **Treatments 3 (10 cm Peat/140 cm Subsoil (>1m)) and 12b (150 cm Subsoil (>1m)) border**

- Photos are provided; see Figure 3.1.15 to 3.1.19.
- A trench was dug along the west side of cells 13 and 36b along the border between Treatments 3 and 12b (Figure 3.1.20; Table B.1.3).
- There was not a large discrepancy in tree height between trees growing within Treatment 3 and on the border to Treatment 12b (no trees were measured growing directly in Treatment 12b).
- Roots were generally evenly distributed around the tree, for all three species evaluated; no clear growth preference towards either treatment.
- Horizontally spreading roots dominated the root systems for all species evaluated at this border.
- Maximum vertical root growth was observed for the Pine (#13) at 150 cm, however spruce (#10) and aspen (#12 and #14) were observed at 115 cm and 60 cm respectively.
- Maximum observed root length was greater for roots exposed growing into Treatment 3 than roots growing into Treatment 12b for 3 of the 4 coniferous trees evaluated.
- Aspen had a low volume (few to plentiful) of fine and small primary and secondary roots at the base of the tree and along the length of the exposed roots.

Figure 3.1.15. Treatment 3 and 12b Border inspection location area (Tree 10 (spruce)).

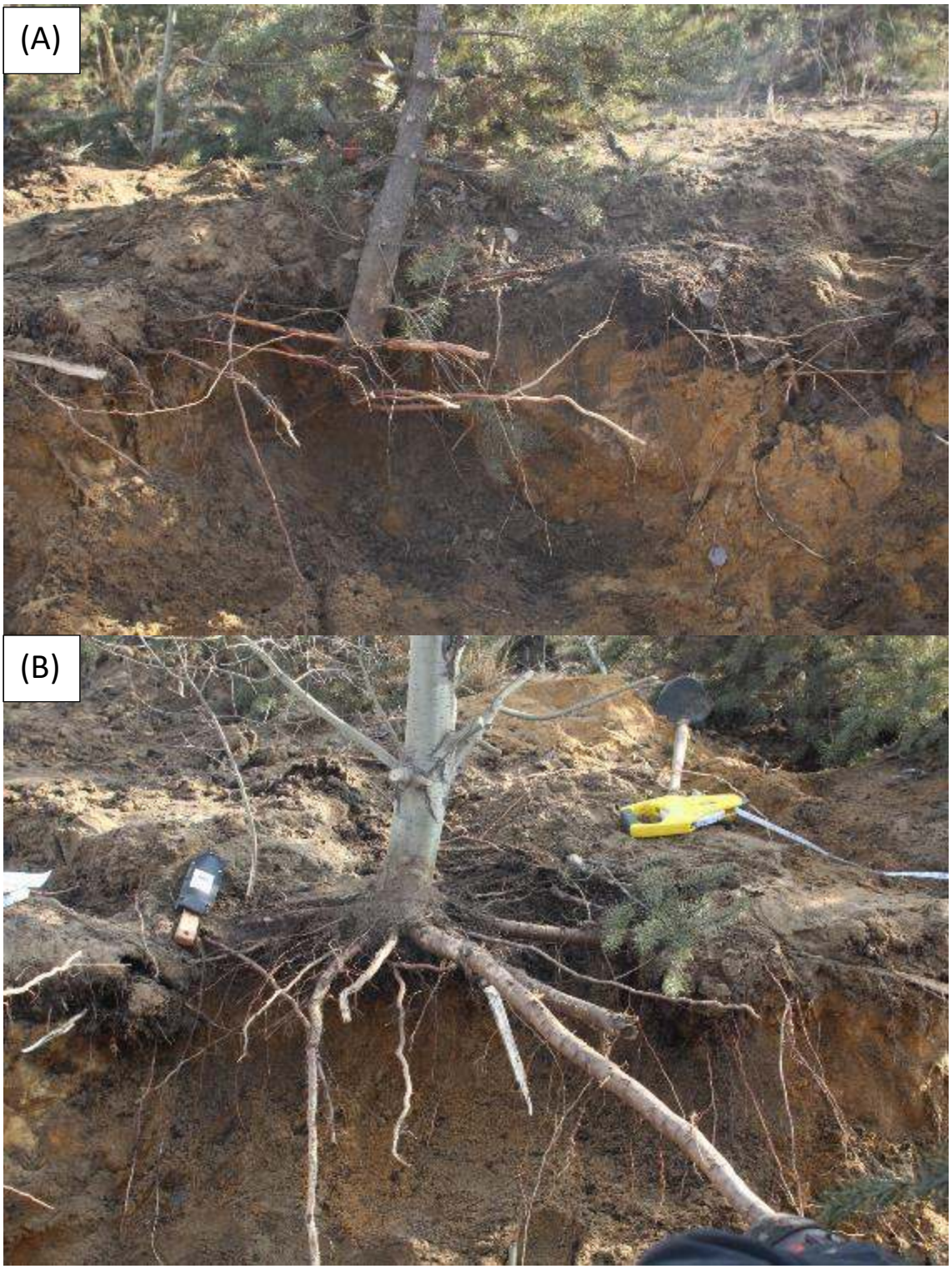

Figure 3.1.16. Treatment 3 and 12b Border inspection location area; (A) Tree 11 (pine) and (B) Tree 12 (aspen).

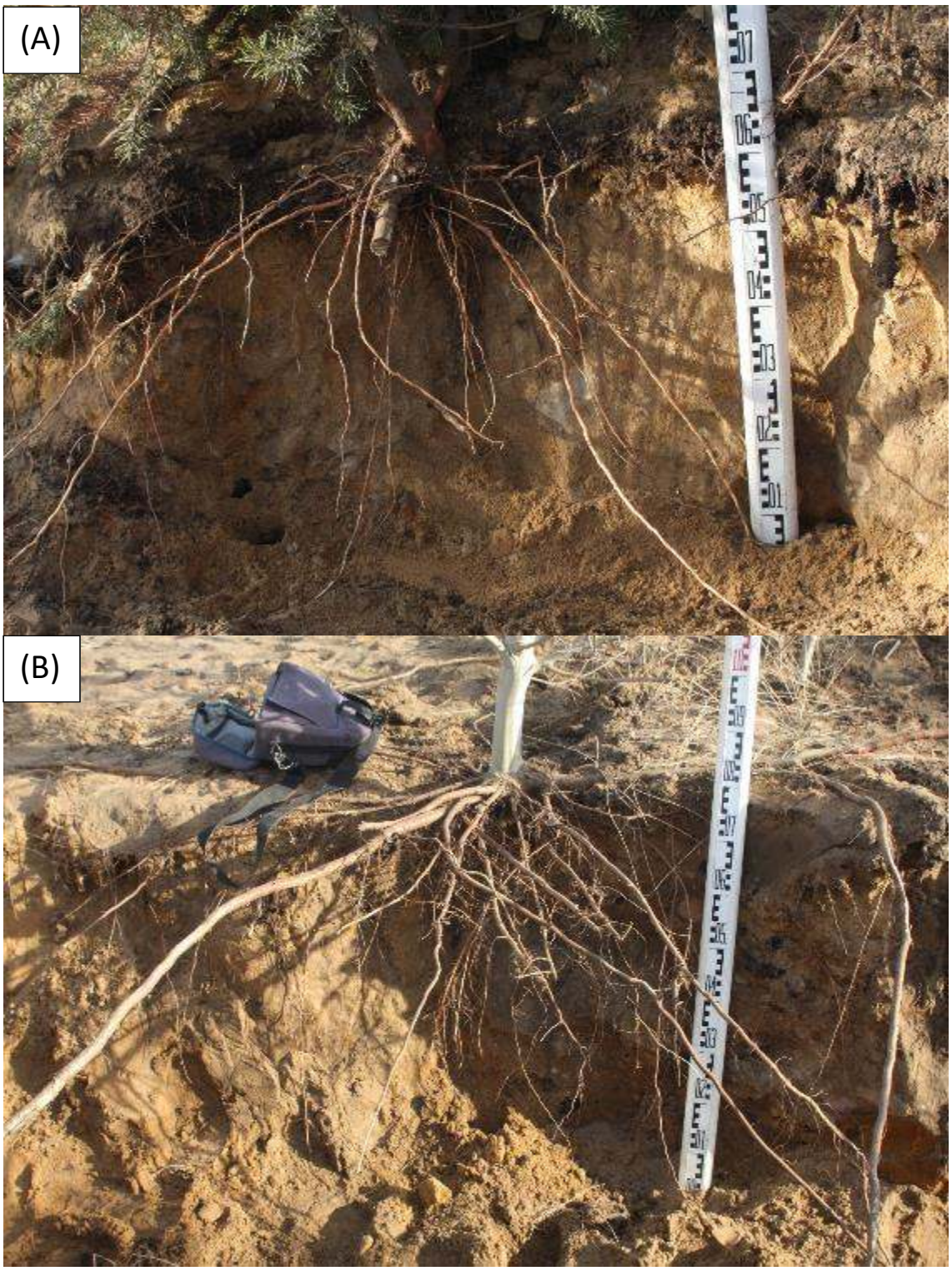

Figure 3.1.17. Treatment 3 and 12b Border inspection location area; (A) Tree 13 (pine) and (B) Tree 14 (aspen).

Figure 3.1.18. Treatment 3 and 12b Border inspection location area (Tree 15 (spruce)).

Figure 3.1.19. Treatment 3 and 12b Border inspection location area (Tree 15 (spruce)).

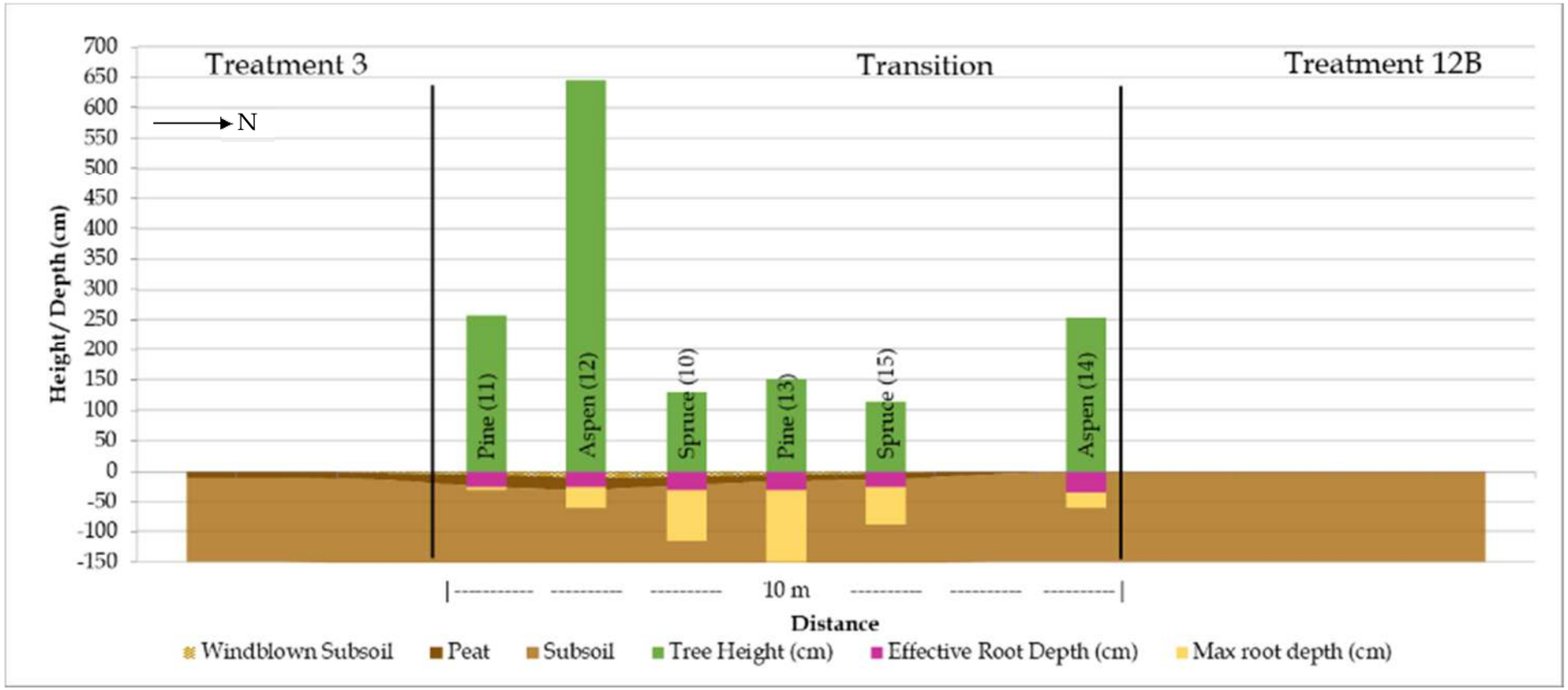

Figure 3.1.20. Tree height, maximum and effective root depth for the border between Treatment 3 (10 cm Peat/140 cm Subsoil (>1m)) and Treatment 12b (150 cm Subsoil (>1m)).
Bars represent individual trees measured on site with the tree number displayed in parentheses within the bar. Data used to develop this figure can be found in Appendix B.

3.1.4 **Treatments 5 (30 cm Peat) and 6 (30 cm Peat/30 cm Bm/90 cm Subsoil (>1m)) border**

- Photos are provided; see Figure 3.1.21 to 3.1.33.
- Two trenches were dug north/south across the border between Treatments 5 and 6. Because not enough aspen were found along the trench, a separate pit was dug to capture an additional tree.
- Trees growing within Treatment 6 were comparable in size to the trees growing directly on the border between Treatments 5/6. However, above-ground tree growth within Treatment 5 were noticeably poorer (Figure 3.1.34; Table B.1.4).
- The interface between peat, Bm, subsoil, and overburden influenced rooting patterns for all three species evaluated.
    - Pine roots were observed frequently along the Bm/subsoil interface, however few roots were observed within the subsoil.
    - No roots were observed within the overburden on the border between Treatment 5 and 6. Roots that were observed to penetrate the overburden were also observed to re-surface into the overlying material within centimeters.
- Pine growing within Treatment 6, but near the border, had 45% of roots growing vertically into the Bm horizon and 45% growing towards the Treatment 5. Few roots grew south, further into Treatment 6.
- Aspen roots extended into Treatment 6 and along the border, however few extended north into Treatment 5.

(A)

(B)

Figure 3.1.21. Treatments 5 and 6 Border inspection location area; (A) trench photo and (B) Treatment 6 soil photo.

Figure 3.1.22. Treatments 5 and 6 Border inspection location area trench photo.

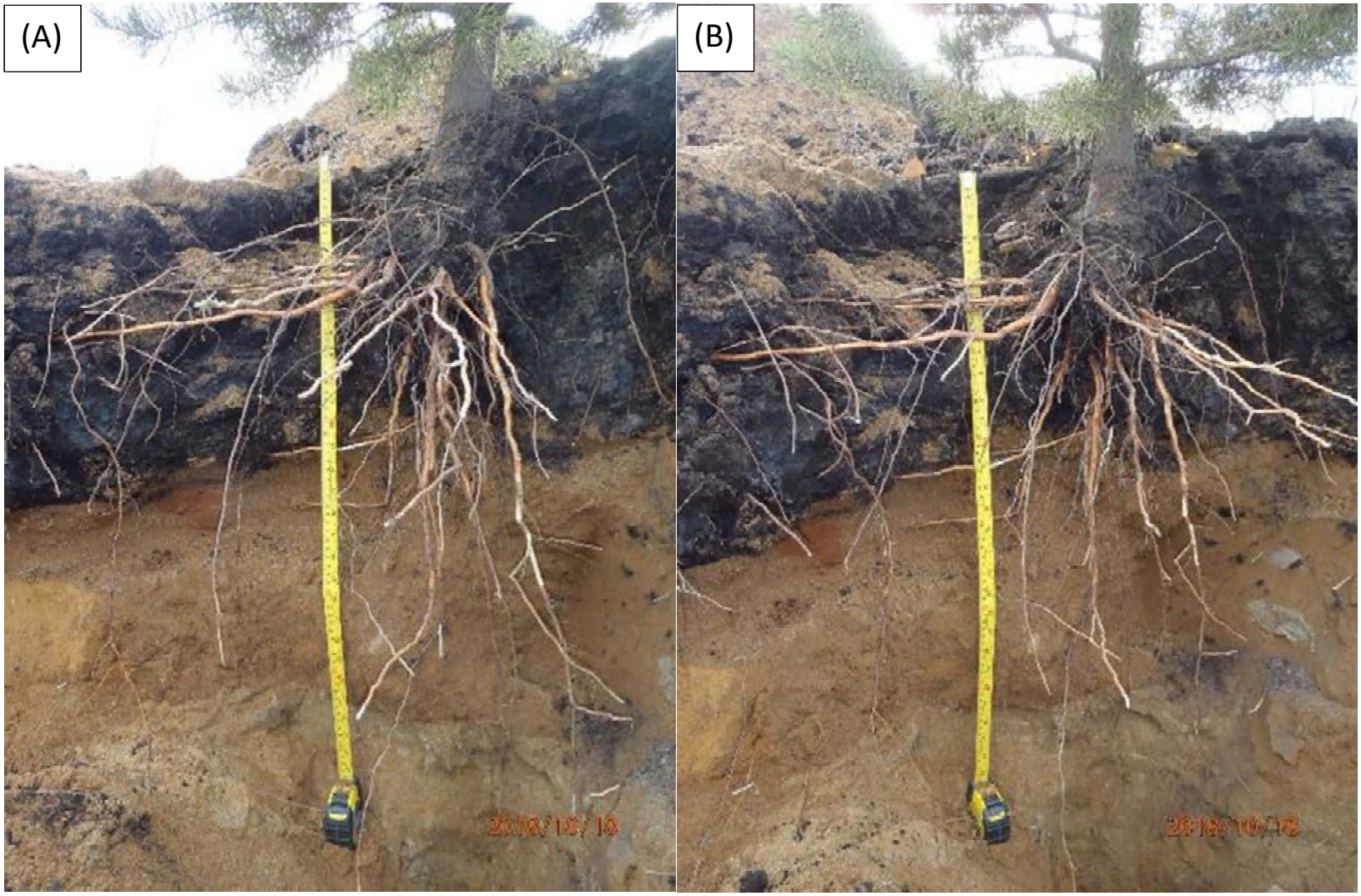

Figure 3.1.23. Treatments 5 and 6 Border inspection location area; both (A) and (B) show Tree 27 (pine).

Figure 3.1.24. Treatments 5 and 6 Border inspection location area (Tree 28 (spruce)).

Figure 3.1.25. Treatments 5 and 6 Border inspection location area (Tree 28 (spruce)).

Figure 3.1.26. Treatments 5 and 6 Border inspection location area (Tree 29 (aspen)).

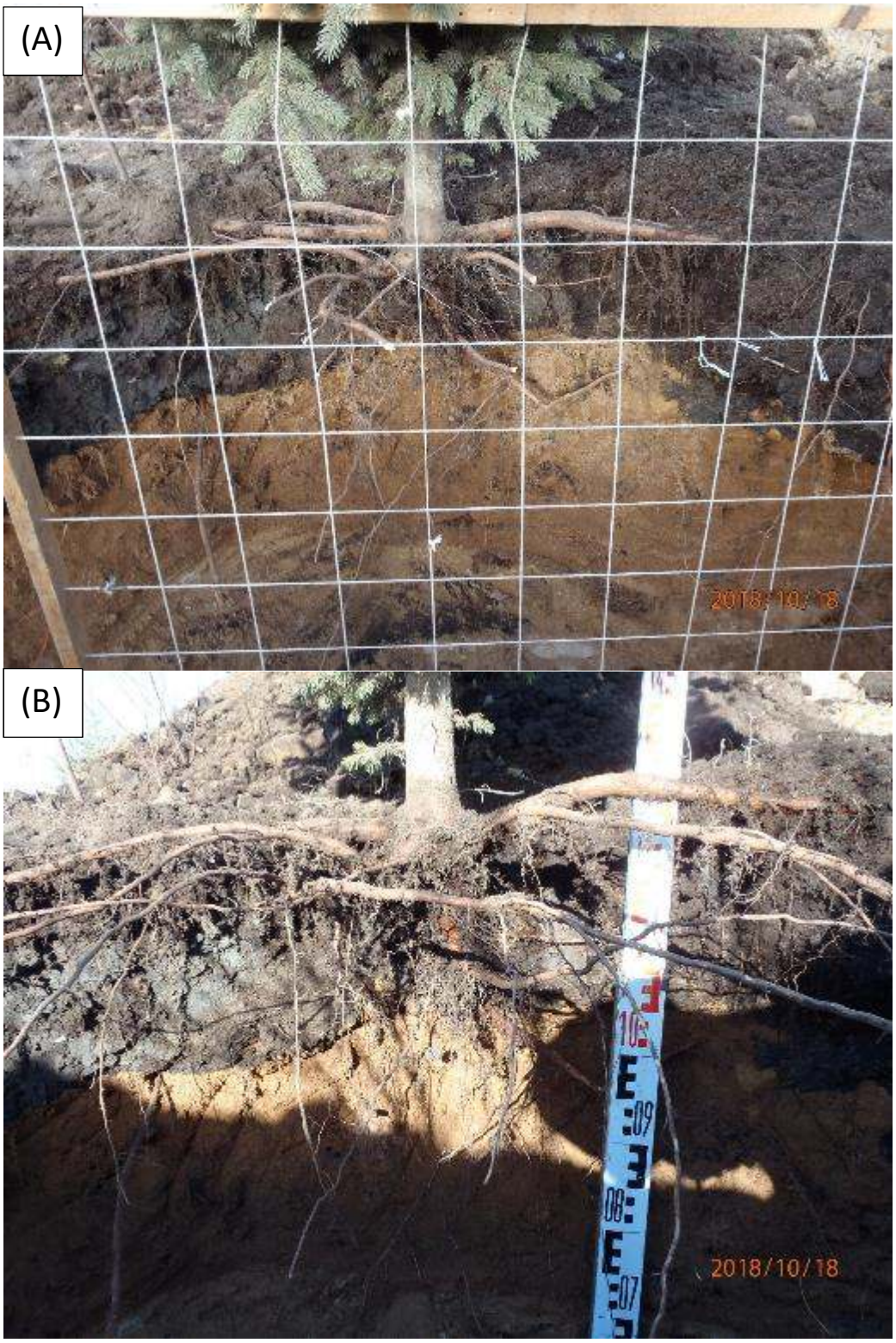

Figure 3.1.27. Treatments 5 and 6 Border inspection location area; both (A) and (B) show Tree 30 (spruce).

(A)

(B)

Figure 3.1.28. Treatments 5 and 6 Border inspection location area; both (A) and (B) show Tree 31 (aspen).

Figure 3.1.29. Treatments 5 and 6 Border inspection location area; exposing the roots of Tree 31 (aspen).

Figure 3.1.30. Treatments 5 and 6 Border inspection location area; exposing the roots of Tree 31 (aspen).

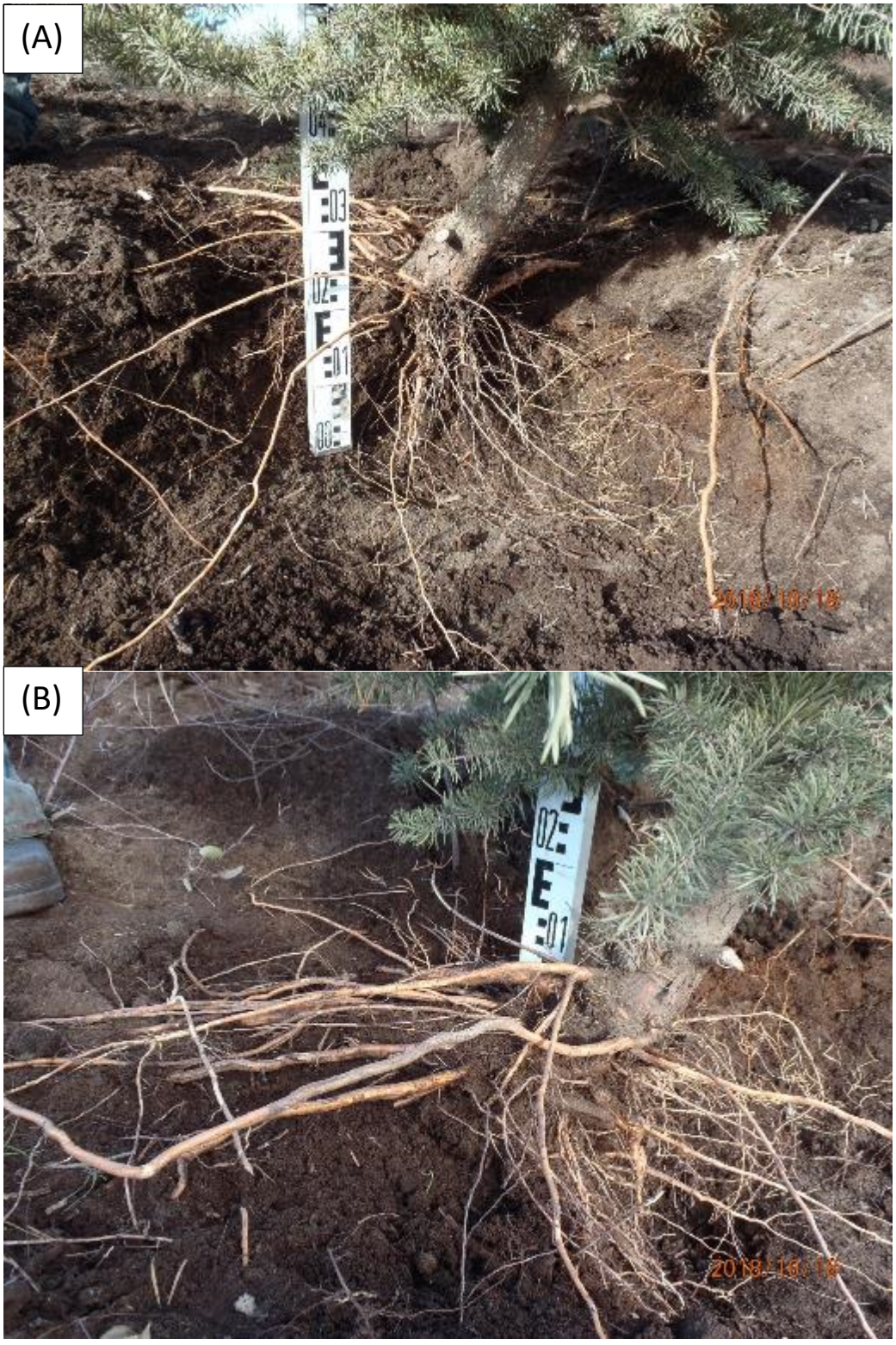

Figure 3.1.31. Treatments 5 and 6 Border inspection location area; both (A) and (B) show Tree 32 (pine).

Figure 3.1.32. Treatments 5 and 6 Border inspection location area (Tree 32 (pine)).

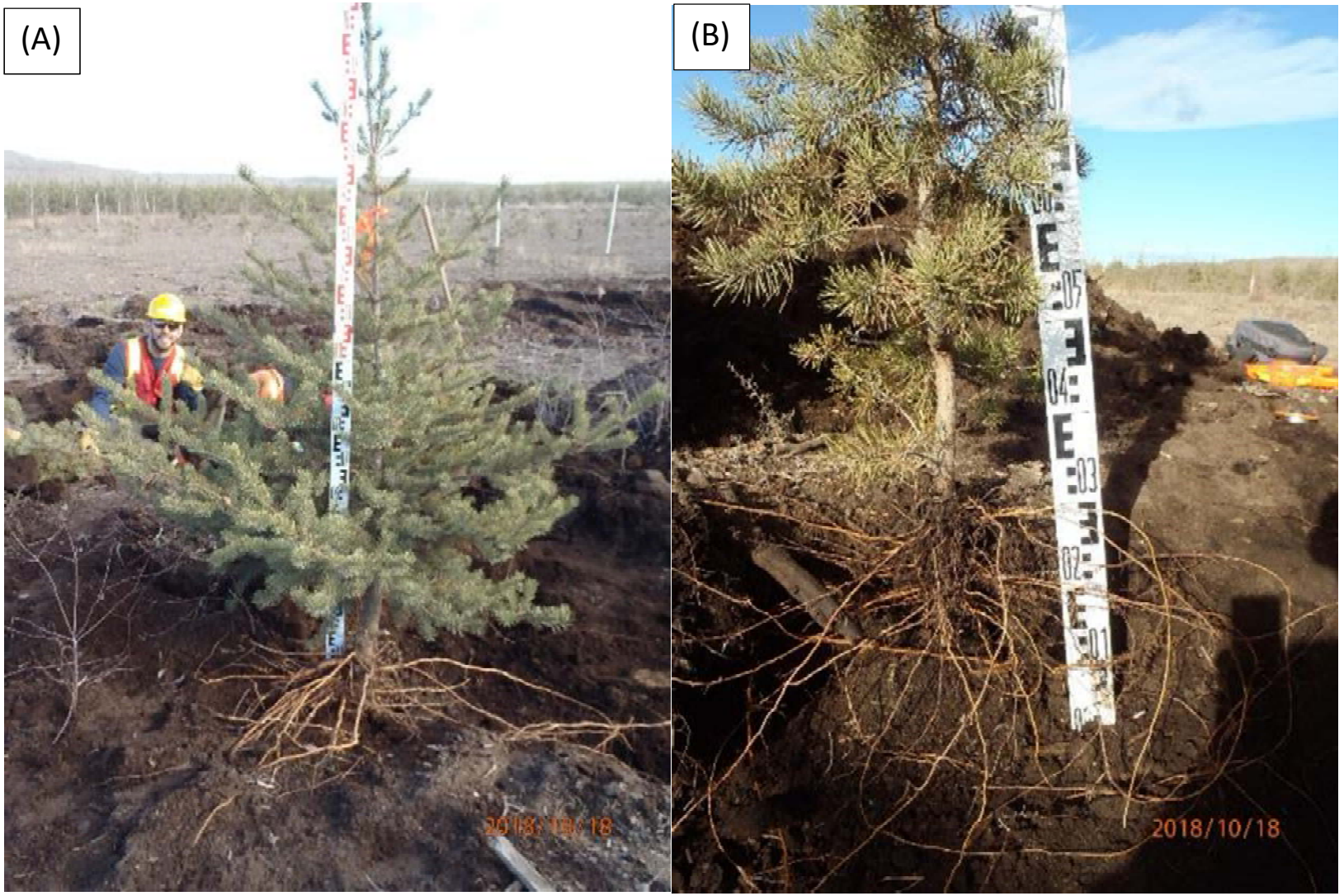

Figure 3.1.33. Treatments 5 and 6 Border inspection location area; (A) Tree 32 (pine) and (B) Tree 33 (pine).

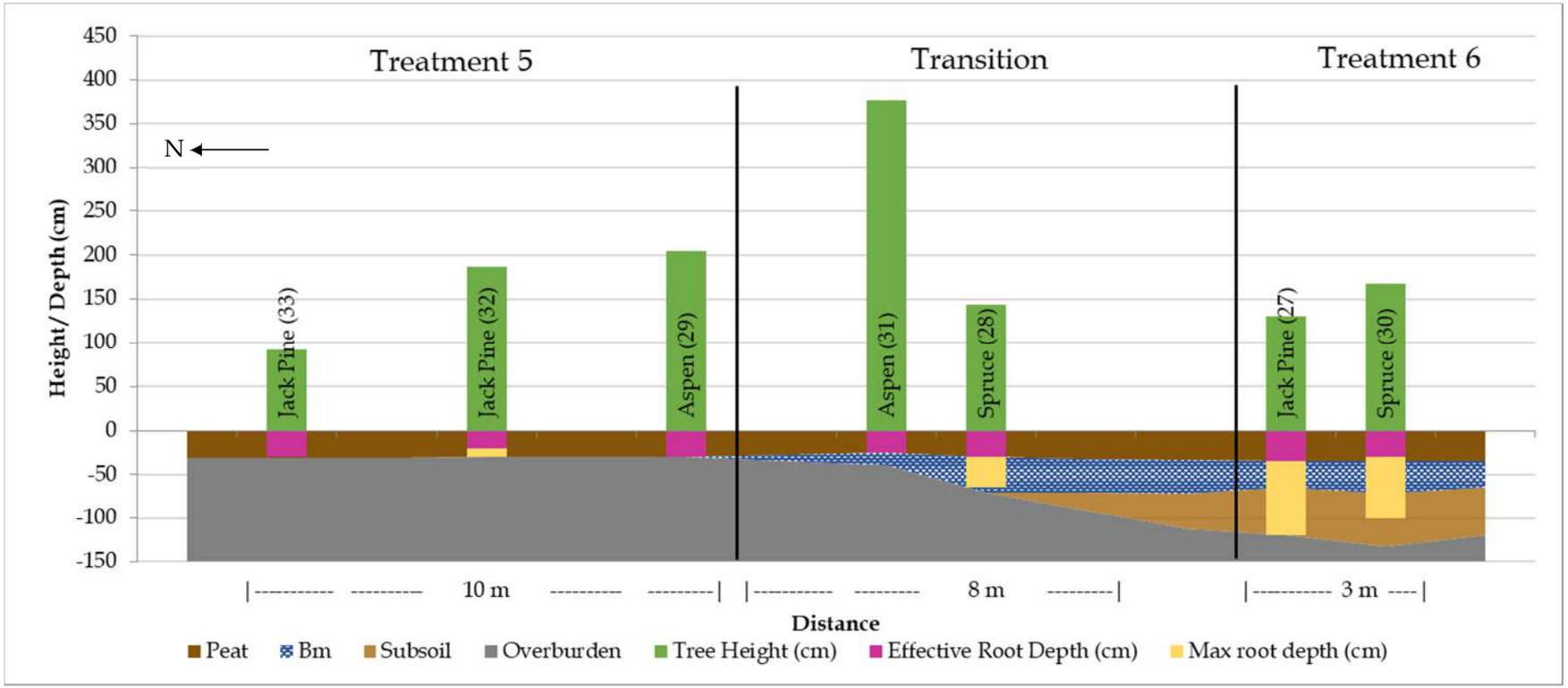

Figure 3.1.34. Tree height, maximum and effective root depth for the border between Treatment 5 (30 cm Peat) and Treatment 6 (30 cm Peat/30 cm Bm/90 cm Subsoil (>1m)).
Bars represent individual trees measured on site with the tree number displayed in parentheses within the bar. Data used to develop this figure can be found in Appendix B.

3.1.5 **Treatments 5 (30 cm Peat) and 9 (20 cm LFH/30 cm Bm/100 cm Subsoil (>1m)) border**

- Photos are provided; see Figure 3.1.35 to 3.1.43.
- Trees growing along the border and within Treatment 9 were of similar height, while trees growing in Treatment 5 were shorter in comparison. However, differences in tree heights between Treatments 5, and Treatment 9 and the border area, were not as obvious as with other borders (Figure 3.1.44; Table B.1.5).
- Roots generally avoided the overburden. When roots were observed to penetrate the overburden, it was only for 1 to 2 cm, and then they were observed to angle back towards the overlying material and grow along the transition within the overlying soil reclamation cover material.
- Horizontally spreading lateral roots dominated the root systems for all species evaluated in the border area.
- There were no major differences between maximum observed rooting depth and effective rooting depth for all three species evaluated.
- Aspen roots grew deeper within Treatment 9 than Treatment 5; within Treatment 5 roots stayed within approximately 15 cm of the surface; within Treatment 9 roots grew within the Bm and subsoil material to a depth of approximately 70 cm.
- Aspen and spruce roots preferentially grew in a north-south direction towards Treatment 5 and 9, respectively.
- Pine roots preferentially grew in a north-south direction towards Treatment 5 and 9, respectively, for 2 of the 3 trees evaluated.
- All three species roots transitioned between horizontal and oblique to grow along the interfaces between materials. Roots growing within Treatment 5 grew along the interface before transitioning to oblique and growing back towards the surface.
- Aspen had a high volume (plentiful to abundant) of fine and small secondary roots at the base of the tree and along the length of the exposed roots.
- Aspen (#52) suckered from root growing within peat treatment.

Figure 3.1.35. Treatments 5 and 9 Border inspection location area; general photo with Tree 56 (pine) in the foreground.

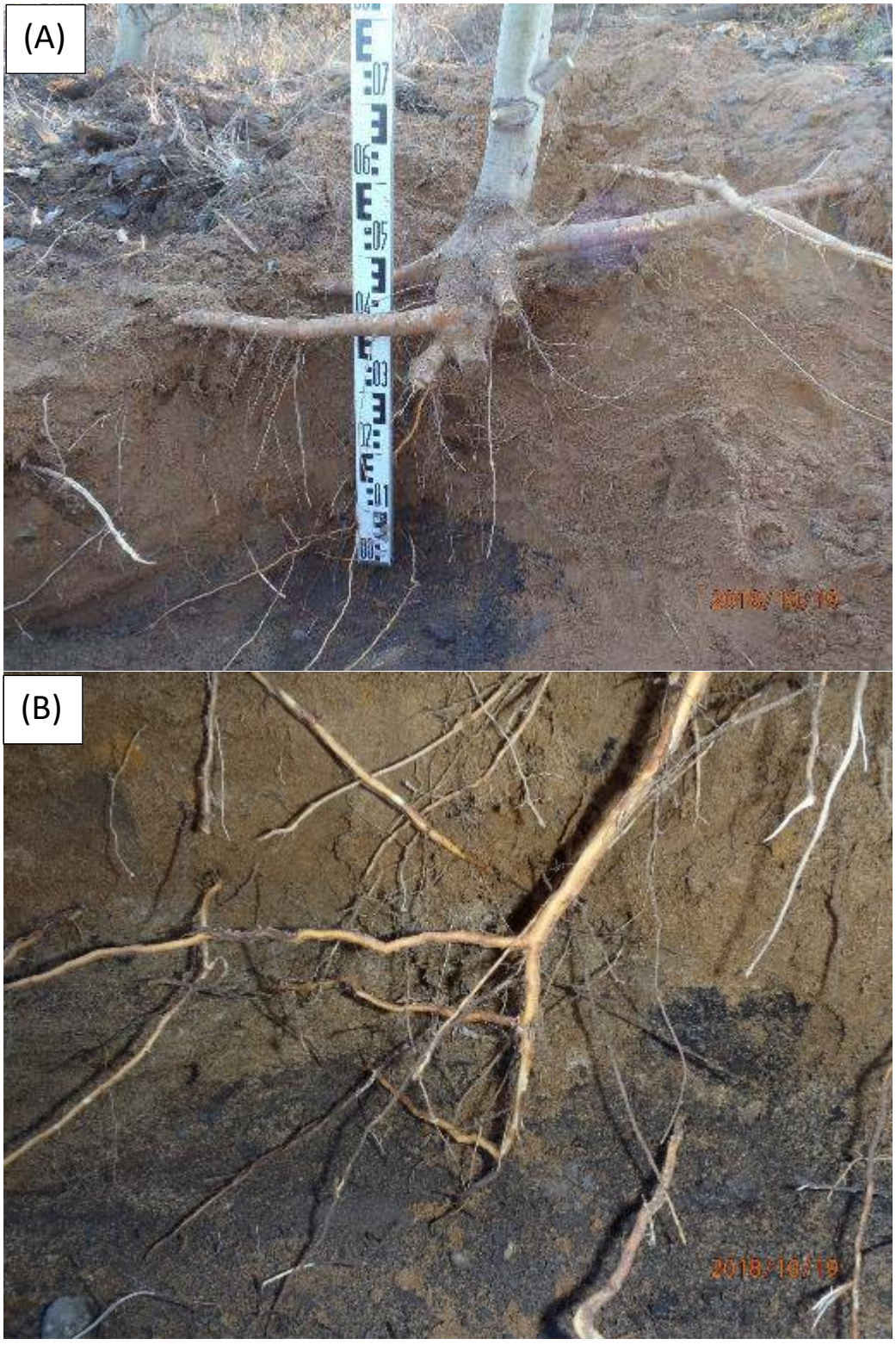

Figure 3.1.36. Treatments 5 and 9 Border inspection location area; both (A) and (B) show Tree 52 (aspen).

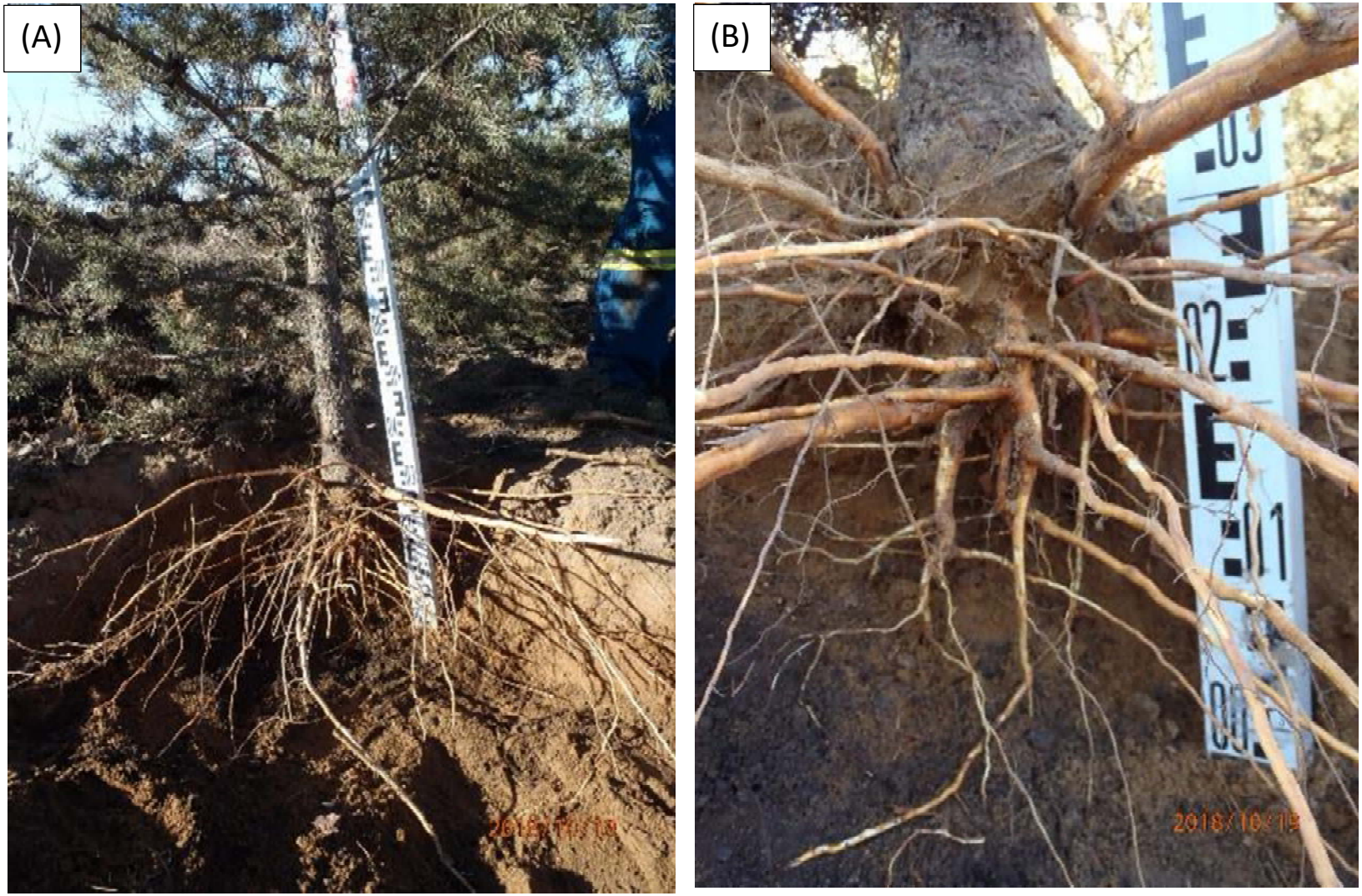

Figure 3.1.37. Treatments 5 and 9 Border inspection location area; both (A) and (B) show Tree 53 (pine).

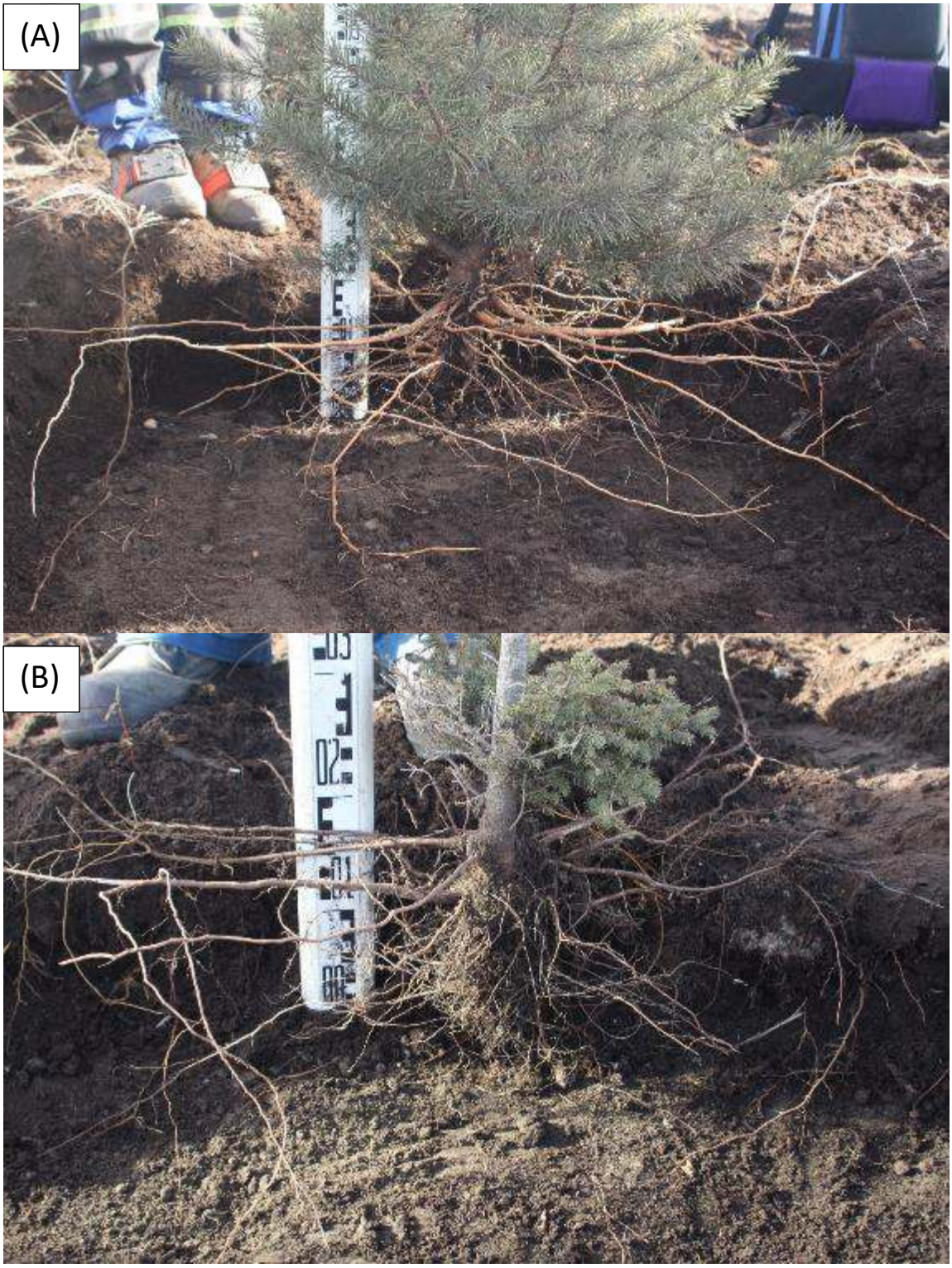

Figure 3.1.38. Treatments 5 and 9 Border inspection location area; (A) Tree 54 (pine) and (B) Tree 55 (spruce).

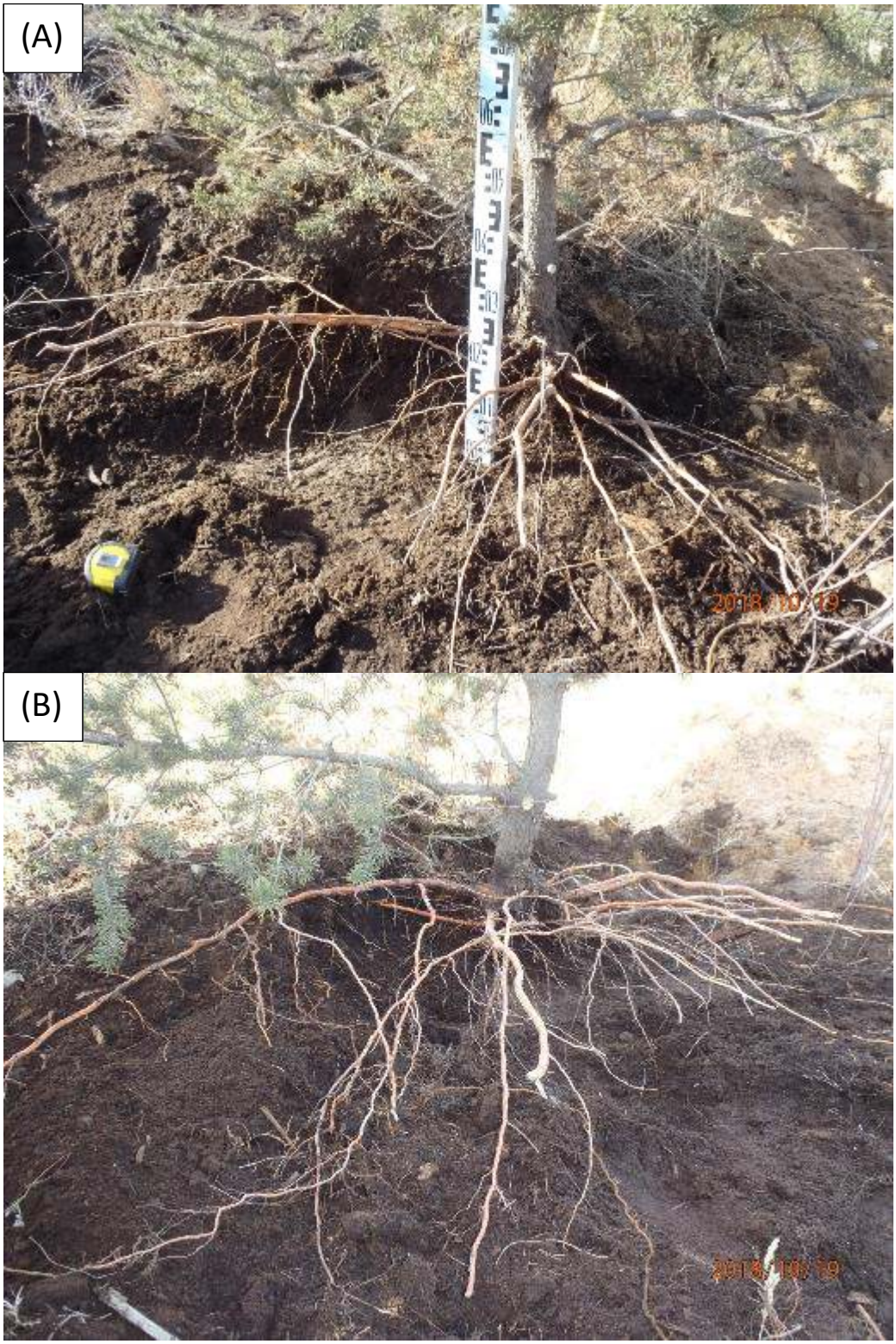

Figure 3.1.39. Treatments 5 and 9 Border inspection location area; both (A) and (B) show Tree 56 (pine).

Figure 3.1.40. Treatments 5 and 9 Border inspection location area (Tree 56 (pine)).

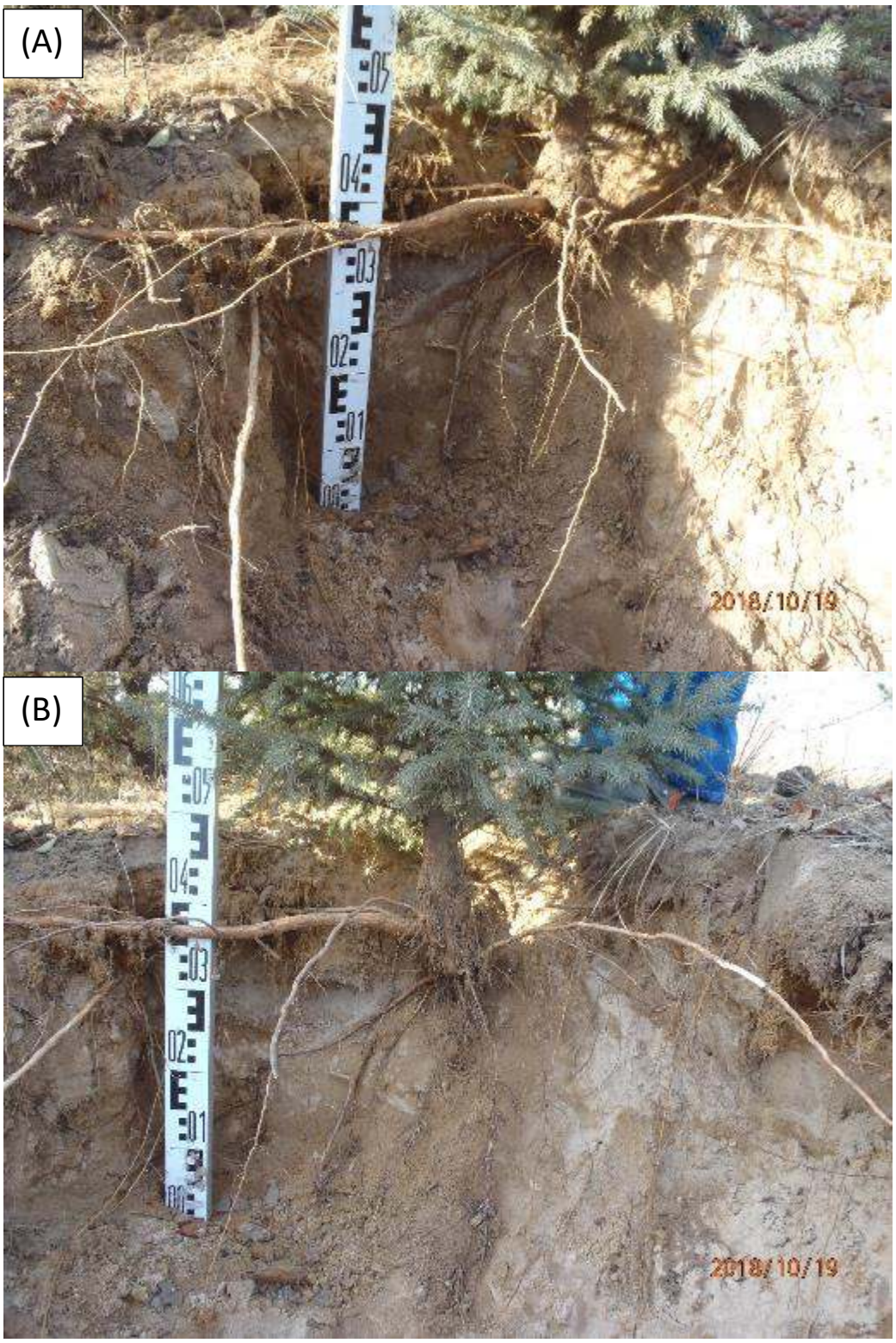

Figure 3.1.41. Treatments 5 and 9 Border inspection location area; both (A) and (B) show Tree 57 (spruce).

Figure 3.1.42. Treatments 5 and 9 Border inspection location area (Tree 57 (spruce)).

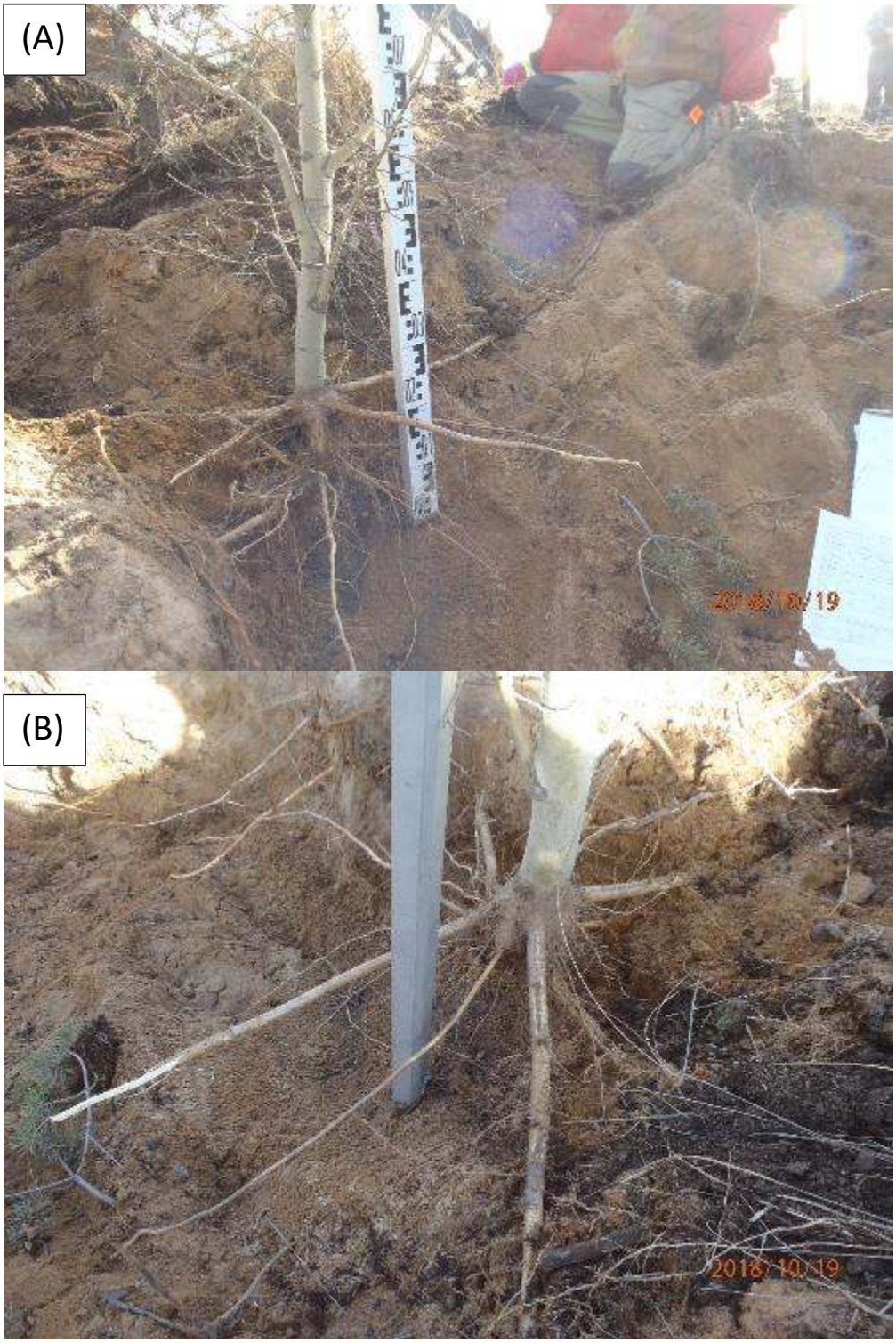

Figure 3.1.43. Treatments 5 and 9 Border inspection location area; both (A) and (B) show Tree 58 (aspen).

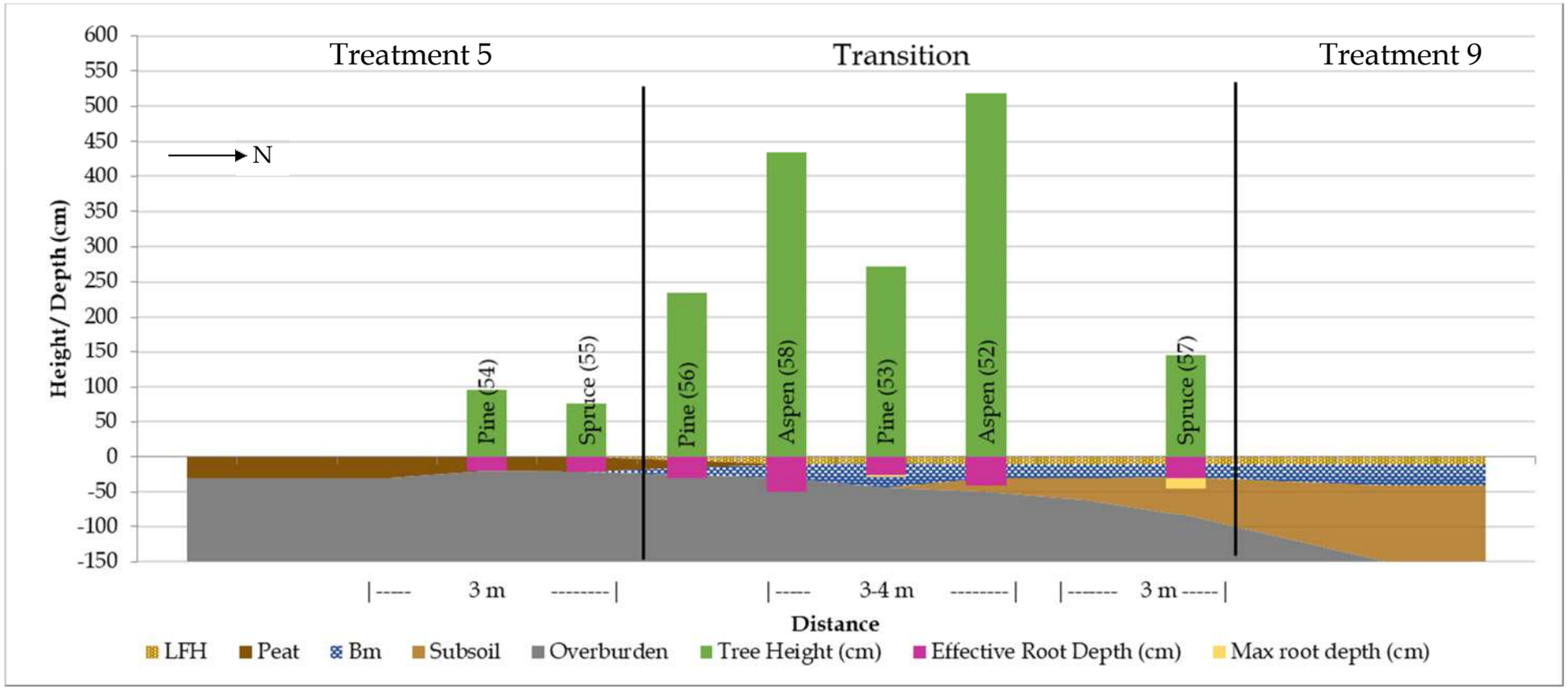

Figure 3.1.44. Tree height, maximum and effective root depth for the border between Treatment 5 (30 cm Peat) and Treatment 9 (20 cm LFH/30 cm Bm/100 cm Subsoil (>1m)).
Bars represent individual trees measured on site with the tree number displayed in parentheses within the bar. Data used to develop this figure can be found in Appendix B.

3.1.6 **Treatments 5 (30 cm Peat) and 12b (150 cm Subsoil (>1m)) border**

- Photos are provided; see Figure 3.1.45 to 3.1.46.
- Several trenches/test pits dug along the border within and between Cells 20 (Treatment 5) and 19B (Treatment 12b) because trees were demonstrating considerable differences in tree height between treatments and the border area (Figure 3.1.47; Appendix B.1.6 to B.1.8).
- Overburden consistency was variable at the surface of the layer (within the rooting zone - harder in some locations, more friable in others).
- Horizontally spreading roots dominated the root systems of trees growing within Treatment 5, however aspen roots generally turned vertical within 1 to 3 meters of the tree in Treatment 12b.
- Aspen roots were observed to extend for meters (lengths up to 17 m were recorded) horizontally from the tree in Treatment 5, however generally turned vertical within 1 to 3 meters of the tree in Treatment 12b.
- Abundant (>100) fine (1<2 mm) to small (2 to < 5mm) roots were observed in pine and spruce trees growing in Treatment 12b (sand texture), with fewer fine and small roots observed in Treatment 5 (peat) on border areas.
- Spruce and pine trees had a higher number of adventitious roots (roots above the tree plug) when growing in border areas where peat cover soil had wind-blown subsoil from Treatment 12b on surface.
- All pine trees along the Treatment 5/12b border had the largest primary roots growing in the direction of the peat Treatment (5) with small diameter secondary roots growing in all directions.
- Roots were often observed to make 90 degree turns to take advantage of the interfaces between organic and coarse textured materials.
- Roots generally followed the transition between materials (*i.e.*, transition between peat and mineral material).
- The largest percentage of roots was found within the upper 20 to 30 cm on the Treatment 5/12b border.
- A greater number of secondary roots were observed close to the tree base in subsoil material compared to peat.
- Root length was shorter in subsoil of Treatment 12b compared to peat of Treatment 5.
- A greater number of smaller diameter primary roots were found in subsoil of Treatment 12b compared to peat in Treatment 5.
- Root orientation in subsoil of Treatment 12b is primarily vertical and oblique, while root orientation in peat of Treatment 5 is primarily horizontal.

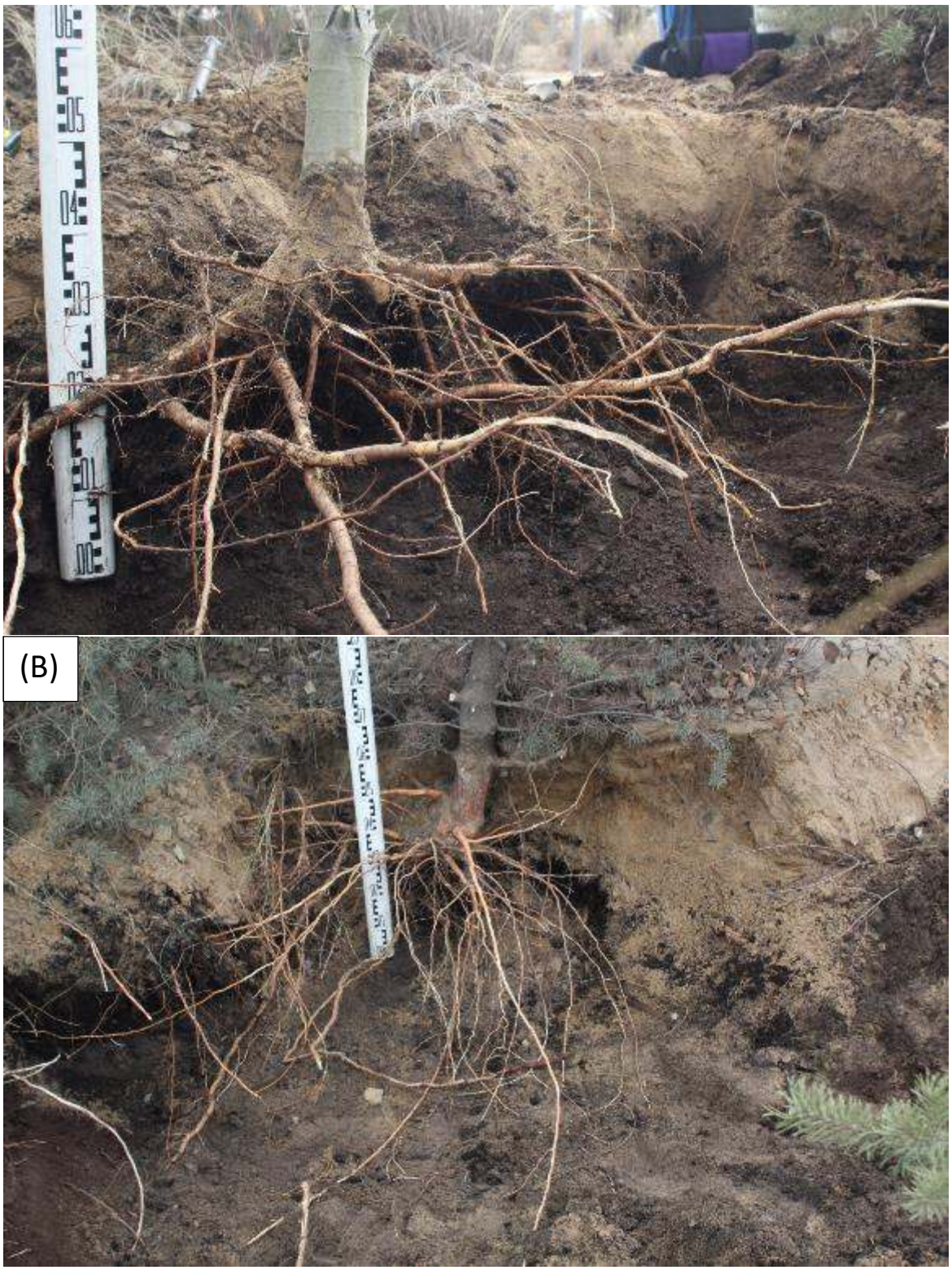

Figure 3.1.45. Treatment 5 and 12b Border inspection location area; Tree 1 (aspen) and Tree 2 (pine).

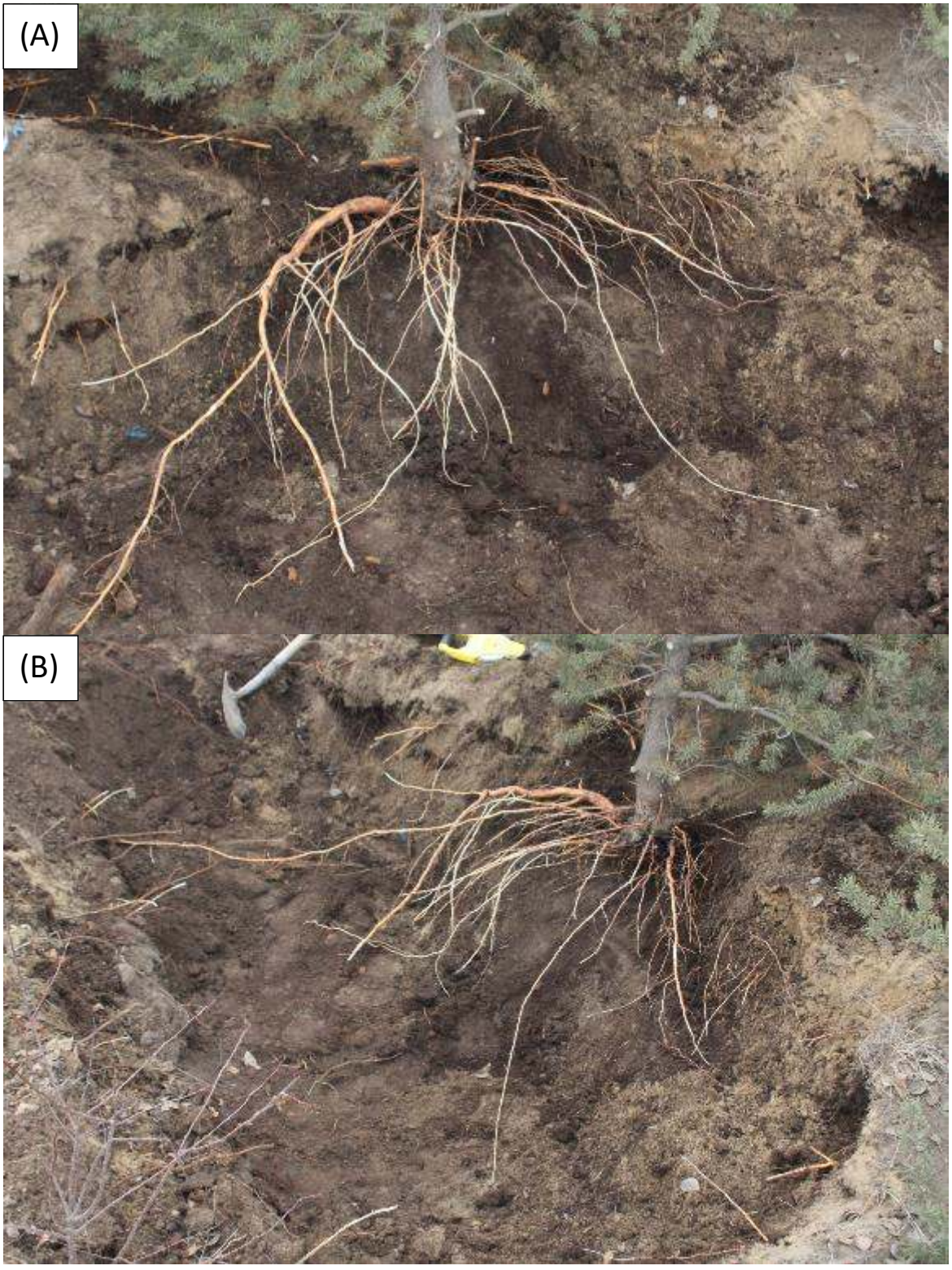

Figure 3.1.46. Treatment 5 and 12b Border inspection location area; both (A) and (B) show Tree 3 (pine).

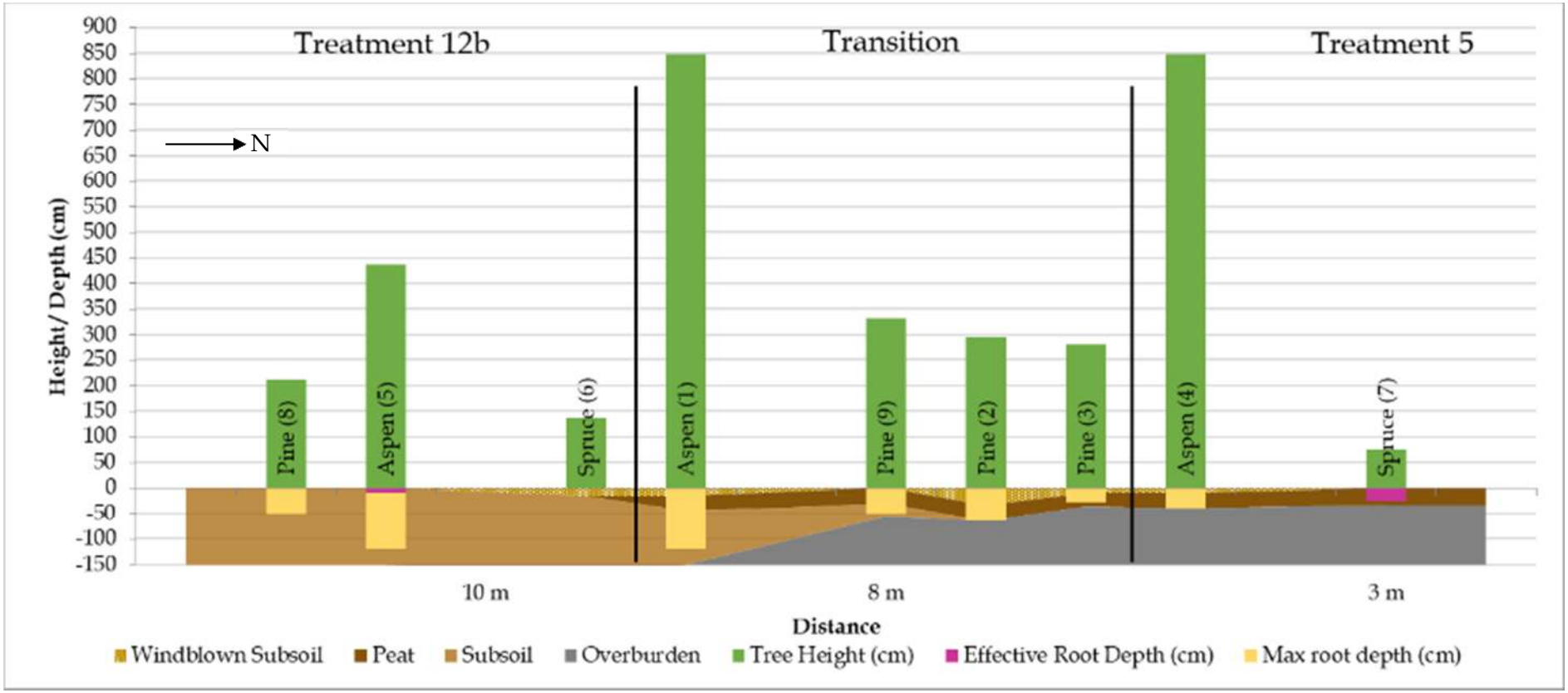

Figure 3.1.47. Tree height, maximum and effective root depth for the border between Treatment 5 (30 cm Peat) and Treatment 12b (150 cm Subsoil (>1m)).
Bars represent individual trees measured on site with the tree number displayed in parentheses within the bar. Data used to develop this figure can be found in Appendix B.

3.1.7 **Treatments 12a (150 cm Centre Pit Bm and 12b (150 cm Subsoil (>1m)) border**

- The roots of one large aspen tree along the 12a/12b border in Cell 19 were exposed (Figures 3.1.48 and 3.1.49).
- The aspen had 12 primary roots.
    - Most roots started to travel vertical approximately 3 m from the tree.
- There were few primary roots going directly north into Treatment 12b within the upper 40 cm of soil. Near the overburden, roots travelled horizontally and may have grown in a northern direction. The majority of roots either grew vertically directly under the tree or in an east/west direction along the border.
- A high density of oblique/vertical roots was also observed directly under the tree.
- Secondary branching of roots occurred about 170, 200, 200, 215, 130 cm from the tree.
    - Most secondary roots were coarse (20 to <50 mm diameter) but some were medium (5 to <20 mm diameter) in size.
- The largest diameter roots travelled horizontally in an easterly direction, then turned oblique or vertical 3 m from the tree.
- Eight of twelve primary roots went oblique to vertical within 40 cm of the tree.
    - This included the four largest diameter roots.
- The average root depths of the horizontal primary roots ranged from 5 to 15 cm below the soil surface before turning oblique within 3 meters from the tree.
- Two vertical roots from directly below the tree were followed (in trench). The roots were vertical to 60 to 80 cm and turned oblique in orientation to 1.45 m and then travelled along the overburden.
- A change in moisture occurred 63 cm below the soil surface, where moisture increased to near saturation (determined visually in the field). Though all materials are classified as a sand, the surface material was slightly less coarse and had 2% additional clay and was at a moisture content of 2.77%. Material at 63 cm below the tree was coarser sand and at a moisture content of 3.47%. Samples were taken in the field and texture was characterized by Element Materials Technology (Edmonton, AB) and moisture content was determined at InnoTech Alberta.
- More coarse (20 to <50 mm diameter), vertical roots present compared to aspen in other treatments.
- No roots were observed in the overburden material, however they were observed at the transition between overburden and overlying material.
- A preference for treatment 12a or 12b was not observed.

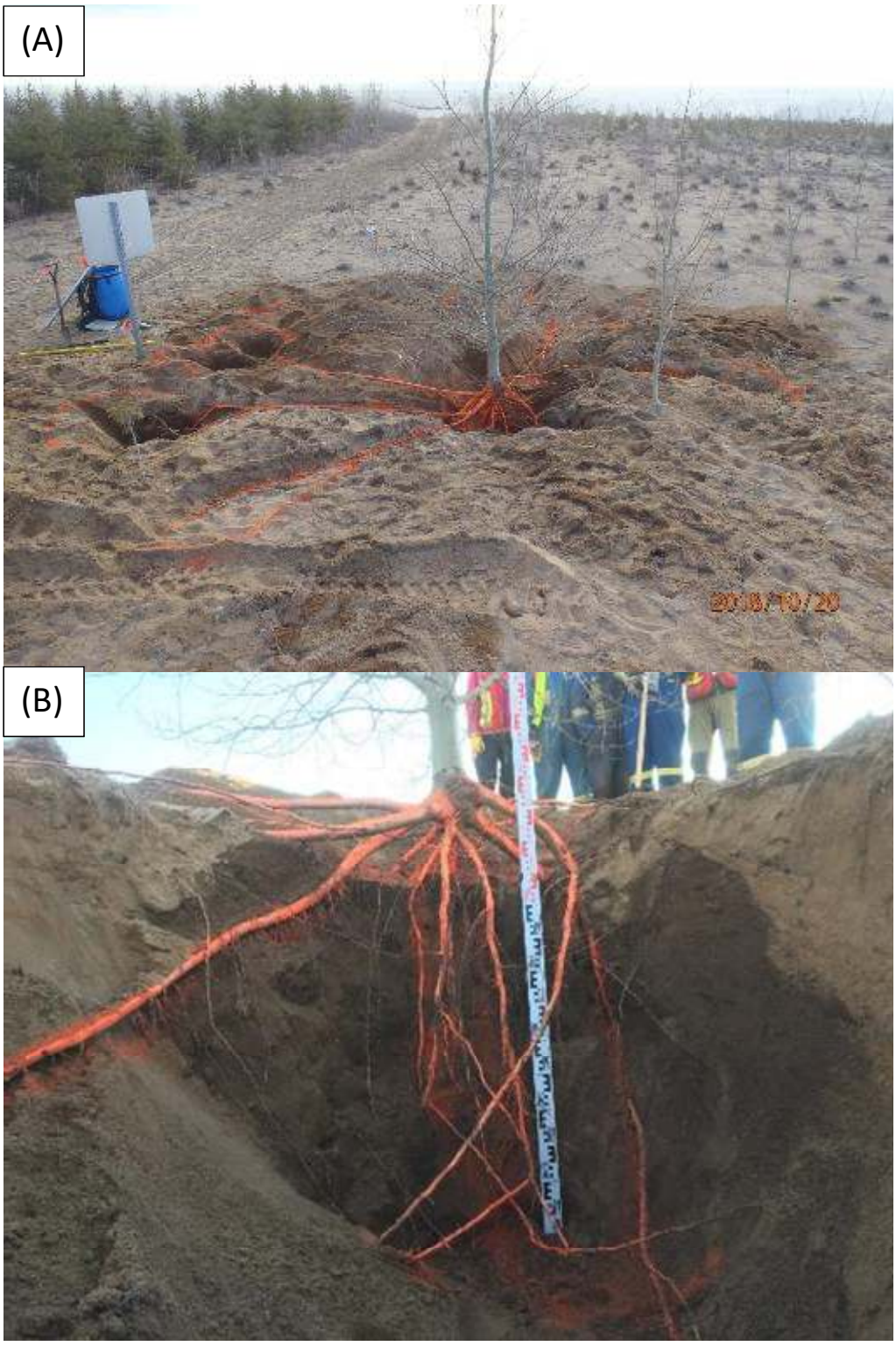

Figure 3.1.48. Treatment 12A and 12B Border inspection location area; both (A) and (B) show the large aspen.

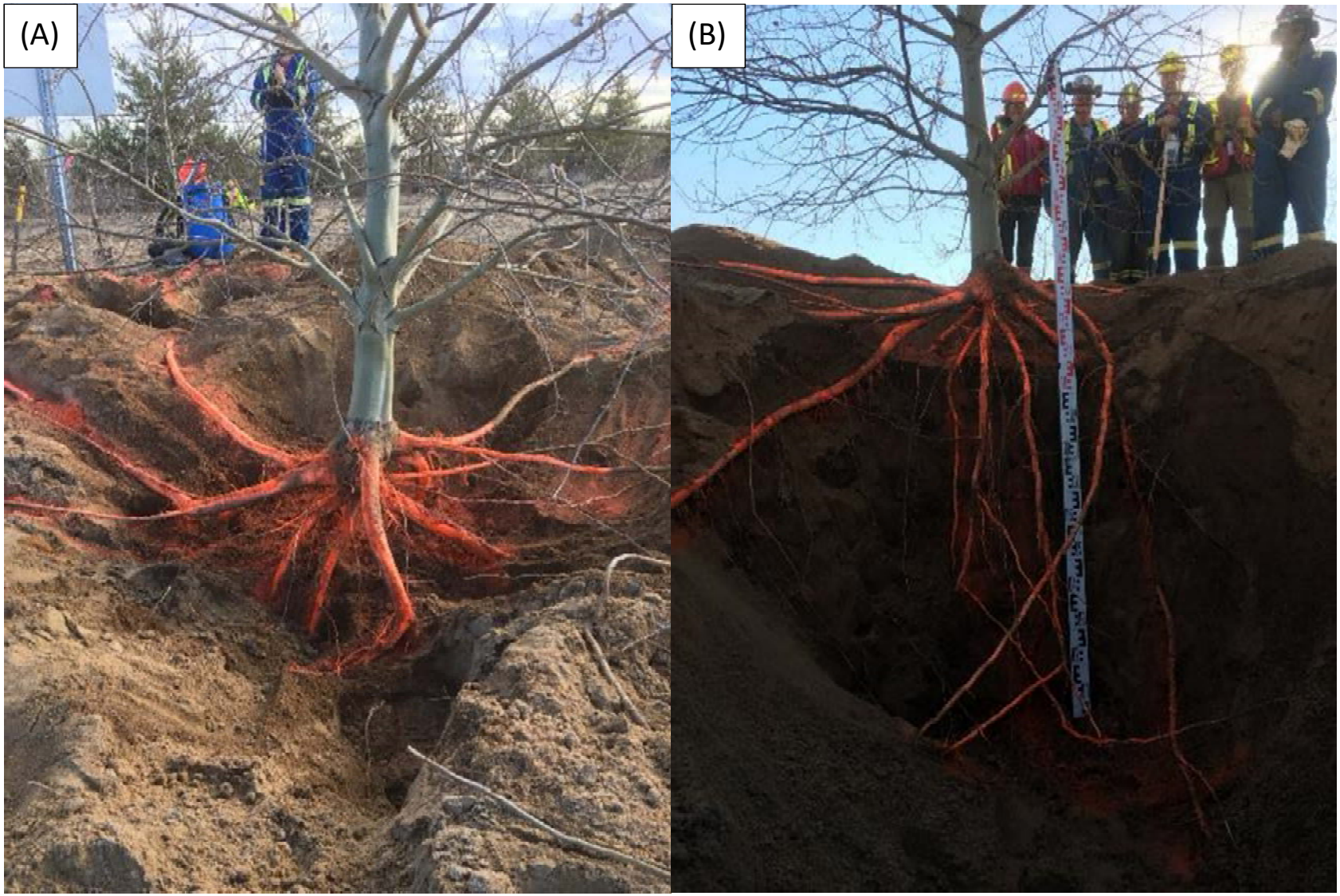

Figure 3.1.49. Treatment 12A and 12B Border inspection location area; both (A) and (B) show the large aspen.

3.2 SELECT TREATMENTS

3.2.1 **Treatment 1 (30 cm Peat/120 cm Subsoil (>1m))**

- Photos are provided; see Figure 3.2.1 to 3.2.3.
- Jack pine and spruce were assessed in the same test pit; aspen were assessed in a separate test pit (Figure 3.2.4; Table B.2.1).
    - Additionally, one aspen was hand dug to confirm root distribution around tree (not dug to full extent, therefore maximum root depth could not be confirmed).
- Roots evenly distributed around trees for all species.
- Horizontally spreading roots dominated the root systems for all examined trees.
- Effective rooting depth was within the peat (<30 cm) for pine, spruce and aspen.
- Maximum rooting depth highest for pine>spruce>aspen.

Figure 3.2.1. Treatment 1 inspection location area (Tree 35 (pine)).

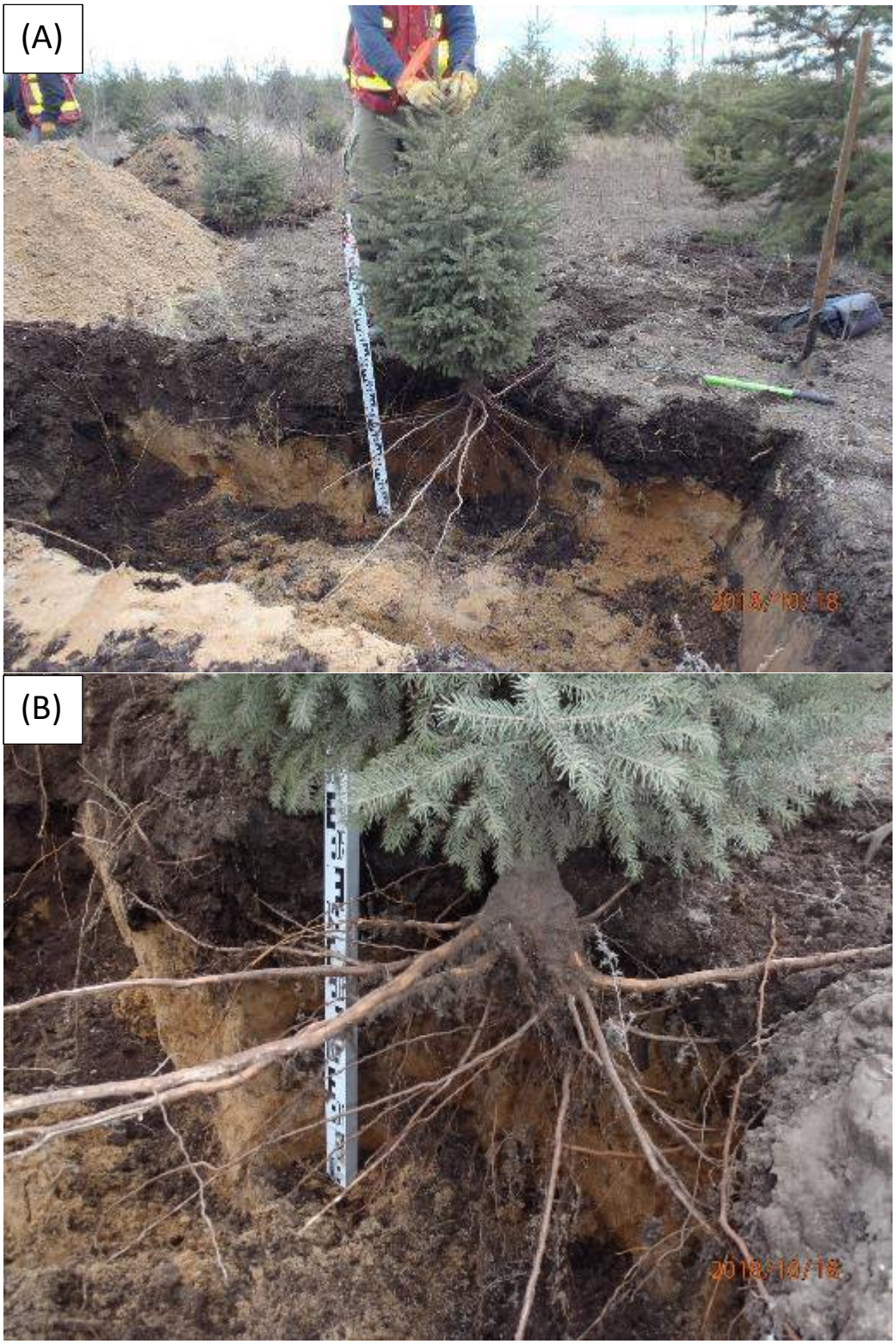

Figure 3.2.2. Treatment 1 inspection location area; both (A) and (B) show Tree 36 (spruce).

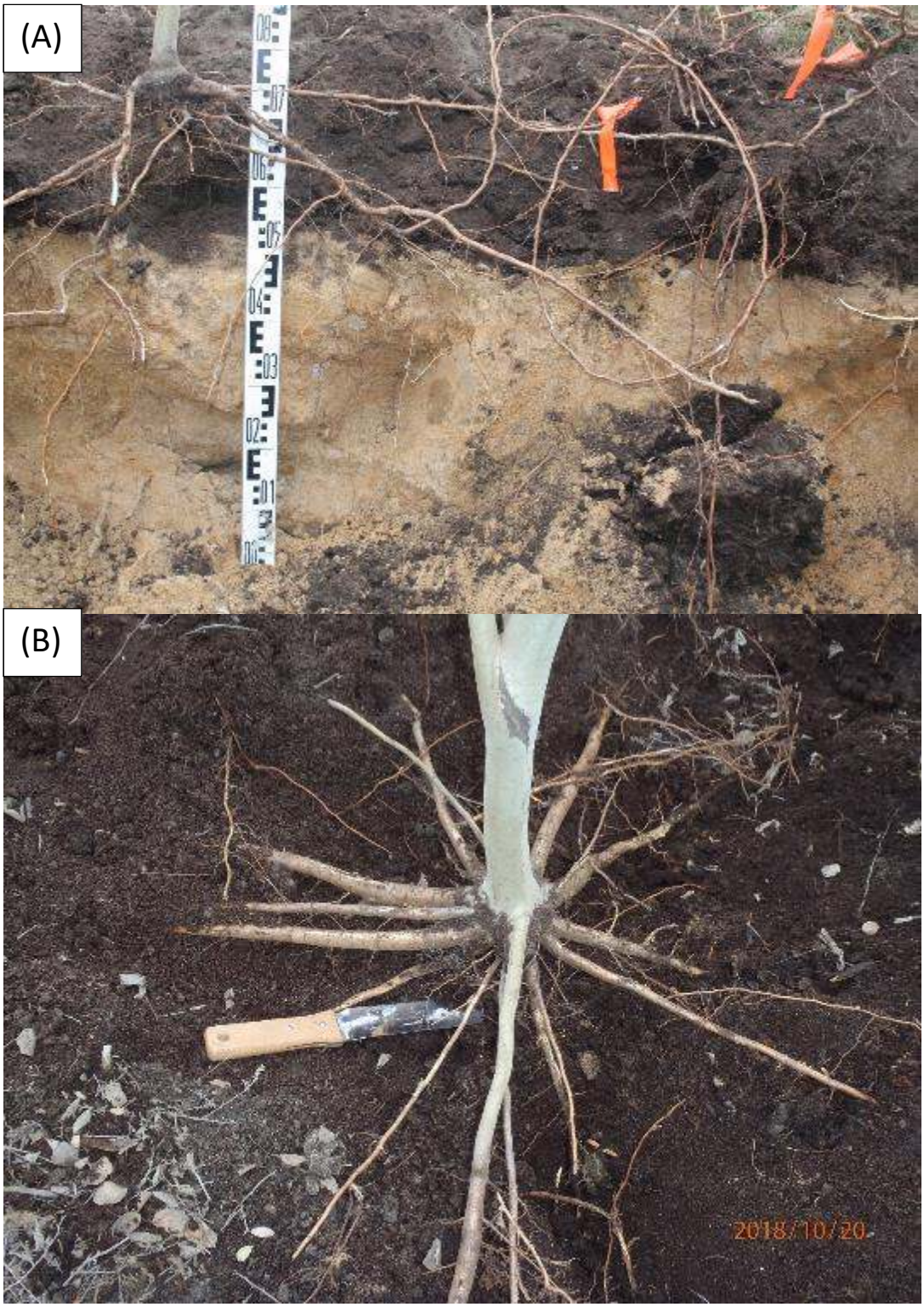

Figure 3.2.3. Treatment 1 inspection location area; (A) Tree 37 (aspen) and (B) Tree 38 (aspen).

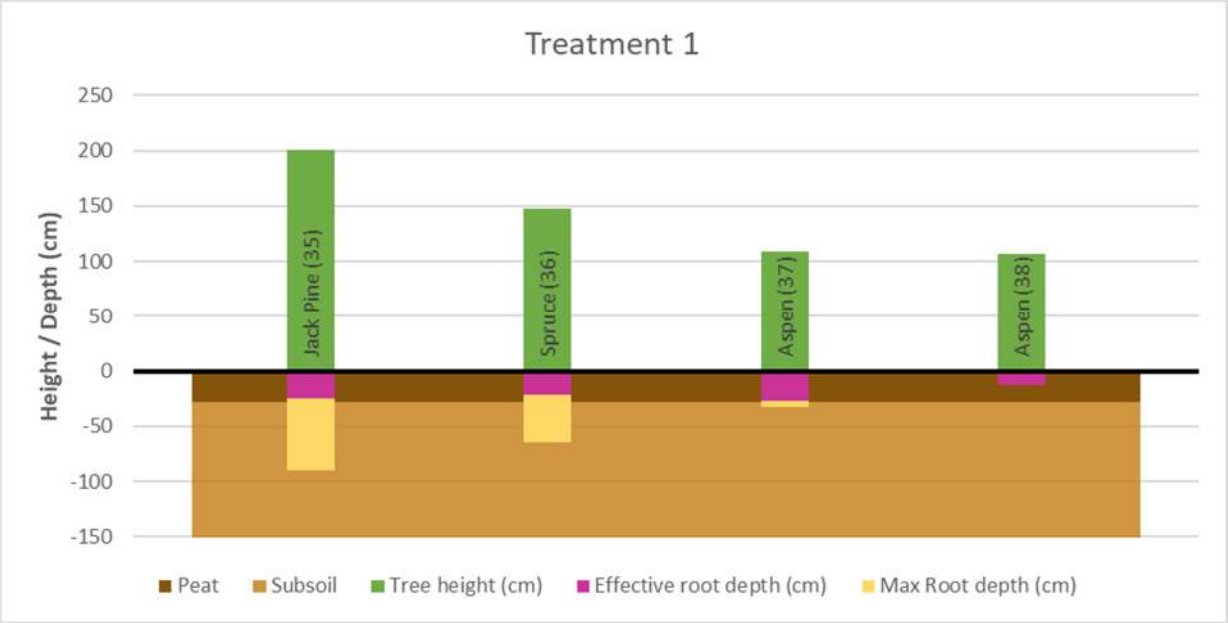

Figure 3.2.4. Tree height, maximum and effective root depth for Treatment 1 (30 cm Peat/120 cm Subsoil (>1m)). Bars represent individual trees measured on site with the tree number displayed in parentheses within the bar. Data used to develop this figure can be found in Appendix B. Note that maximum root depth was not confirmed for tree #38.

3.2.2 **Treatment 3 (10 cm Peat/140 cm Subsoil (>1m))**

- Photos are provided; see Figure 3.2.5 to 3.2.7.
- Two test pits were dug; aspen and pine were evaluated in one and the spruce in another (Figure 3.2.8; Appendix B.2.2). The pits were not dug to the overburden.
- Horizontally spreading roots dominated the root systems of all examined trees.
- A 7 cm vertical root was observed under the aspen tree (tree #46) which branched into 3 oblique roots, one of which did a 90 degree turn within the subsoil (Table B.2.2; Figure 3.2.5).
- Maximum root depth was greatest for aspen>spruce>pine.
- Effective rooting depth was within 30 cm of the surface for all species, however root volume was higher in the surface peat coversoil (0 to 10 cm).

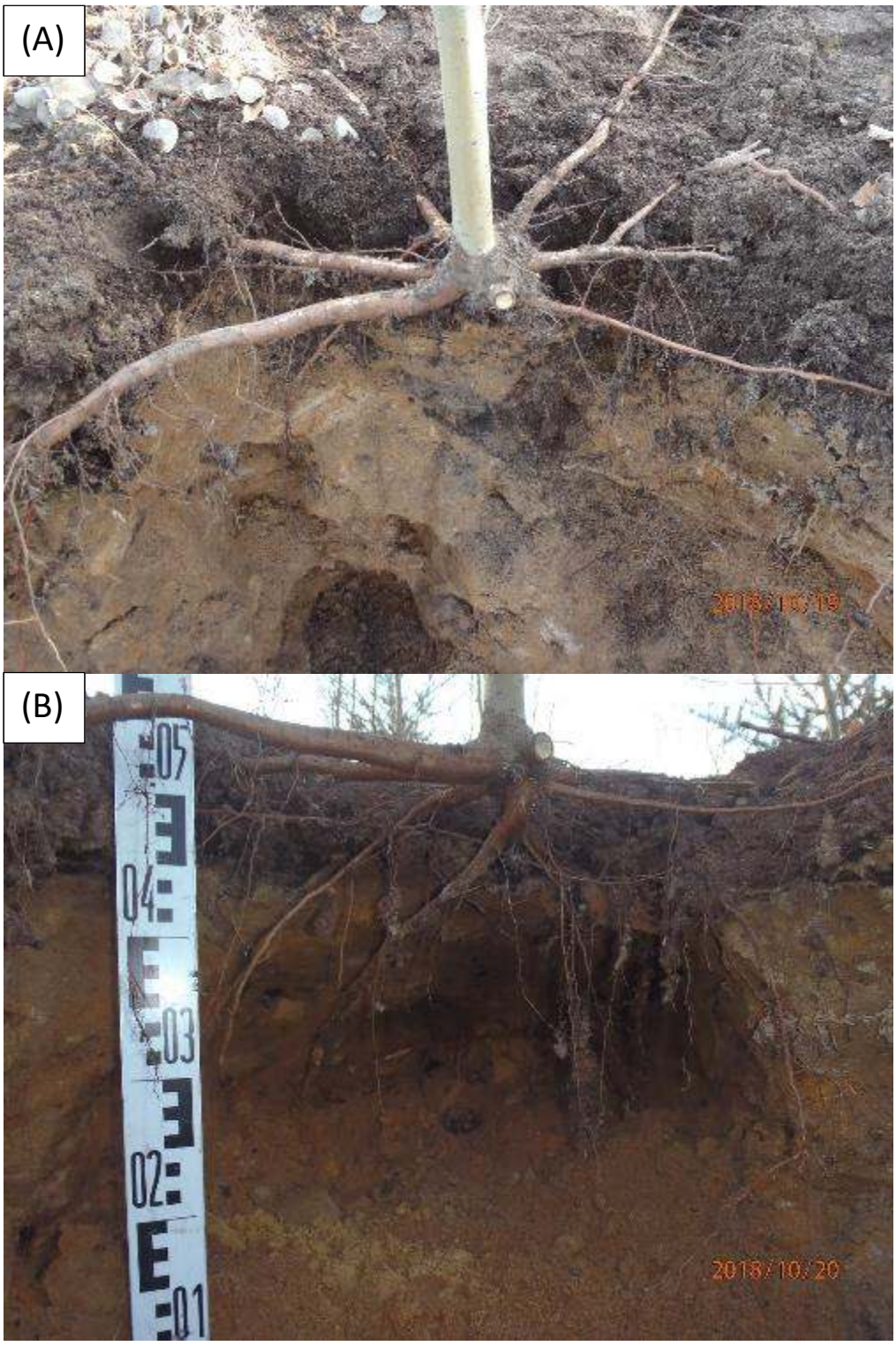

Figure 3.2.5. Treatment 3 inspection location area; both (A) and (B) show Tree 46 (aspen).

Figure 3.2.6. Treatment 3 inspection location area (Tree 46 (aspen)).

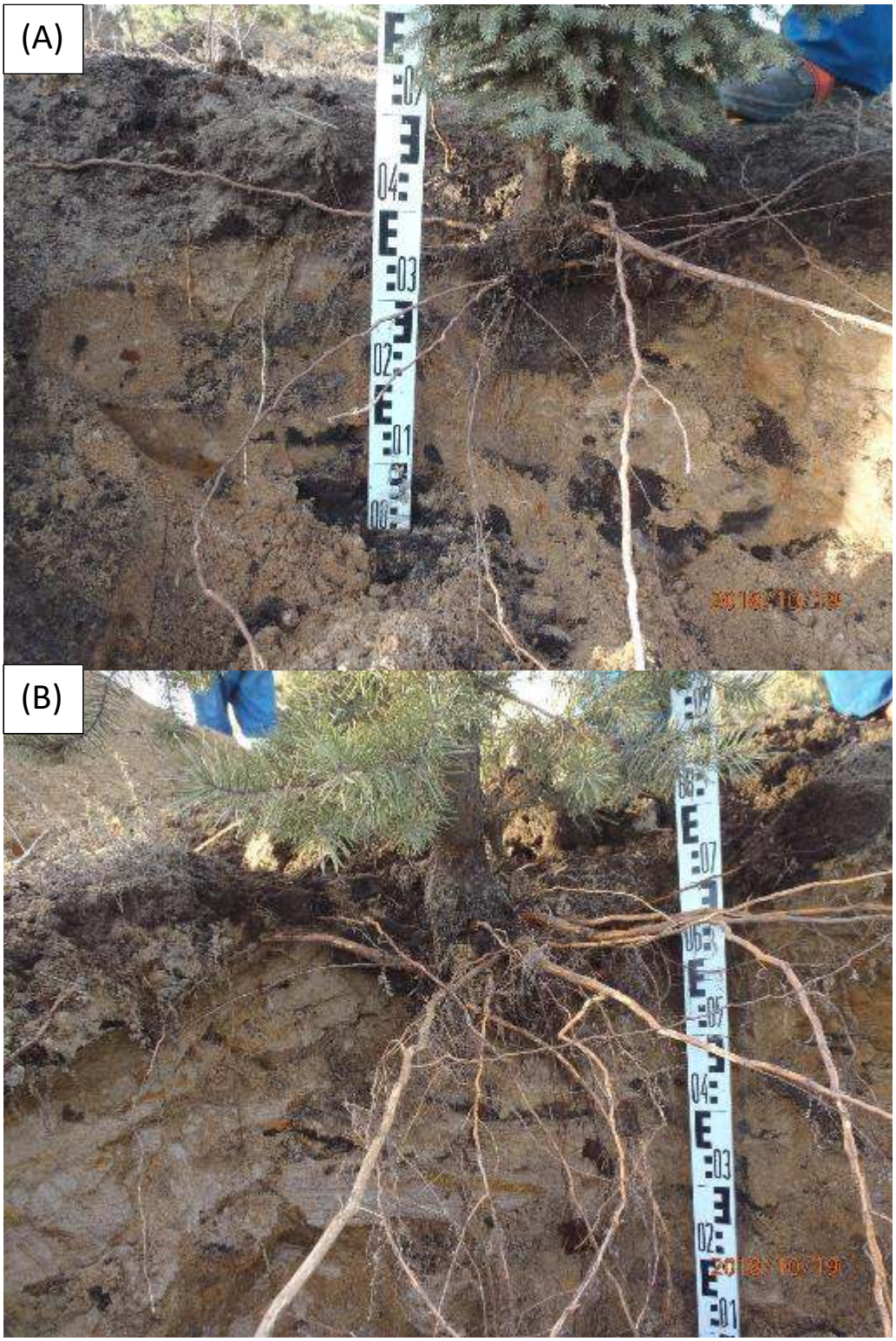

Figure 3.2.7. Treatment 3 inspection location area; (A) Tree 47 (spruce) and (B) Tree 48 (pine).

Figure 3.2.8. Tree height, maximum and effective root depth for Treatment 3 (10 cm Peat/140 cm Subsoil (>1m)). Bars represent individual trees measured on site with the tree number displayed in parentheses within the bar. Data used to develop this figure can be found in Appendix B.

3.2.3 **Treatment 4 (30 cm Peat/30 cm Blended B/C)**

- Photos are provided; see Figure 3.2.9 to 3.2.17.
- Three test pits were excavated to expose roots from 6 individual trees within Treatment 4 Figures 3.2.18 and 3.2.19; Table B.2.3).
- Roots were evenly distributed around the trees for all species (Figure 3.2.17).
- Horizontally spreading roots dominated the root systems for all three species within the peat material, however roots were generally vertical within the underlying Blended B/C horizon.
- A high volume of primary roots were observed for pine and spruce, particularly when compared to shallower peat (10 cm) or LFH treatments.
- The number of fine (1 to < 2 mm diameter) and small (2 to <5 mm diameter) abundant roots was higher than in other examined treatments.
- Pine (tree #23) had a high volume of medium sized (5 to < 20 mm diameter) roots within the peat material that extended out for meters from tree (*i.e.*, root length was higher than expected given the size of the tree and the diameter of the root at the base of the tree).
- Vertical roots under the aspen tree extended down into the Blended B/C horizon (Figure 3.2.18).
- Aspen suckering was observed.
- There was a high volume of secondary fine (1 to <2 mm diameter) roots for all tree species.
- The effective rooting depth was generally within the peat layer (30 cm) and rooting depths were relatively consistent within the treatment for all three species.
- No roots observed within the overburden (the overburden was exposed in this treatment and no evidence of root penetration was observed. Few roots were observed growing into the overburden; the majority were within the peat or along the peat/Blended B/C border.

Figure 3.2.9. Treatment 4 inspection location area (Tree 21 (aspen)).

Figure 3.2.10. Treatment 4 inspection location area; both (A) and (B) show Tree 22 (pine).

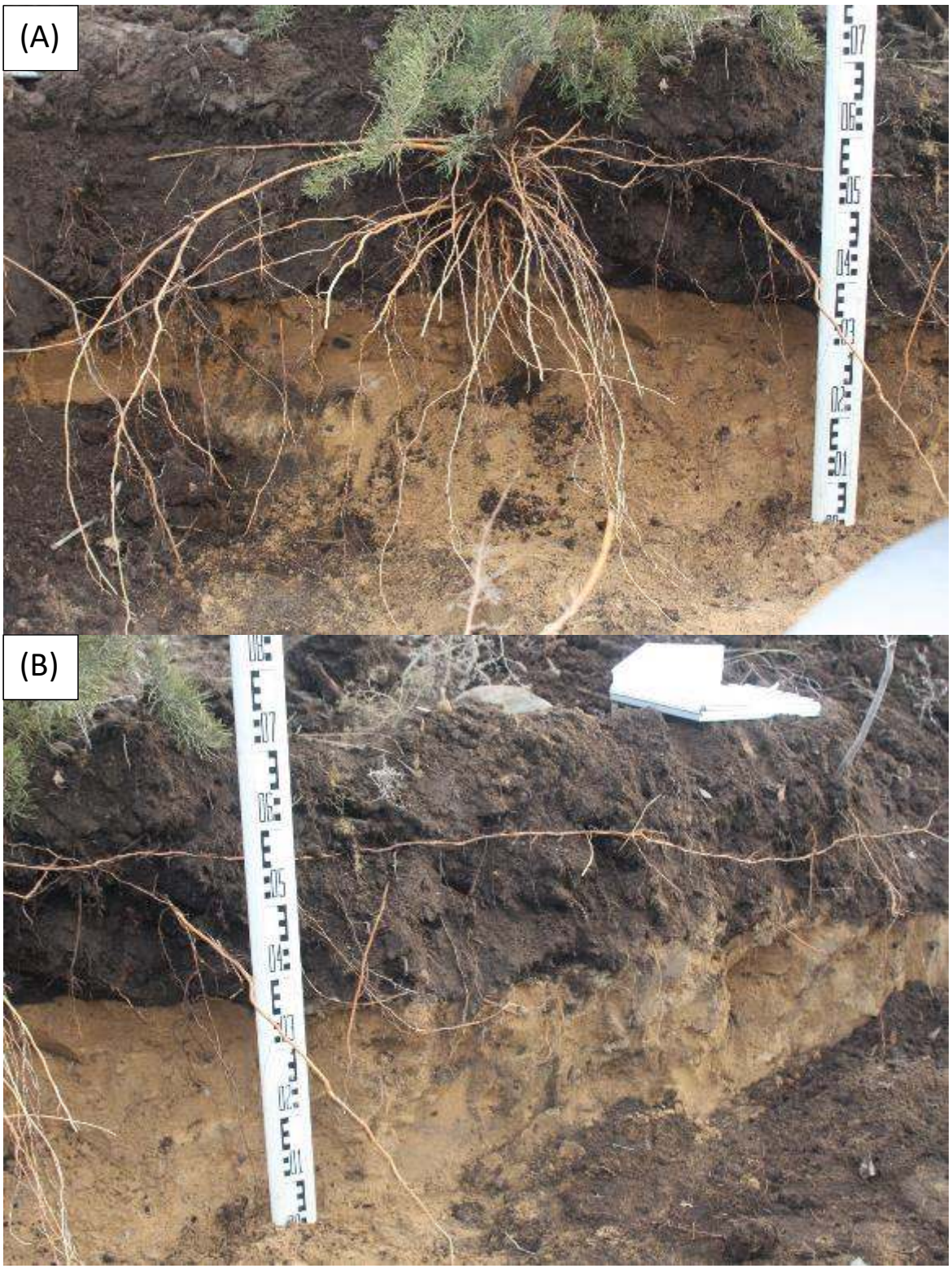

Figure 3.2.11. Treatment 4 inspection location area; both (A) and (B) show Tree 23 (pine).

Figure 3.2.12. Treatment 4 inspection location area (Tree 23 (pine)).

Figure 3.2.13. Treatment 4 inspection location area (Tree 23 (pine)).

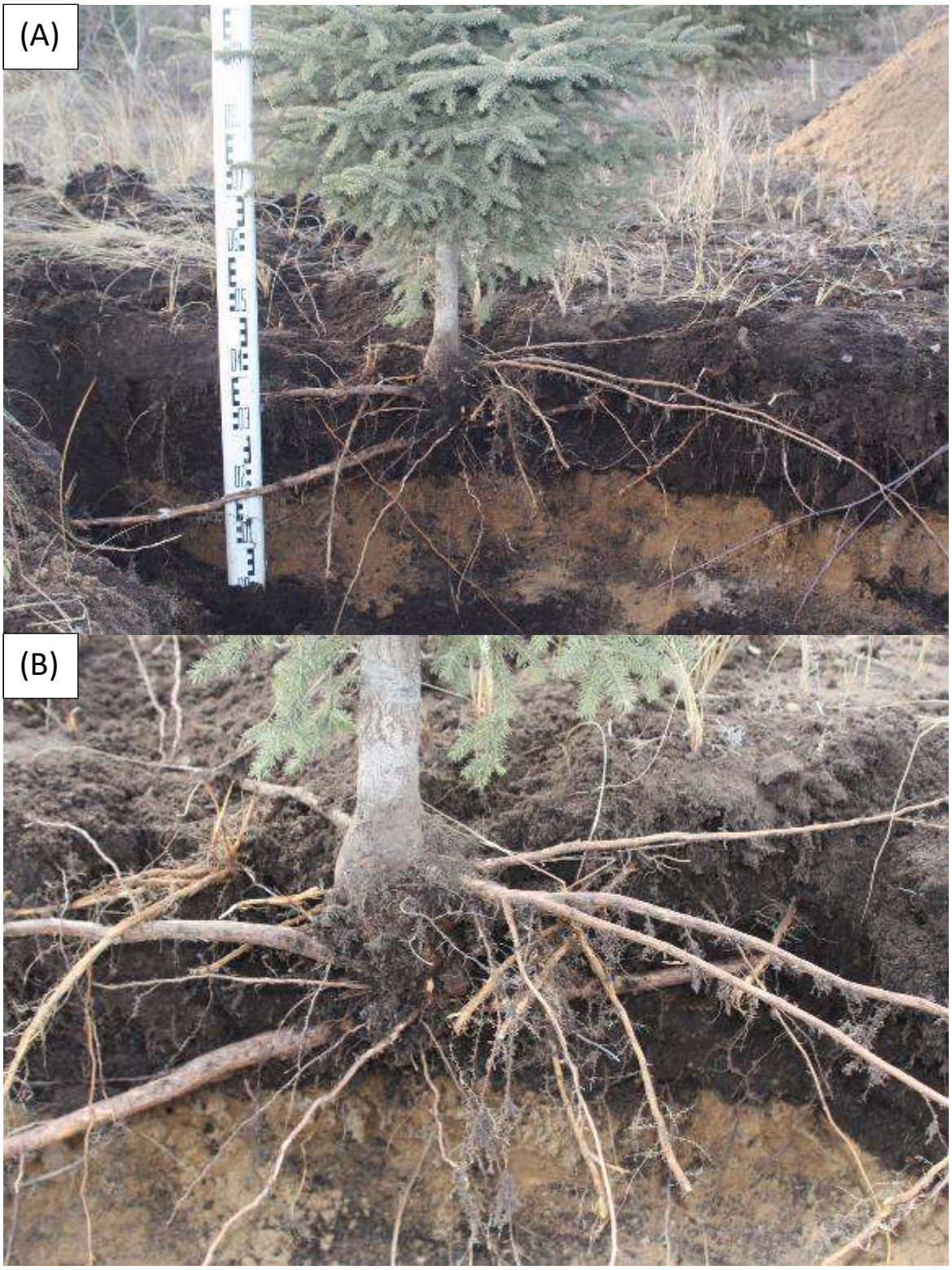

Figure 3.2.14. Treatment 4 inspection location area; both (A) and (B) show Tree 24 (spruce).

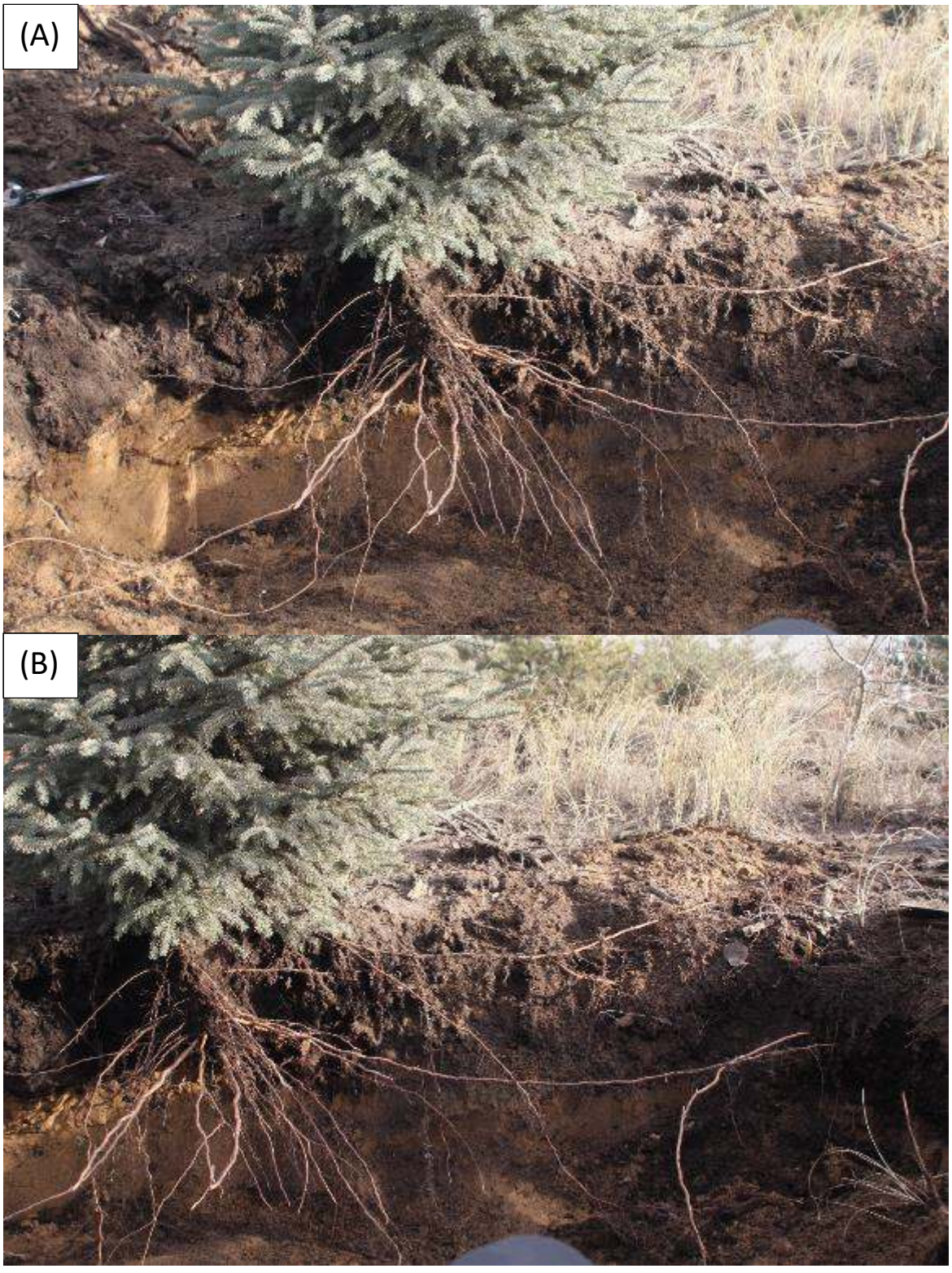

Figure 3.2.15. Treatment 4 inspection location area; both (A) and (B) show Tree 25 (spruce).

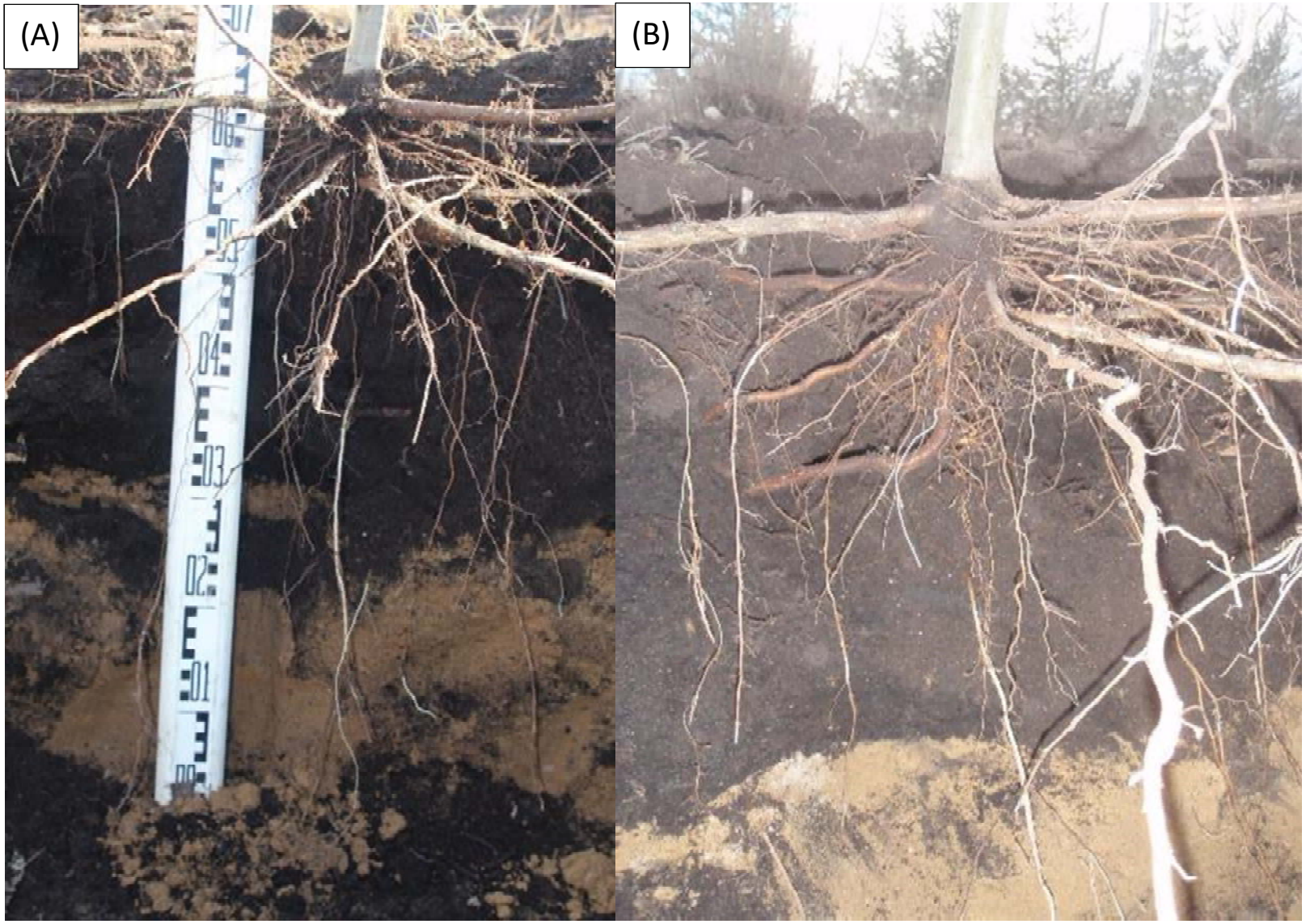

Figure 3.2.16. Treatment 4 inspection location area; both (A) and (B) show Tree 26 (aspen).

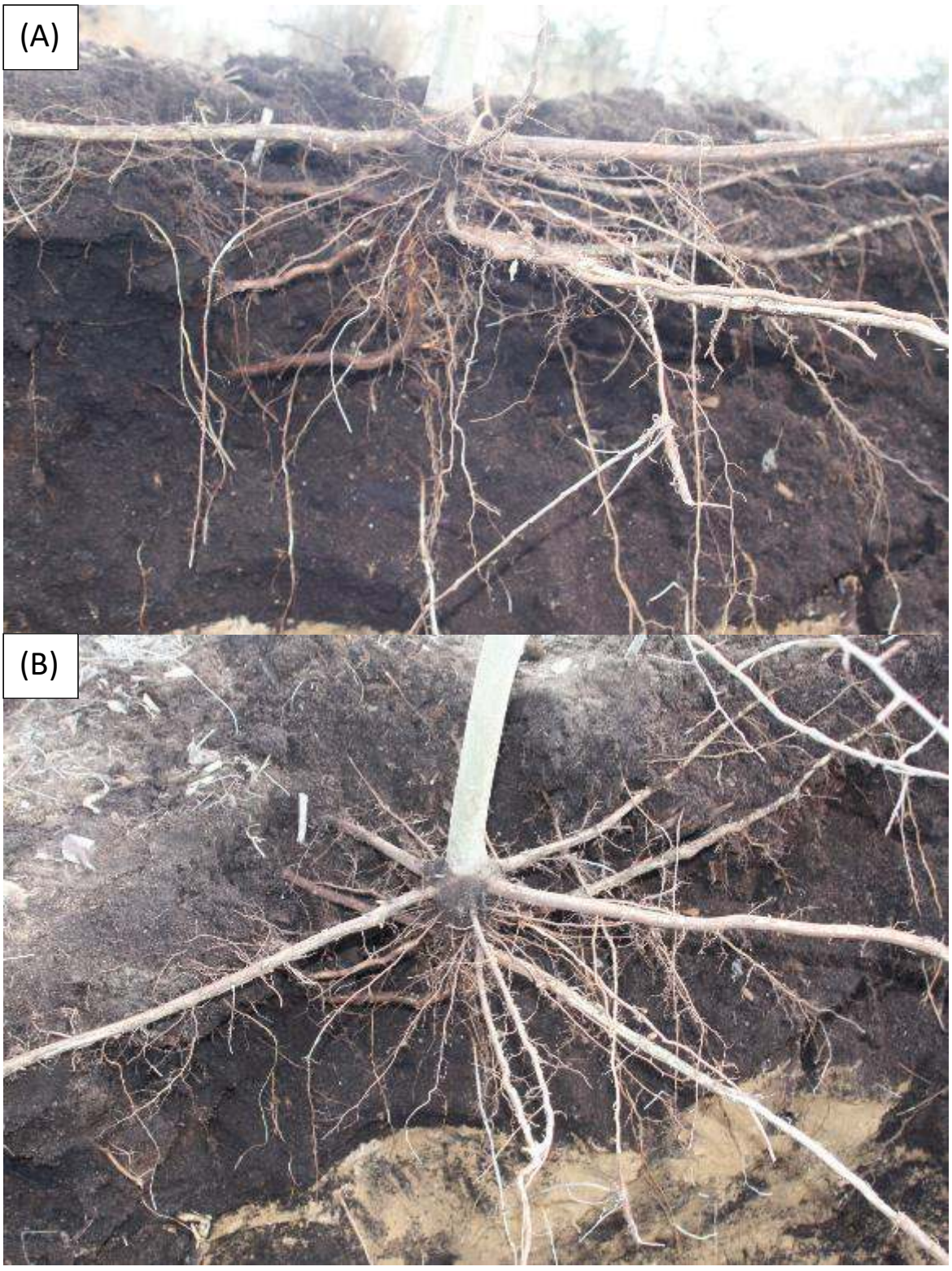

Figure 3.2.17. Treatment 4 inspection location area; both (A) and (B) show Tree 26 (aspen).

Figure 3.2.18. Vertical root directly below aspen tree in Treatment 4.

Figure 3.2.19. Tree height, maximum and effective root depth for Treatment 4 (30 cm Peat/30 cm Blended B/C). Bars represent individual trees measured on site with the tree number displayed in parentheses within the bar. Data used to develop this figure can be found in Appendix B.

3.2.4 **Treatment 6 (30 cm Peat/30 cm Bm/90 cm Subsoil (>1m))**

- Only one tree (Aspen #34) was evaluated within Treatment 6 independently from the border inspection trenches between Treatment 6 and Treatment 5; although Jack pine (#27) and spruce (#30) were located completely within Treatment 6, they were evaluated as part of the border (Figures 3.2.20 and 3.2.21; Table B.2.4).
- Although three soil materials were present, aspen roots were only observed in the peat coversoil horizon/material.
- The aspen formed a vertical root at the base of the tree that extended to the interface of the peat and Bm horizons, where it turned 90 degrees and grew up towards the surface (Figure 3.2.20).
- Aspen #31 growing on the Treatment 5/6 border also exhibited avoidance of the Bm material, but to a lesser extent than Aspen #34.
- Pine and spruce grew through the Bm and into the subsoil, however the effective rooting depth was within the peat (30 cm).

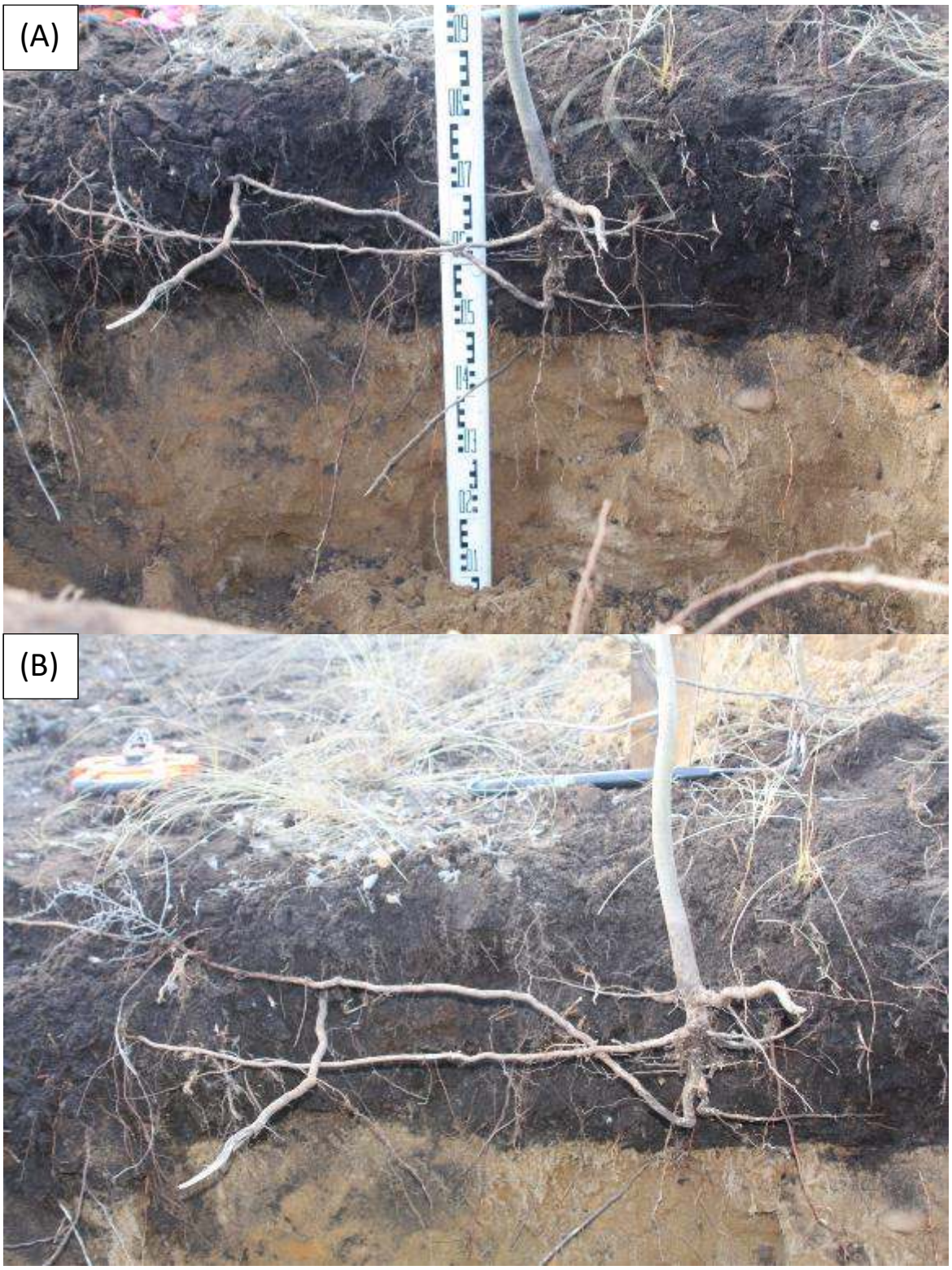

Figure 3.2.20. Treatment 6 inspection location area; both (A) and (B) show Tree 34 (aspen).

Figure 3.2.21. Tree height, maximum and effective root depth for Treatment 6 (30 cm Peat/30 cm Bm/90 cm Subsoil (>1m)).

Bars represent individual trees measured on site with the tree number displayed in parentheses within the bar. Data used to develop this figure can be found in Appendix B.

3.2.5 **Treatment 7 (20 cm LFH/130 cm Subsoil (>1m))**

- Photos are provided in Figures 3.2.22 to 3.2.25 of inspected trees.
- All trees were assessed from one test pit/trench (Figure 3.2.26; Table B.2.5).
- The LFH depth varied within the test pit/trench from 15 to 21 cm.
- Horizontally spreading roots dominated the root systems for all three species.
- Although roots were generally evenly distributed around the trees for all three species, and the trees were well within the treatment (i.e., not in proximity of a border), there did appear to be a greater horizontal growth (i.e., root length) in a north-south direction as opposed to east-west, particularly for aspen trees.
- For all trees, the effective rooting was the depth of the LFH material (Figure 3.2.26).
- Aspen roots were observed growing into interface between the LFH and the subsoil material.
- Aspen trees had a high volume of primary and secondary roots (plentiful to abundant) near the base of the tree as well as along the length of the exposed primary roots.
- The presence of the Bm horizon (20 to 50 cm) in Treatment 9 resulted in roots travelling deeper into the Subsoil (≥50 cm) material than in Treatment 7, which does not contain a Bm horizon.

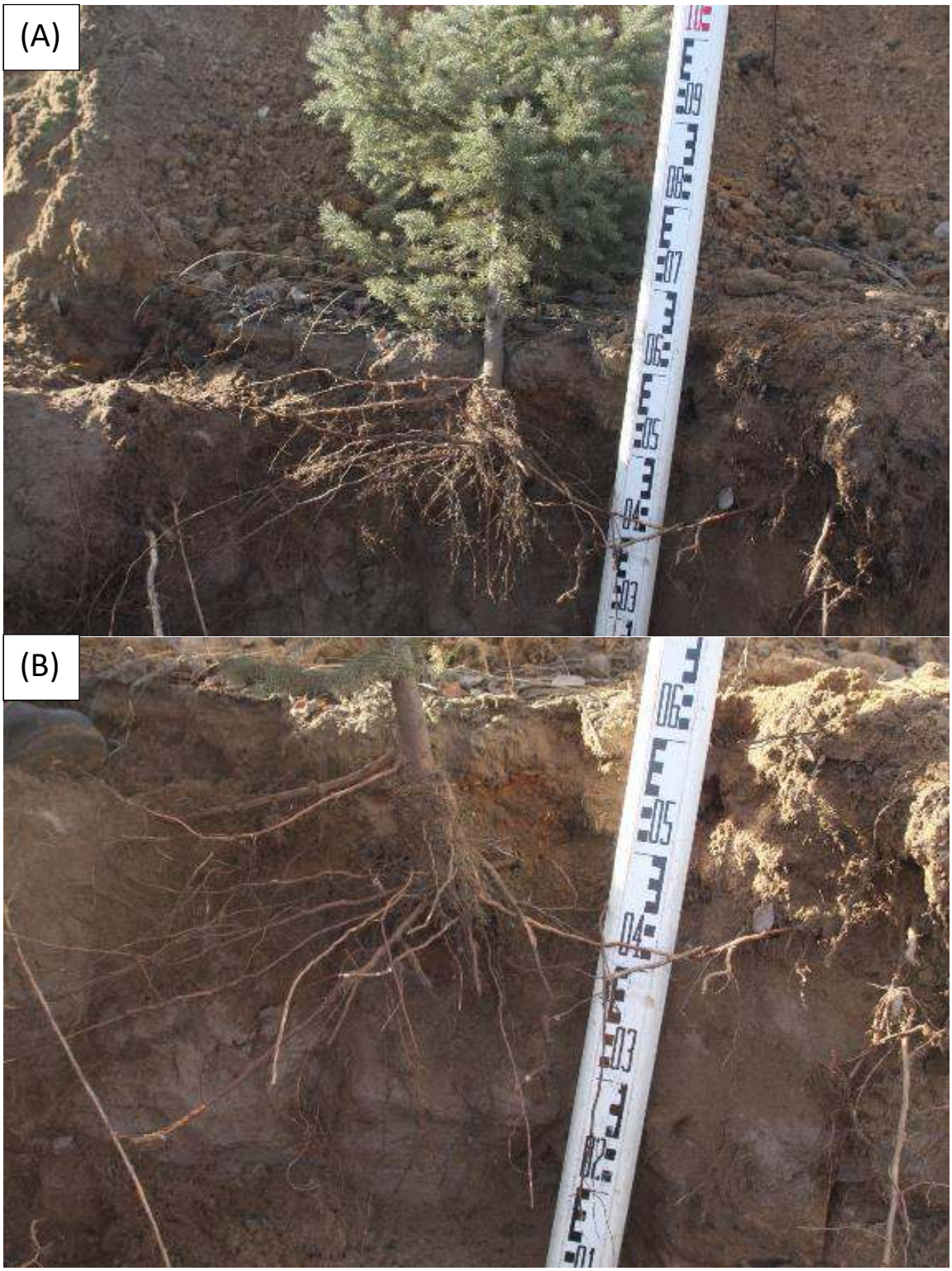

Figure 3.2.22. Treatment 7 inspection location area; both (A) and (B) show Tree 39 (spruce).

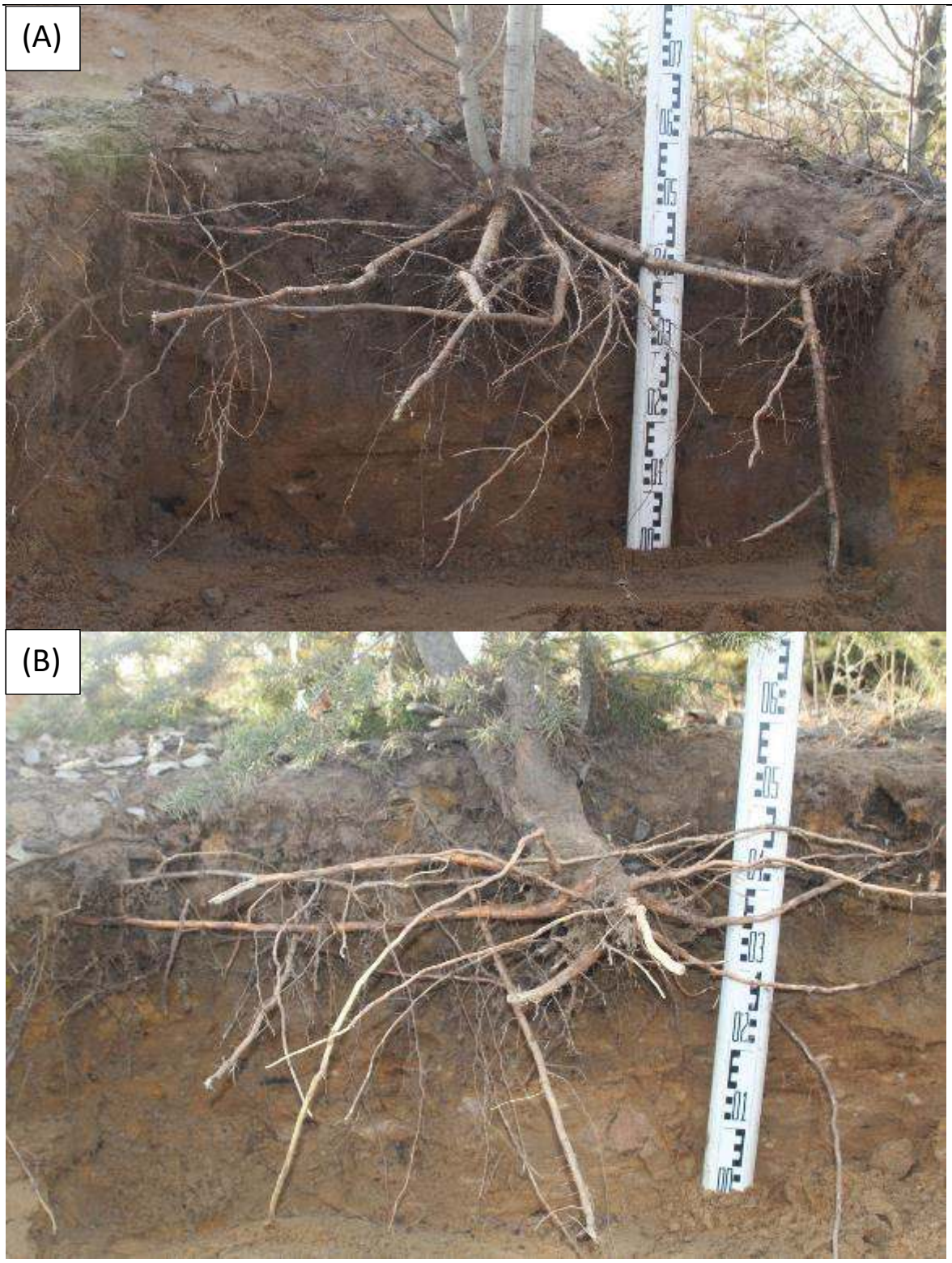

Figure 3.2.23. Treatment 7 inspection location area; (A) Tree 40 (aspen) and (B) Tree 41 (pine).

Figure 3.2.24. Treatment 7 inspection location area; (A) Tree 42 (aspen) and (B) exposing the roots of Tree 42.

Figure 3.2.25. Treatment 7 inspection location area; Tree 42 (aspen) root exposed.

Figure 3.2.26. Tree height, maximum and effective root depth for Treatment 7 (20 cm LFH/130 cm Subsoil (>1m)) from below 1 m).

Bars represent individual trees measured on site with the tree number displayed in parentheses within the bar. Data used to develop this figure can be found in Appendix B.

3.2.6 **Treatment 9 (20 cm LFH/30 cm Bm/100 cm Subsoil (>1m))**

- Photos are provided for the inspected trees in Figures 3.2.27 to 3.2.33.
- Roots were exposed in 2 separate test pits for evaluation of 5 individual trees (Figure 3.2.34; Table B.2.6).
- Bm and Subsoil horizons were difficult to differentiate.
- Roots were evenly distributed around the trees for all three species evaluated.
- Effective rooting depth was within the Bm material for most of the tree species examined.
- Maximum rooting depth for the larger trees investigated was 1.15 and 1.32 m for aspen and 1.22 m for pine.
- The spruce evaluated was relatively small (1.37 m in height) and had more roots growing horizontally (max root length was 2.4 m) along the interface between the LFH/Bm and Bm/Subsoil.
- Aspen roots were observed to change rooting behavior at the horizon interfaces (90 degree turns) (Figure 3.2.29); no changes in pine roots were observed at horizon interfaces (Figure 3.2.32).

Figure 3.2.27. Treatment 9 inspection location area trench photo.

Figure 3.2.28. Treatment 9 inspection location area (Tree 16 (pine)).

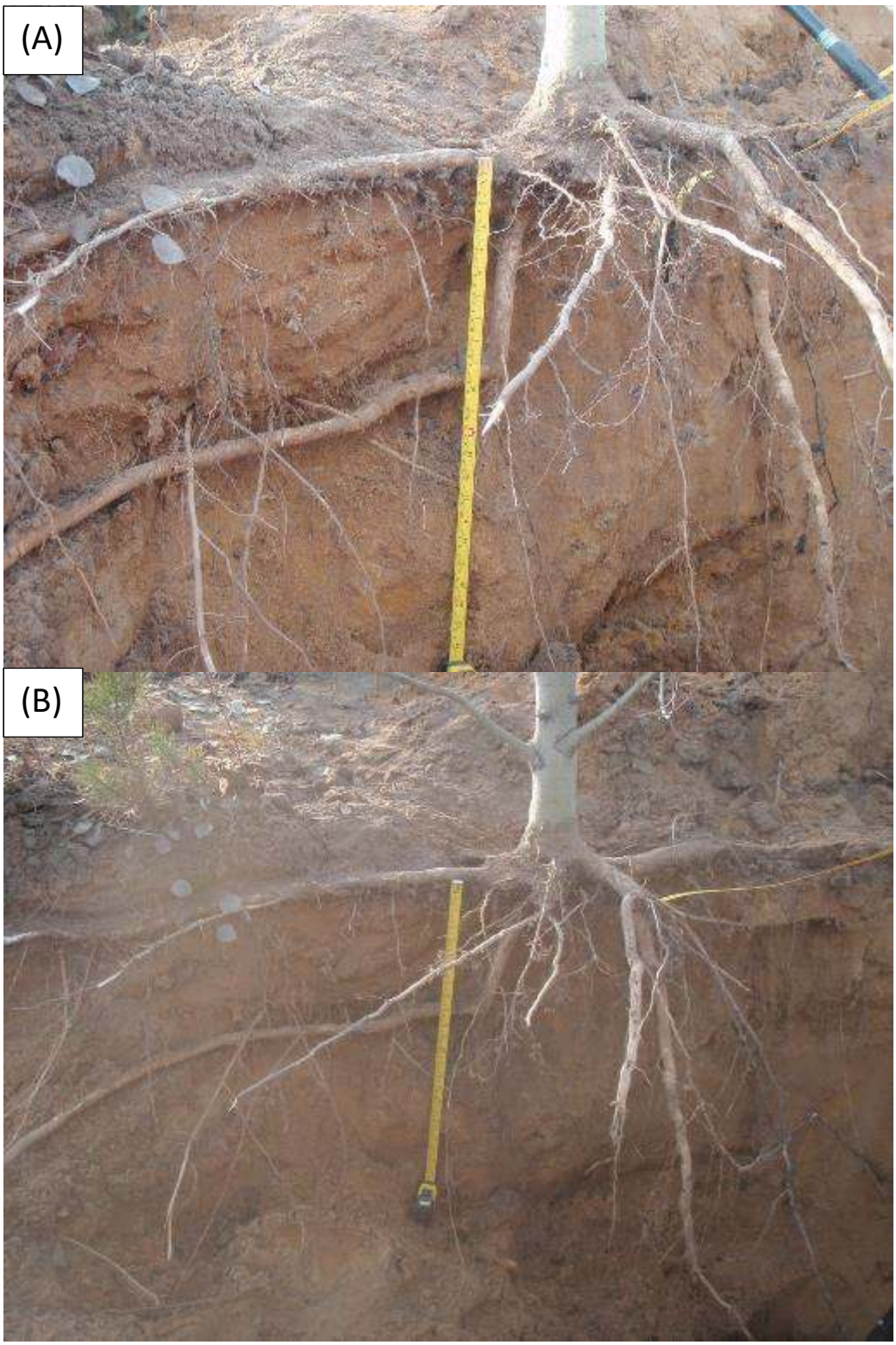

Figure 3.2.29. Treatment 9 inspection location area; both (A) and (B) show Tree 17 (aspen).

Figure 3.2.30. Treatment 9 inspection location area (Tree 18 (spruce)).

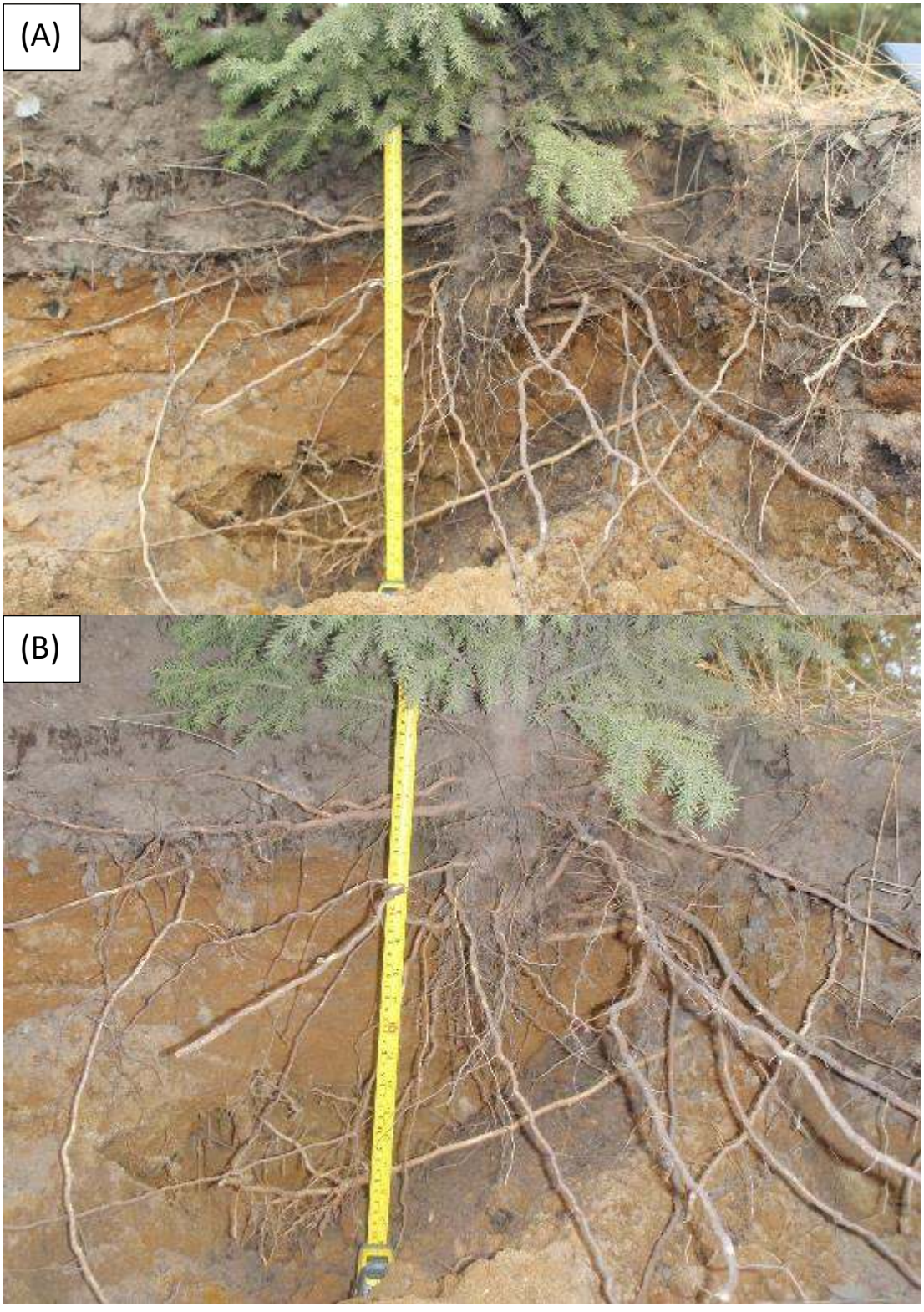

Figure 3.2.31. Treatment 9 inspection location area; both (A) and (B) show Tree 18 (spruce).

Figure 3.2.32. Treatment 9 inspection location area; both (A) and (B) show Tree 19 (pine).

Figure 3.2.33. Treatment 9 inspection location area (Tree 20 (aspen)).

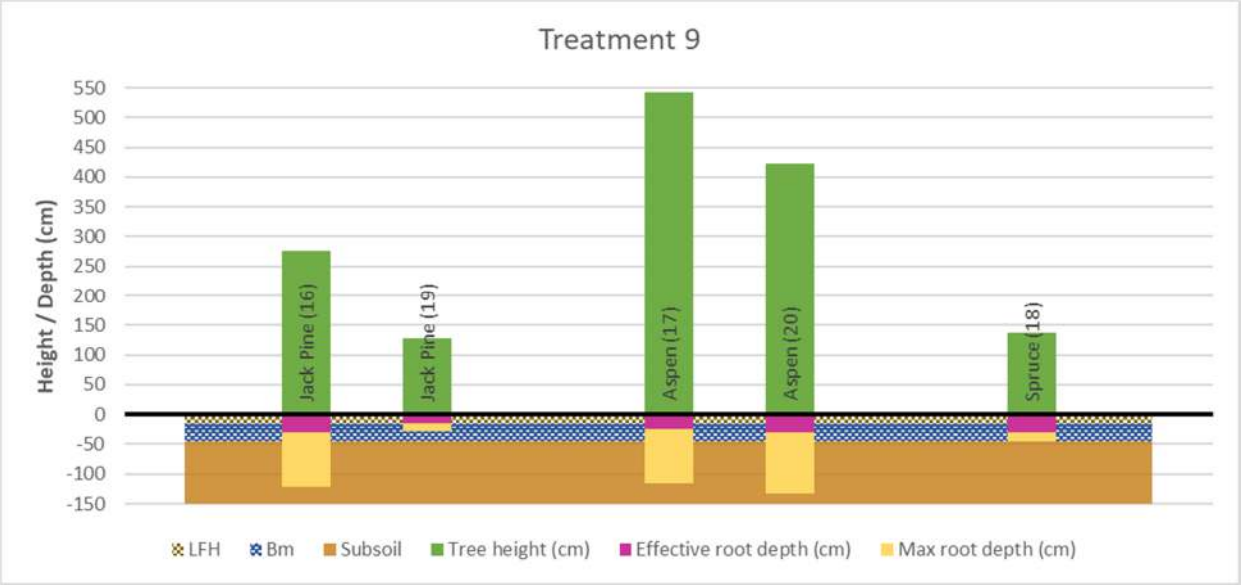

Figure 3.2.34. Tree height, maximum and effective root depth for Treatment 9 (20 cm LFH/30 cm Bm/100 cm Subsoil).

Bars represent individual trees measured on site with the tree number displayed in parentheses within the bar. Data used to develop this figure can be found in Appendix B.

3.2.7 **Treatment 10 (30 cm Peat/120 cm Blended B/C)**

- Photos are provided of the inspected trees in Figures 3.2.35 to 3.2.38.
- The trees were all completely within Treatment 10 in Cell 30 (Figure 3.2.39; Table B.2.7).
- Aspen trees demonstrated a unique rooting behavior with one or more vertical roots directly below the base of the tree (Table B.2.7; Figure 3.2.35 to 3.2.38).
- Aspen roots remained within the Peat horizon and/or directly along the interface between the Peat and Blended B/C horizons.
- Aspen displayed an avoidance behavior with respect to the Blended B/C material. Very few roots were observed growing within the Blended B/C horizon (Figure 3.2.39).
- Multiple horizontal secondary roots extended from the vertical primary roots deeper within the Peat (on the aspen tree). However, the vertical root tips either died or extended horizontally along the interface between Peat and Blended B/C. Essentially, there were two whorls of roots distributed around the tree and/or the vertical root extending below the tree: one near the surface and the other 10 to 15 cm below the surface.
- Given the unique growth pattern displayed by the aspen, two additional trees were investigated. Both trees showed similar patterns as the initial tree investigated with vertical roots extending into the Peat from the base of the tree and then changing to oblique/horizontal to extend along the Peat/Blended B/C interface.
- There were few horizontal primary roots within the surface 10 cm on the aspen trees compared to treatments with shallower organic surface depths.
- At least one primary root was observed at the Peat and Blended B/C interface for all tree species investigated.

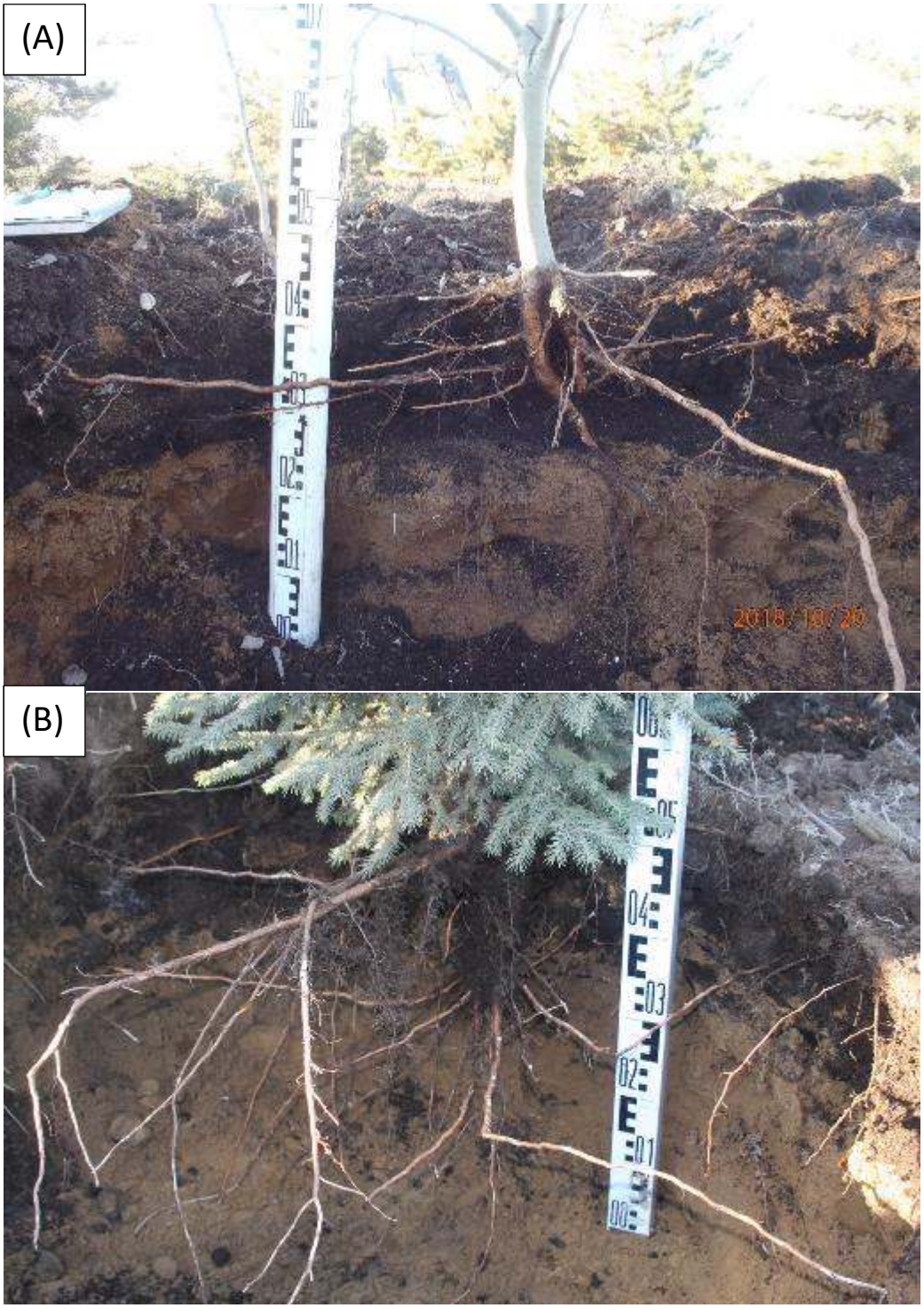

Figure 3.2.35. Treatment 10 inspection location area; (A) Tree 49 (spruce) and (B) Tree 50 (aspen).

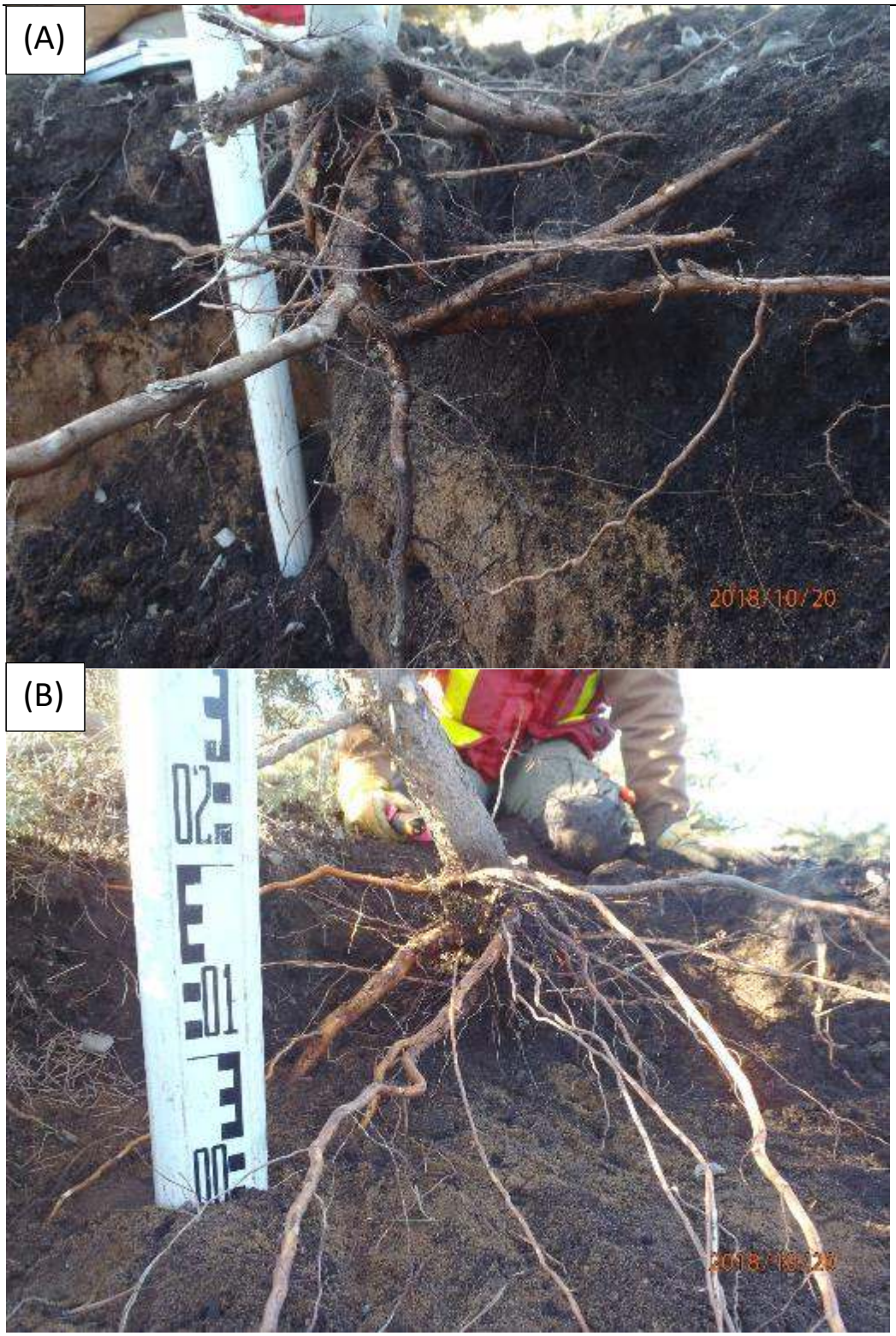

Figure 3.2.36. Treatment 10 inspection location area; (A) Tree 50 (aspen) and (B) Tree 51 (pine).

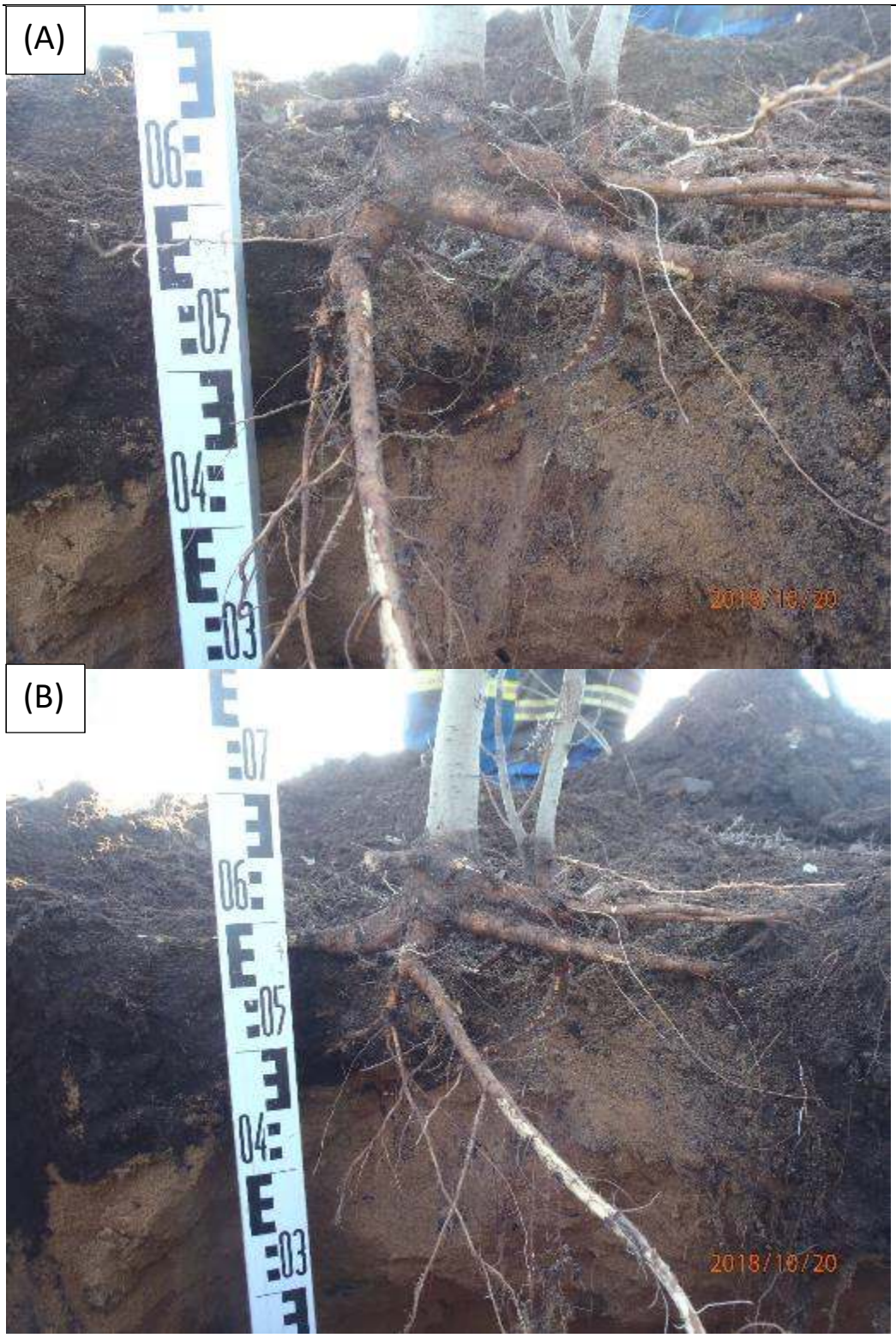

Figure 3.2.37. Treatment 10 inspection location area; both (A) and (B) show Additional Aspen 1.

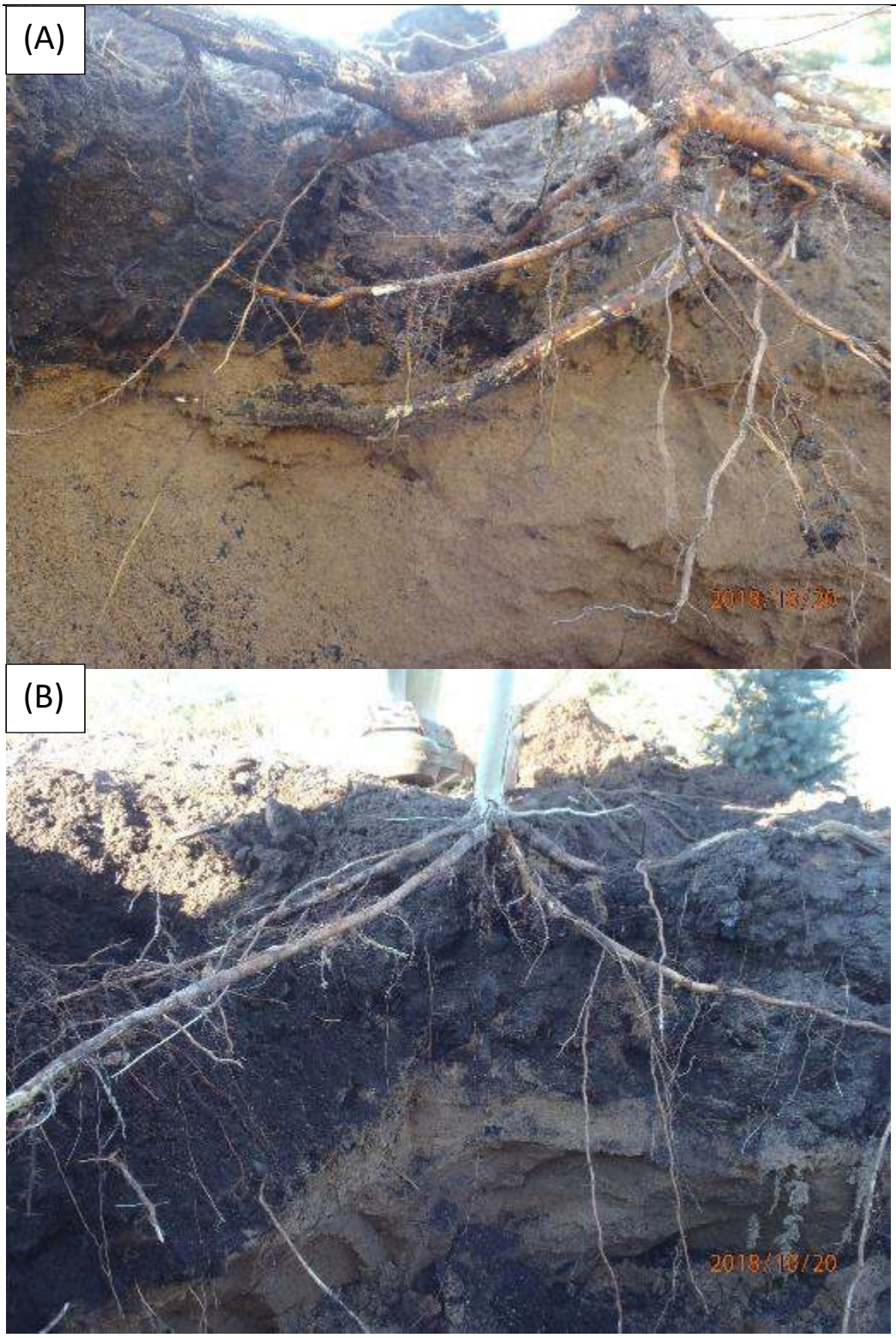

Figure 3.2.38. Treatment 10 inspection location area; (A) Additional Aspen 1 and (B) Additional Aspen 2.

Figure 3.2.39. Tree height, maximum and effective root depth for Treatment 10 (30 cm Peat/120 cm Blended B/C). Note: Aspen (50) maximum root depth unconfirmed.
Bars represent individual trees measured on site with the tree number displayed in parentheses within the bar. Data used to develop this figure can be found in Appendix B.

3.2.8 **Treatment 11 (30 cm Peat/70 cm Blended B/C)**

- Photos are provided of the inspected trees in Figures 3.2.40 to 3.2.43.
- Two test pits were dug in Treatment 11 to evaluate 3 individual trees (Figure 3.2.44; Table B.2.8).
- Roots were relatively evenly distributed around the base of the tree for all 3 species evaluated.
- Effective rooting depth was essentially the depth of the Peat horizon; few roots were observed in the materials below the 30 cm Peat horizon.
- The aspen had a high volume of primary and secondary roots (plentiful to abundant) near the base of the tree and along the length of the primary roots exposed.
- Secondary roots were more abundant on aspen in Treatment 11 than observed in other 30 cm Peat treatments (Table B.2.8).
- For the aspen, the exposed root branched at 1.3 m and there were multiple suckers within 30 cm of the branching.
- Very few roots were observed in the Blended B/C (Figure 3.2.44); aspen roots were observed to border from oblique/vertical to horizontal in a 90 degree turn at the surface of the Blended B/C material (Figures 3.2.42 and 3.2.43).

Figure 3.2.40. Treatment 11 inspection location area trench photo.

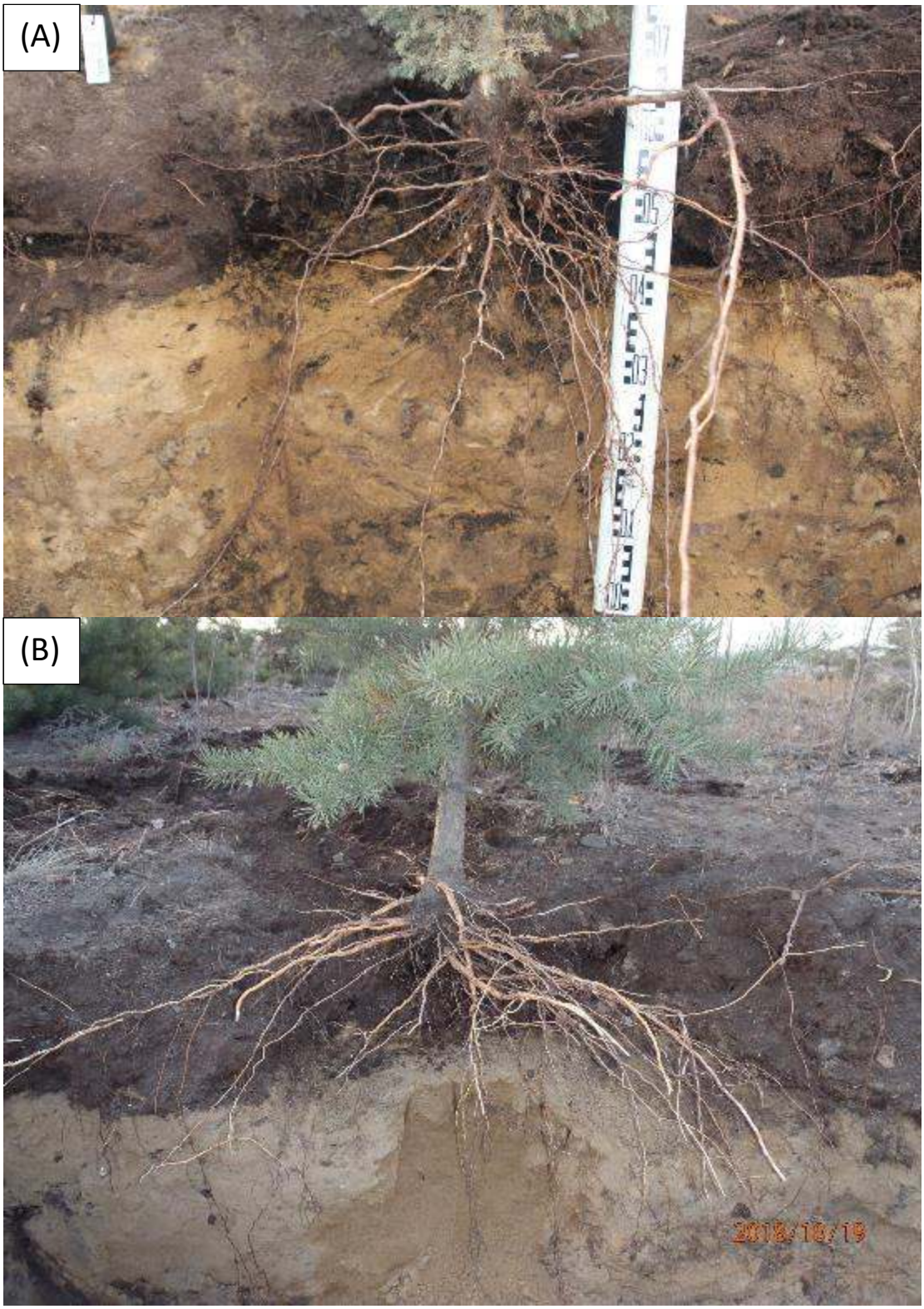

Figure 3.2.41. Treatment 11 inspection location area; (A) Tree 43 (spruce) and (B) Tree 44 (pine).

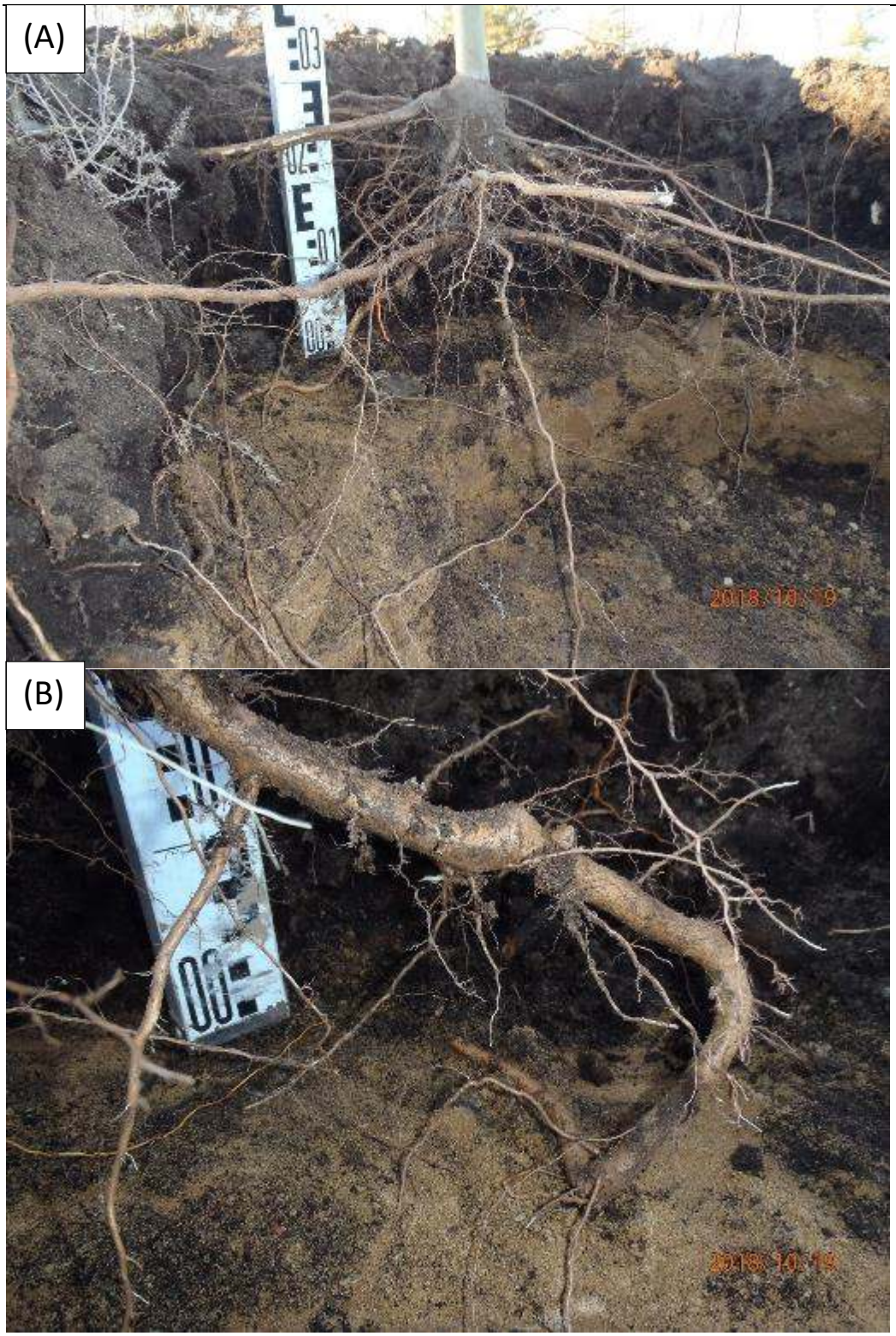

Figure 3.2.42. Treatment 11 inspection location area; both (A) and (B) show Tree 45 (aspen).

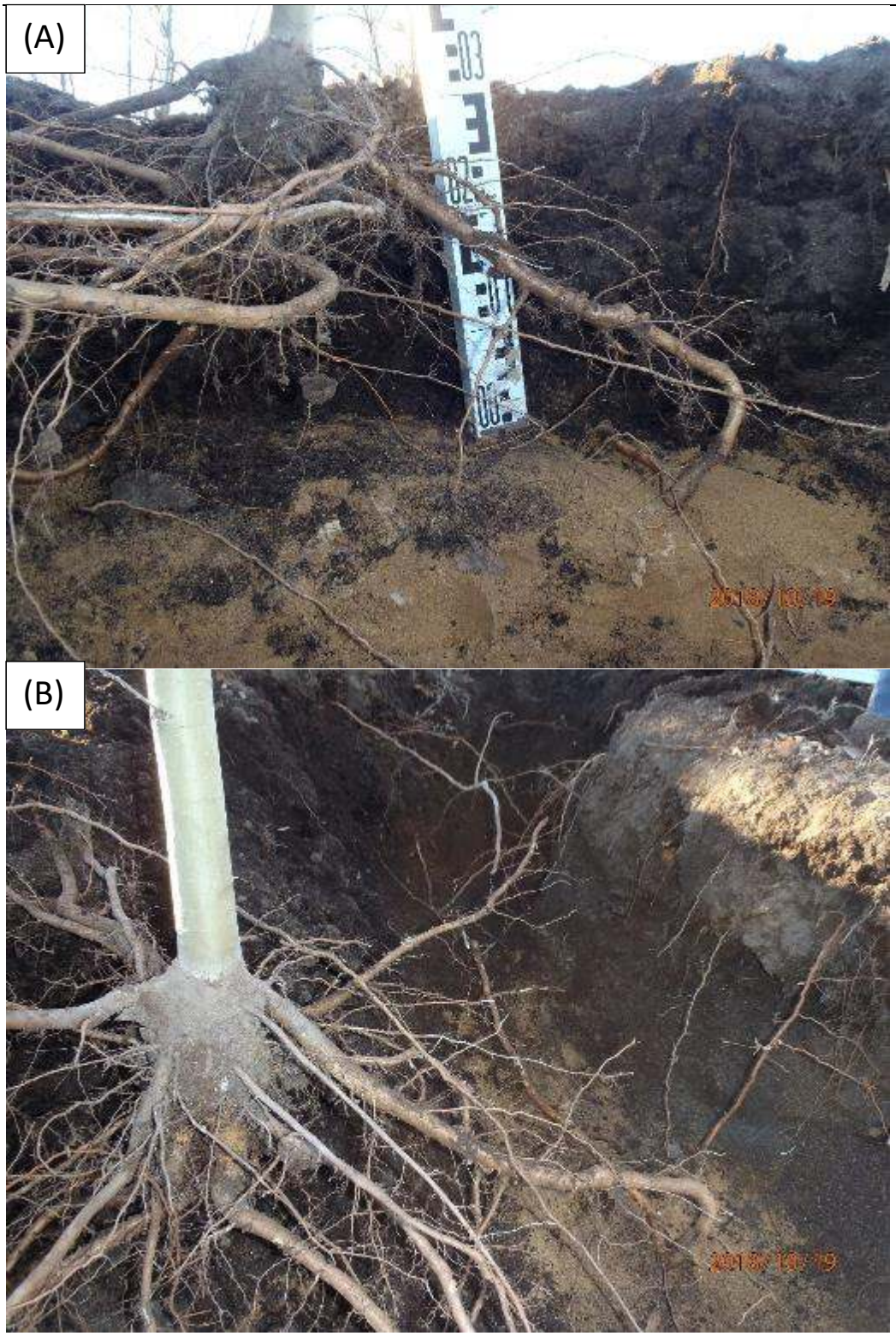

Figure 3.2.43. Treatment 11 inspection location area; both (A) and (B) show Tree 45 (aspen).

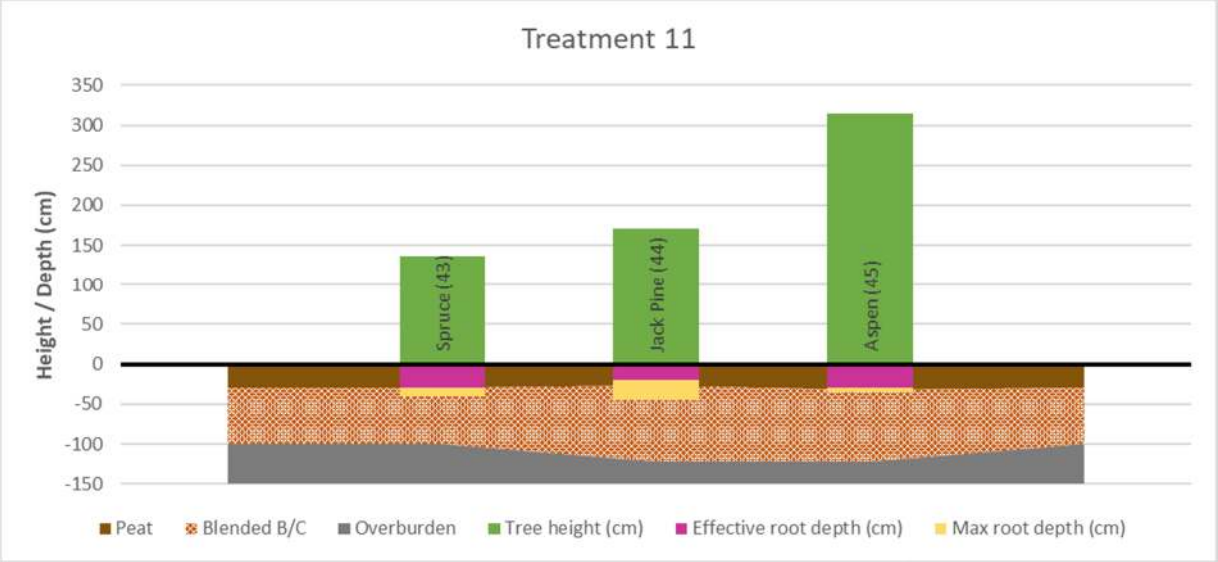

Figure 3.2.44. Tree height, maximum and effective root depth for Treatment 11 (30 cm Peat/70 cm Blended B/C). Bars represent individual trees measured on site with the tree number displayed in parentheses within the bar. Data used to develop this figure can be found in Appendix B.

3.3 TREATMENT COMPARISONS

Comparisons between treatments were completed for Treatments 1, 6, 7 and 9 (Figure 3.3.1) to determine if differences in rooting patterns and distribution could be seen between treatments with Peat vs LFH, with and without, the addition of Bm material over Subsoil. Rooting patterns within Treatments 4, 5, 10 and 11 (Figure 3.3.1) were also compared to determine if varying depths of Blended B/C material over lean oil sands overburden influenced rooting behavior when capped with the same depth of coversoil material (Peat). Data for Treatment 1, 6, 7 and 9 comparisons is provided in Table B.3.1 and Treatments 4, 5, 10 and 11 are provided in Table B.3.2 (see Appendix B).

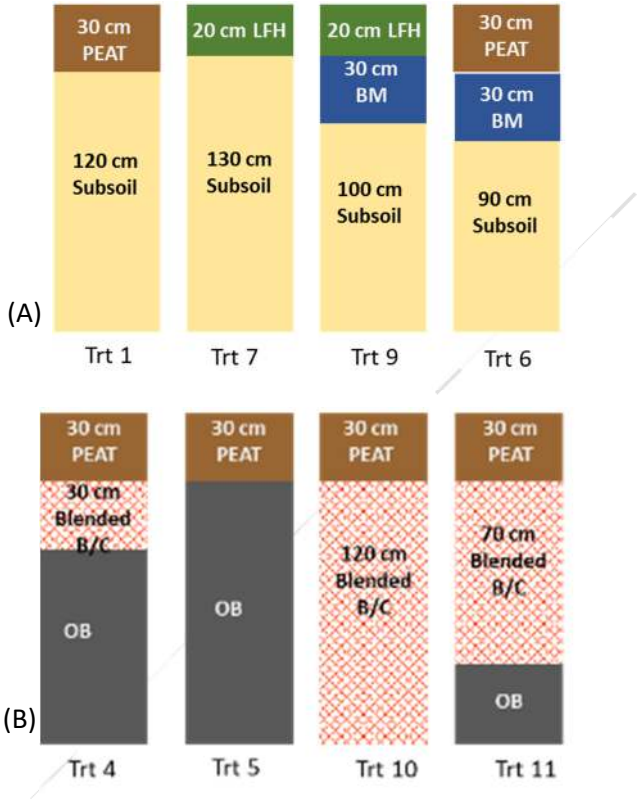

Figure 3.3.1. Aurora Soil Capping Study materials depths for A) Treatments 1, 7, 9 and 6 and B) Treatments 4, 5, 10 and 11.

General observations for Treatments 1, 6, 7 and 9 (Table B.3.1):

- Roots within treatments were generally evenly distributed around trees.
- Horizontally spreading lateral roots dominated the root systems for all species evaluated at all compared treatments.
- The effective rooting depth was deeper in treatments with the Bm horizon (20-50 cm with LFH coversoil [Treatment 9] or 30-50 cm with peat coversoil [Treatment 6]) than without the Bm horizon (with LFH [Treatment 1] or peat [Treatment 7] coversoil) for all three species evaluated.

- Maximum rooting depth was deeper in treatments with the Bm horizon (Treatment 6 and 9) than without (Treatment 1 and 7) for pine, however results were not as conclusive for spruce and aspen.
- Treatment 7 had the longest lateral observed roots for aspen and pine.
- Maximum observed root lengths varied across treatments from 2.27 to 9.96 m for aspen, 1.04 to 3.55 m for pine and 1.72 to 3.98 m for spruce.
- Within Treatment 9, roots are present in the Bm material and access the Subsoil horizon extending deeper in the profile (compared to Treatment 7 which does not have a Bm horizon from 20-50 cm).

General observations for Treatments 4, 5, 10 and 11 (Table B.3.2):

- Roots within treatments were generally evenly distributed around trees.
- Horizontally spreading roots dominated the root systems for all species evaluated at the treatments compared.
- Roots did not reach the overburden in Treatment 10 or 11.
- The effective rooting depth was within the Peat coversoil for all 4 treatments (Treatment 4, 5, 10 and 11).
- Maximum vertical rooting depth was similar between Treatments 10 and 11 and deepest in Treatment 4 which had roots growing down to the overburden for trees similar in size (or smaller) compared to the other treatments.
- The longest observed root length was aspen in Treatment 4, however aspen root lengths for Treatments 10 and 11 were more similar to Treatment 4. Root length in Treatment 5 was considerably less than Treatments 4, 10 and 11.
- Secondary roots were more abundant on aspen in Treatment 11 than observed in Treatments 4, 5, and 10.

General observations for all Treatments:

- Aspen displayed a different rooting behavior in Treatments 4, 10 and 11 compared to Treatments 1, 6 and 7. While the vertical roots of Treatments 1, 6 and 7 extend into the Subsoil, the vertical roots of trees in Treatments 4, 10 and 11 extend below the tree then transition to horizontal at, or above, the Blended B/C material.
- There was a higher density of small primary roots in Peat treatments (such as Treatment 4) compared to LFH treatments (Treatment 7) particularly for pine, and to a lesser extent, aspen.

4.0 DISCUSSION

Unexpected tree growth patterns were observed at the Aurora Soil Capping Study through 2017 and 2018, which could not be explained based on known soil conditions or trends in above-ground biometrics. These unexpected growth patterns included: (i) patterns of growth at treatment boundaries that were much better than in either of the adjacent treatments on their own, and (ii) individual trees that were growing much better than the surrounding trees in the treatment. The root evaluation was performed to assess if patterns of root growth could help to explain unexpected patterns in above-ground tree growth.

It was hypothesized that rooting behavior and distribution would differ on borders versus within treatments. We anticipated that roots would tend to spread horizontally towards the different treatments when located on borders, but when within treatments, we expected to see roots spreading both horizontally and vertically without a strong behavioral preference. It was also anticipated that, both along borders and within treatments, there would be a greater distribution of roots in organic materials, due to the availability of water and nutrients.

General observations with regards to borders and treatments are provided below. Key findings related to root growth patterns are highlighted for both borders and treatments. The findings are discussed in relation to the expected root growth behavior and distribution.

4.1 BORDER GENERAL OBSERVATIONS

- Effective root depth was much more difficult to estimate in border areas than within treatments given the differences in root distribution around the tree (generally in the direction of treatments on either side of the border) and the different soil materials and depths that are present within the profile at the border areas.
    - However, in general, it appears the effective rooting depth is confined to the coversoil material, or just below, regardless of the coversoil type and the underlying subsoil.
- Increased tree growth along border areas was observed at some locations, but not at all examined border locations. For example:
    - There was a large difference observed in aboveground tree growth along the Treatment 5/12b (30 cm peat/overburden; 150 cm subsoil) border than within the treatment cells.
    - Along the Treatment 5/6 (30 cm peat/overburden; peat/Bm/subsoil) border the trees within Treatment 6 were comparable in size to the trees growing directly on the border, however, trees within Treatment 5 were noticeably poorer (low aboveground biomass).
    - Trees within the border between Treatments 2 and 5 (10 cm LFH/subsoil; 30 cm peat/overburden) were either similar or slightly taller than trees growing within either Treatment 2 or 5.
    - Trees within the border between Treatments 5 and 9 (30 cm peat/overburden; LFH/Bm/subsoil) were similar in size to trees growing within either Treatment 5 or 9.

- Aspen growing in coarse-textured subsoil materials—such as Treatment 12b (150 cm subsoil) and/or treatments with relatively thin organic surface materials (*e.g.*, Treatment 3 (10 cm Peat))—had a low volume (few to plentiful) of fine and small primary and secondary roots at the base of the tree and along the length of the exposed roots.
- Root length was less in Treatment 12b (150 cm subsoil) than Treatment 5 (30 cm peat); root orientation was also different, being primarily horizontal in Treatment 5 and transitioning to vertical within meters from the tree in Treatment 12b.
- Treatments adjacent to Treatment 5 (30 cm peat) had higher moisture content close to the border, which may have resulted from water accumulating at the surface of the overburden in Treatment 5 and flowing laterally into adjacent Treatments.

Key findings from the borders that were studied include:

- Primary roots in border areas were generally found to be growing in the direction of the treatments (*i.e.*, primarily extending in 2 directions to exploit the benefits that each treatment provides for their growth) (Figure 4.1.1).
- All species are influenced by the horizon interfaces and have an increase in root density. It's not clear if the increase of roots at the interfaces is due to a preference to remain in the above horizon and/or due to a restriction or limitation in the underlying horizon. However, in the case of the LOS overburden, the roots are likely restricted from rooting because of structure/consistence limitations (Figure 4.1.2).
- The largest diameter primary roots grew towards the Peat coversoil treatments (for all species; more pronounced in aspen), particularly at the border investigation area between Treatment 5 (peat coversoil) and 12b (subsoil) (Figure 4.1.1).

In some cases, patterns of above-ground growth at treatment boundaries were noticeably better than in either of the adjacent treatments. Given the observed rooting patterns, the availability of varying soil materials to trees along borders could play a role. For example, roots of trees along borders tended to grow in the direction of the treatments, as we had expected, and not along the border itself; it appears that roots may be accessing resources from materials present in both treatments. Roots also tended to use the interfaces between reclamation materials, which suggests they could be accessing resources from a variety of materials. It appears that trees growing along borders tended to utilize peat material when it was an adjacent treatment, particularly when the other treatment had little organic matter; this finding is in alignment with our hypothesis that there would be a greater distribution of roots in organic materials. The availability of a variety of materials could play a part in exceptional growth of trees along select borders.

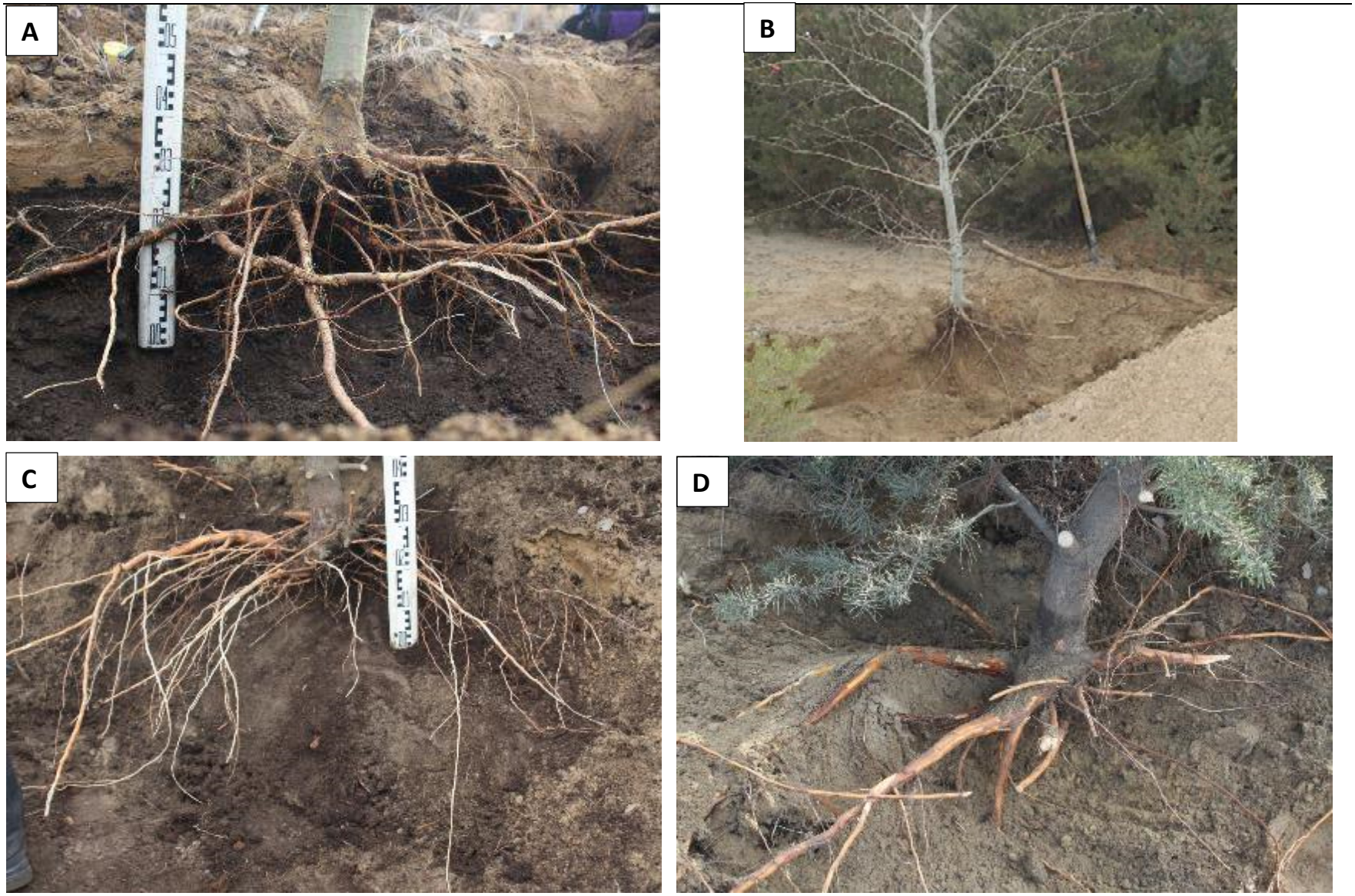

Figure 4.1.1. Rooting pattern for aspen (A and B) and pine (C and D) at the border between Treatment 5 and 12b.

Figure 4.1.2. Rooting pattern for aspen (A) and spruce B) at the border between Treatment 3 and 12b and spruce at the border between Treatment 5 and 2 (C).

4.2 TREATMENT GENERAL OBSERVATIONS

- Roots generally avoid the lean oil sand overburden substrate or are unable to effectively root in the overburden material.
- Roots were generally evenly distributed around trees when growing within treatments, whereas in border areas primary roots were often found to be growing in the direction of the treatments.
- In shallower Peat and LFH coversoil treatments (*i.e.*, 10 cm), roots were observed more frequently at the interface or below the coversoil horizon, whereas in the deeper Peat and LFH coversoil treatments (*i.e.*, 20 to 30 cm) the majority of roots were often within the coversoil horizon.
    - May indicate that deeper coversoil horizons do not necessarily result in deeper rooting.
- Aspen growing in treatments with >20 cm organic substrate (either LFH or Peat) above a coarse-textured substrate (*e.g.*, Treatments 1, 4, 6, 7, 9, 10 and 11) had a higher volume of primary and secondary roots near the base of the tree compared to aspen growing in treatments with no coversoil horizon (Subsoil only such as Treatment 12b) or treatments with a thinner coversoil horizon depth (*e.g.*, Treatment 3 (peat/subsoil)). There were also more secondary roots along the length of the primary roots exposed in the treatments with >20 cm of LFH or Peat compared to treatments with no or <20 cm Peat/LFH.
- The volume of roots (small to medium; 2 to <5mm and 5 to <20 mm diameter) for pine and spruce trees was higher (abundant) in deeper Peat coversoil treatments (*e.g.*, Treatment 4 (peat/blended BC/OB)) compared to shallower Peat coversoil treatments (*e.g.*, Treatment 3 (peat/subsoil)) or LFH treatments (*e.g.*, Treatment 7 (LFH/subsoil)) (Figure 3.3.1).
- Maximum rooting depth (MRD) appeared to be correlated with coversoil material (*i.e.*, MRD of Peat < LFH, or MRD in Treatments 10 (peat/blended B/C) and 11 (peat/blended B/C) < Treatments 9 (LFH/Bm/subsoil) and 2(LFH/subsoil)).
- The presence of Bm material appeared to influence rooting patterns and distribution differently depending on the surface treatment material (Peat or LFH), and/or placement depths (thicknesses) of materials (20 vs 30 cm).
    - Within Treatment 9 (LFH/Bm/subsoil) roots utilized the Bm and accessed the underlying Subsoil, extending deeper in the profile; within Treatment 7 (LFH/subsoil), the Subsoil was more shallow but the roots did not extend as deep.
    - However, within Treatment 6 (peat/Bm/subsoil), aspen appeared to avoid the Bm horizon. Roots extended back to the surface and did not root into the Bm horizon.
    - It appears that root development is affected by coversoil material type. Roots demonstrated a preference to remain in the peat coversoil when overlying coarse textured subsoil materials, however behaved differently and were frequently observed in subsoil materials when LFH was used as the coversoil material. Roots may not

recognize the interface between LFH coversoil and subsoil material and/or require additional resources unavailable in the LFH material.

- Roots generally remain within the coversoil in treatments which have Blended B/C subsoil.
    - Aspen, spruce and pine roots in Treatment 10 (peat/blended B/C) generally remain in the peat coversoil rather than root into the underlying Blended B/C subsoil. It's not clear if this is due to a preference for roots to remain in the peat coversoil or due to a limitation of the underlying subsoil material.
    - Aspen roots in Treatment 11 (peat/blended B/C/OB) grew along the interface between Peat and Blended B/C, however few roots were observed within the Blended B/C. Similar rooting behavior was observed for Spruce. Pine primary and secondary roots were observed to extend into the Blended B/C, however the roots did not extend deep within the material.
    - Few secondary roots extending into Blended B/C in Treatment 4 (peat/blended B/C/OB).

Key findings for the treatments that were studied include:

- Roots were generally evenly distributed around trees when growing within treatments.
- Effective rooting depth was observed to be primarily within the coversoil for treatments with a 30 cm Peat layer.
- Maximum rooting depth was higher in treatments containing a Bm horizon (three horizons versus treatments with two horizons), even if the treatment had the same depth of coversoil (*e.g.*, Treatment 7 versus Treatment 9).
- The presence of the Blended B/C subsoil within the rooting zone influenced rooting behavior. Aspen roots, more so than pine or spruce generally remain in the coversoil horizon rather than rooting down into the Blended B/C subsoil.
- The three horizon treatments with LFH coversoil (Treatment 9) had rooting below 1 m. However, for Peat coversoil treatments rooting depths reached 70 cm in Treatment 4 and only 38 cm in Treatments 10 and 11.

Roots did not behave quite as expected within treatments. While roots did tend to show higher distribution in organic materials, rooting behavior (i.e., vertical and horizontal distribution) varied depending on the soil materials present. The presence of a Bm horizon and the presence of an LFH coversoil both appeared to be associated with greater maximum rooting depths. Like the borders, the availability of a greater number of soil materials could be a factor related to tree growth. For deeper peat and LFH treatments (*i.e.*, 20 to 30 cm), majority of roots were typically found within the coversoil, but in shallower coversoil treatments (*i.e.*, 10 cm), roots were frequently observed at the interface or below the coversoil horizon. When the coversoil was deeper (*i.e.*, 20 to 30 cm), roots tended to avoid subsoil material, possibly because they are able to get the resources they require mainly from the deeper coversoil. The data collected on root growth patterns helps to inform possible reasons why some treatments appear to be performing better than others, in terms of above-ground tree growth. The

mechanisms influencing tree growth (such as nutrient or water availability and utilization, soil temperature, etc.) would require further research.

4.3 ADDITIONAL OBSERVATIONS

- Spruce roots were found growing through LFH and Subsoil into a Peat inclusion approximately 45 cm below the ground surface at the border between Treatments 2 and 5 (Tree #60) (Figure 4.3.1).
- Aspen root observed to graft onto spruce roots in Treatment 1 (Tree #37) (Figure 4.3.2).

Figure 4.3.1. Spruce roots growing through LFH and Subsoil into Peat inclusion approximately 45 cm below ground surface.

Figure 4.3.2. Aspen root observed to graft to spruce root in Treatment 1.

5.0 CONCLUSIONS

Assessment of root growth patterns and distribution at the Aurora Soil Capping Study provided insight into possible reasons for unexpected above-ground tree growth observed on site, and may prove valuable for informing future reclamation practices and avenues of future research. Trees tended to perform well when they had access to a variety of soil materials *(i.e.,* on borders where there was access to organic materials in adjacent treatments, and within treatments when soil profile with multiple horizons was present). The distribution of roots tended to be greatest in organic soil materials. Roots tended to avoid overburden and some subsoil material (sometimes showing abrupt changes of direction to avoid certain materials) or remain along the interface between soil horizons. Trees showed adaptability to different soil conditions, (*i.e.,* moisture, nutrients) via root systems that appeared to respond to the varying material types present on site. Varying soil materials and their distribution across the landscape may provide a benefit to trees growing on reclamation sites.

APPENDIX A – FIELD METHODOLOGY

Pre-Trench Data Collection

1. Recorded Treatment (*i.e.*, reclamation material) where the evaluation occurred according to the Syncrude "as built" provided.
2. Identified the trees to be investigated within a trench or test-pit.
3. Recorded GPS location of profile evaluated.
4. Recorded the general location of the tree in proximity to the treatments (*i.e.*, how far away from the border is the tree?).
5. Took quantitative and qualitative measurements of the trees, including:
    a. Tree species,
    b. Base diameter,
    c. Diameter at breast height (1.3 m) (DBH),
    d. Tree height,
    e. Presence and number of lateral surface roots, and
    f. Comments regarding overall tree health and comparison to surrounding trees.
6. Hand exposed the base of the tree for approximately 10-15 cm to determine the extent of the horizontal roots of the tree and the best location for the trench to be dug. Horizontal roots that intersected the trench were cut with a saw to ensure the tree position was not compromised.

Excavating the Trench

7. A trench was dug by a mini-excavator as close as possible to the tree(s) to maximize root exposure of investigated tree(s). In general, each trench was one width of the bucket wide and never more than 1.5 m deep (shallower depths were suitable if it was obvious that the maximum rooting depth has been identified, or if it was determined that it would be easier to hand expose deeper). The length depended on the proximity of the trees evaluated. The trenches included an inclined ramp at one end of the trench for a safe point of entry/exit. Considerations for trenches included the following:
    a. Trench walls were as close to vertical as possible.
    b. A spotter was always present during trench excavation. Workers were made aware of the potential for falling trees when excavating and working in the appropriate safety measures were taken to secure the trees.
    c. The spoil pile(s) were located at an adequate distance from the excavation to ensure it will would not pose a risk of sloughing back into the excavation. All efforts were made to ensure the treatment materials are stored separately, to allow for replacement back into the trench in the appropriate order.

Soil Data Collection

8. A 1.0 m wide area with equal distances on either side of the base of the tree was established to expose the tree roots. Efforts were made to ensure the width remained consistent (*i.e.*, 1.0 m) for appropriate photos, however the depth varied between pits/profiles.
9. The depth of each reclamation material within 1 meter (50 cm on either side of the tree) measured and an average was recorded.

10. Any anomalies or observations where the soil may be influencing root growth/patterns were noted.

Exposing the Root System

11. The face(s) of the trench or test-pit was cleaned with handheld tools (soil knife, shovel, trowel, small rake, etc). If a trench was constructed between trees, both trench wall faces were cleaned.
    a. The surface soil was excavated first followed by gradually working downward into the face of the exposed profile.
    b. Where feasible, the soil was removed in a direction parallel to the roots to avoid breaking finer roots.
12. The roots were exposed as thoroughly as possible without damaging them where possible to create as much contrast between the roots and soil.
13. At borders, the largest primary root growing in the direction of each treatment was hand exposed with a shovel (*i.e.*, north and south) (Minimum of 1 root exposed / treatment to measure the total length). Within treatments, only 1 root was hand exposed to measure root length.

Photos

14. The measuring pole was placed vertically along the side of the profile.
15. A photo of the datasheet was taken to ensure it would be possible to differentiate trees during data analysis.
16. Photos of each individual reclamation material treatment were taken as consistent as possible between inspection locations. Photo number (from the camera) was recorded on the datasheet.
17. If possible, a full photo of the profile was obtained.
18. A photo with and without the grid on the profile was taken.
19. Additional photos that were relevant to project were taken (surrounding area, trench, etc.).

Root Data Collection

20. The total observed root length of each root exposed was recorded;
    a. Measured and recorded the diameter of the exposed root at the base of the tree;
    b. Measured and recorded the diameter of the exposed root at the final measurement point (either the end of the root or where it broke off);
    c. Measured and recorded the diameter of the exposed root at the mid-point; and
    d. Measured and recorded the average depth of the exposed root.
21. Recorded the number of primary roots and the associated diameters.
22. Recorded the orientation of the primary roots.
23. Recorded the distribution of primary roots around the tree.
24. Within each reclamation material recorded the abundance of fine, small, medium and coarse roots within one meter of the tree (0.5 m on either side of the trunk), using the table provided:

Class	Average number/square decimeter (10 x 10 cm)					
	Very fine (<1mm)	Fine (1 - <2 mm)	Small (2 - <5 mm)	Medium (5 - <20 mm)	Coarse (20 - <50 mm)	Very Coarse (≥ 50 mm)
Few	10	10	<5	1	Record Actual #	
Plentiful	10-100	10-100	1-10	1-5		
Abundant	>100	>100	>10	>5		

25. Recorded the presence/absence of a tap root (central root growing vertically from the base of the tree).
26. Estimated the % of roots (area) within each reclamation material.
27. Estimated the effective rooting depth - defined as the depth at which 80% of the roots were present.
28. Recorded the maximum observed rooting depth.
29. Recorded any comments and/or observations to help explain the rooting patterns and/or distribution within the soil profile.

APPENDIX B – DATA TABLES

This appendix contains tables which summarize the data collected (i) along select borders between treatments, (ii) within select treatments and (iii) for treatment comparisons. Data from these tables was used to inform the Results, Discussion, and Summary and Conclusions.

B.1 SELECT BORDERS BETWEEN TREATMENTS

Table B.1.1. Transition between Treatment 5 (30 cm Peat) and Treatment 2 (10 cm LFH/140 cm Subsoil (>1 m)) root observations.

Parameter	Spruce				Spruce				Spruce			Aspen				Pine			
Tree #	59				60				62			61				63			
Tree Height (m)	1.63				2.19				1.01			5.6				3.95			
Basal Diameter (mm)	46.9				45.7				27.07			79				n/a			
DBH (mm)	9.55				17.56				5.36			49				70.96			
Tree Location	In Treatment 5, grading into LFH treatment; LFH/subsoil present on east side of soil profile				Tree located on Border approximately 1 m N of where Treatment 5 peat ends				Tree located on the Treatments 2/5 border, within Treatment 2			Tree located ~ 4 m North of Treatment 5 on border between cells				Tree is located ~ 10 m North of Treatment 5 well within Treatment 2			
Material	**LFH**	**Peat**	**Subsoil**	**OB**	**LFH**	**Peat**	**Subsoil**	**OB**	**LFH**	**Peat**	**Subsoil**	**LFH**	**Peat**	**Subsoil**	**OB**	**LFH**	**Peat**	**Subsoil**	**OB**
Depth (cm)	n/a	0 to 30	n/a	>30	0 to 8-10	n/a	8-10 to 45	ranges from starting at 30 to 70 w/in 1 m of tree	0 to 9	n/a	>9	0 to 8-0	n/a	8-10 to 40-50	>50	0 to 16	n/a	16 to OB	n/a
% roots in material		100		0	Shallow nature of LFH makes it very difficult to estimate				90		10	unconfirmed		unconfirmed	none observed	85		15	
Effective Root Depth (cm)	30				15 to 20				9 (*i.e.*, LFH)			25				20 to 25			
Max root depth (cm)	30				60				30			35 (may be deeper for roots further distances from tree				>70			
Above ground tree height/ **max** root depth ratio	5.4				3.7				3.4			16.0				5.6			
Above ground tree height/ **effective** root depth ratio	5.4				11.0				11.2			22.4				15.8			
# and size (mm) of 1° roots at base of tree	9 medium (6.7 to 16.92)				2 coarse (20 to <50); 5 medium (5 to <20 mm)				8 small (2 to <5 mm) to medium (5.94 to 10.11)			2 coarse roots (40 mm+); root base is ~20 cm and has 3 whorls of roots extending out (top/mid/bottom)				2 coarse; abundant (>5) medium (2 sizes 15 to 20 and 5 to 12 mm)			
Root orientation	1° and 2° roots horizontal				Few oriented E/W along border; 1 coarse root extends S into Treatment 5; 1 coarse root extents N into Treatment 2; 1 medium root extends vertically into subsoil; remainder are horizontal medium roots that extend along LFH/subsoil interface				Horizontal and oblique			1° roots mainly horizontal, 1 vertical; abundant fine 2° roots coming from 1° roots all extending oblique/horizontal from tree (none extend very deep)				Horizontal; majority of roots observed to grow along interface between LFH and subsoil; 2 vertical/oblique roots			
Direction of horizontal roots (distribution around tree)	90% headed toward Treatment 2 (LFH Treatment)								1° roots mostly growing in N and S directions (no obvious preference for one treatment vs the other)			Majority of 1° roots on W and S side of tree; more branches into 2° roots on Treatment 2 side of tree; bottom 'whorl' of roots evenly distributed				Fewer roots on E side, evenly distributed on all other sides			

Parameter	Spruce		Spruce		Spruce		Aspen	Pine	
Max observed root length (m)	Trmt 2 - 1.37	Trmt 5 - 2.49	Trmt 2 - 0.60	Trmt 5 - 1.99	Trmt 2 - 0.52 (broken tip)	Trmt 5 - 1.75	Trmt 5 - 12.53	Trmt 5 - 3.66	Trmt 2-1.59
Exposed Root diameter at tree (mm)	Trmt 2 - 7.4	Trmt 5 - 9.0	Trmt 2 - 17.44	Trmt 5 - 23.22	Trmt 2 - 3.98	Trmt 5 - 5.05	Trmt 5 - 4.7	Trmt 5 - 9.22	Trmt 2-16.23
Average depth of exposed root (cm)	Trmt 2 - no data	Trmt 5 - 8	Trmt 2- 60	Trmt 5 - 10 to 30	Trmt 2 - 6	Trmt 5 - 5	Trmt 5 - 12 (deepest depth observed was 35 cm)	Trmt 5 - 15 to 20	Trmt 18 2- (at the end)
Root diameter at midpoint (mm)	Trmt 2 - no data	Trmt 5 - 4.79	Trmt 2 - no data	Trmt 5 - no data	Trmt 2 - 2.8	Trmt 5 - 1.7	Trmt 5 - n/a	Trmt 5 - 3.54	Trmt 2-no data
Root diameter at end (mm)	Trmt 2 - 0.78	Trmt 5 - 1.18	Trmt 2 - 1.61	Trmt 5 - 4.62	Trmt 2 - 1.76	Trmt 5 - 0.64	Trmt 5 - 0.84	Trmt 5 - 2.44	Trmt 2-1.93
Abundance fine (1<2 mm) roots	Plentiful (10 to 100) 1°, 2° and 3°		More branching on Treatment 2 side of tree w/ greater abundance of 2° and 3° fine roots.		Abundant (>100) 2° and 3°		Abundant (>100) 2°	Plentiful (10 to 100) 1°	
Abundance small (2 to <5 mm) roots	Abundant (>10) 2°		Abundant (>10) 1° extending from bottom		Plentiful (1-10) 1° and 2°		Abundant (>10) 1° and 2°	Plentiful (1 to 10) 1°; Few (<10) 1° (extend vertically into subsoil)	
Abundance medium (5 to 20 mm) roots	Abundant (>5) 1°		Plentiful (1 to 5) 1°		Plentiful (1-5) 1°		Abundant (>5) 1°	Abundant (>5) 1°	
Abundance coarse (20 to <50 mm) roots	None		2		None		2	2	
Root Notes	Roots observed along the peat/overburden interface but stay in the peat; no roots observed in overburden		Large peat inclusion below subsoil directly under tree at 45 cm depth; tap root extends to >60 cm down to Peat Inclusion; Exposed root 1 extents S into Treatment 5 and follows LFH/subsoil interface horizontally and then peat/OB interface; Exposed root 2 extends N into Treatment 2, branches into three 2° roots close to tree, 2 extend horizontally, 1 oblique into subsoil;		One 1° root grows horizontally S, does a 90° turn and grows E; one 1° root oblique to LFH/subsoil interface and grows horizontally		Exposed root extended S into Treatment 5, relatively straight line from tree, no major branching	coarse roots branches into 2 roots at ~50 cm bgs; at 70 cm bgs branches again and continues vertically; exposed root 1 growing in SW direction; exposed root 2 growing in NE direction	

Table B.1.2. Border between Treatment 1 (30 cm Peat/120 cm Subsoil (>1m)) and Treatment 3 (10 cm Peat/140 cm Subsoil (>1m)) root observations.

Parameter	Spruce		Spruce		Spruce		Spruce	
Tree #	64		65		66		67	
Tree Height (m)	1.97		1.86		1.55		0.94	
Basal Diameter (mm)	49		58		51.8		27.49	
DBH (mm)	14		12		8.55		6.44	
Tree Location	Tree located within Treatment 3		Tree located on the Treatment 1 and 3 border, north of tree #64		Tree located on the Treatment 1 and 3 border, north of Tree #64 and #65, almost within Treatment 1		Tree located within Treatment 1, beside Tree #66	
Material	**Peat**	**Subsoil**	**Peat**	**Subsoil**	**Peat**	**Subsoil**	**Peat**	**Subsoil**
Depth (cm)	0 to 10	>10	0 to 12	>12	0 to 22	>22	0 to 28	>28
% roots in material	90	10	90	10	90	10	90	10
Effective Root Depth (cm)	10		Peat + 5 cm of subsoil		22		28	
Max root depth (cm)	90		120		40		36	
Above ground tree height/ **max** root depth ratio	2.19		1.55		3.88		2.61	
Above ground tree height/ **effective** root depth ratio	19.70		10.94		0.07		0.03	
# and size (mm) of 1° roots at base of tree	3 coarse (20 to <50 mm), 6 medium (5 t0 <20 mm), with 2 emerging from top of plug, 5 from the middle, 2 from the bottom; small (2 to <5 mm) and medium secondary branching within 1 m of tree		1 coarse (20 to <50 mm), 10 medium (5 to <20 mm), and ~10 small (2 to <5 mm); roots emerging from top/middle/bottom of the pug		11 medium roots (5 to <20 mm); 2 emerging from top of plug, 5 from middle, 4 from bottom of plug; fine (1 to <2 mm) secondary branching		8 medium roots (5 to <20 mm) and 1 small root (2 to <5mm); 4 emerging from the top of the plug and 5 from the bottom; only ~7 secondary branches within 1 m grid	
Root orientation	Horizontal in peat, vertical in subsoil		Horizontal in peat, vertical in subsoil		Horizontal in peat; oblique, turning horizontal about 40 cm depth in subsoil		Horizontal	
Direction of horizontal roots (distribution around tree)	No strong preference, fewer heading into Treatment 3		Evenly distributed around the tree		Some preference for Treatment 1, overall well distributed around the tree		Evenly distributed around the tree	
Max observed root length (m)	Trmt 1 - 1.86		Trmt 3 - 1.89	Trmt 1 - 3.08	Trmt 3 - 1.04	Trmt 3 - 0.93	East along border - 1.77	n/a - only one root evaluated

Parameter	Spruce		Spruce		Spruce		Spruce	
Exposed Root diameter at tree (mm)	Trmt 1 - 24.84	n/a - only one root w/in Treatment 1 evaluated	Trmt 3 - 30.38	Trmt 1 - 11.38	Trmt 3 - 4.15	Trmt 3 - 8.9	East - 6.57	
Average depth of exposed root (cm)	Trmt 1 - 5		Trmt 3 - 5	Trmt 1 - 5	Trmt 3 - 5	Trmt 3 - 5	East - 10	
Root diameter at midpoint (mm)	Trmt 1 - 5.15		Trmt 3 - 6.25	Trmt 1 - 5.36	Trmt 3 - 2.07	Trmt 3 - 4.70	East - 2.81	
Root diameter at end (mm)	Trmt 1 - 0.26		Trmt 3 - 1.55	Trmt 1 - 1.10	Trmt 3 - 1.99	Trmt 3 - 2.84	East - 0.78	
Abundance fine (1<2 mm) roots	Plentiful (10 to 100)		Plentiful (10 to 100)		Plentiful (10 to 100)		Few (10)	
Abundance small (2 to <5 mm) roots	Plentiful (1 to 10)		Abundant (>10)		Plentiful (1 to 10)		Plentiful (1 to 10_	
Abundance medium (5 to 20 mm) roots	Abundant (>5)		Abundant (>5)		Abundant (>5)		Abundant (>5)	
Abundance coarse (20 to <50 mm) roots	2		1		None		None	
Root Notes	Fine roots emerging from base of plug enter into subsoil with some going deep into subsoil (see max rooting depth), but for the most part roots stay in the peat or at the peat-subsoil boundary; few fine roots on primary or secondary roots, most cluster off of plug		No taproot; few secondary branching overall but many small roots emerging from the base of the plug		2 roots emerging from the bottom of the plug are oblique, then turn horizontal at ~40 cm depth; more fine roots observed than Tree 64 and 65; more small and medium roots (with fine root forks) observed deeper in the soil than Tree 64 and 65		Most primary roots horizontal in peat; one primary root emerges from bottom of the plug and after 10 cm turns 90 degrees to travel horizontally ~3 cm into the subsoil; one primary root from the top of the plug goes vertical through peat and subsoil, then 3 cm into subsoil to turns horizontal; more fine roots in subsoil compared to peat; roots travelling towards Treatment 3 stay in the peat while roots travelling into Treatment 1 dip just into the subsoil	

Table B.1.3. Border between Treatment 3 (10 cm Peat/140 cm Subsoil (>1m)) and Treatment 12b (150 cm Subsoil) root observations.

Tree Species	Spruce		Spruce		Pine			Pine			Aspen		Aspen
Tree #	10		15		11			13			12		14
Tree Height (m)	1.3		1.15		2.57			1.5			6.45		2.55
Basal Diameter (mm)	38.55		40.18		63.94			49.58			102.43		5.05
DBH (mm)	6.2		6.22		27.41			10.34			64.04		21.19
Tree Location	Tree located directly on border between treatments, closer to Treatment 3		On border closer to Treatment 12b		Tree located directly on border between treatments, closer to Treatment 3			Tree located directly on border between treatments			Tree located directly on border between treatments		On north edge of border, more within treatment 12b
Material	**Peat**	**Subsoil**	**Peat**	**Subsoil**	**Windblown Subsoil**	**Peat**	**Subsoil**	**Windblown Subsoil**	**Peat**	**Subsoil**	**Peat**	**Subsoil**	**Subsoil**
Depth (cm)	0 to 7	7 to >100	0 to 10	10 to >60	0 to 3	3 to 14	14 to >75	0 to 3	3 to 11	11 to >100	0 to 10	10 to >100	0 to >100
% roots in material	70	30	50	50	75		15	70		30	70	30	70% in top 30 cm, 30% below 30 cm
Effective Root Depth (cm)	Approximately 40		Difficult to determine, approximately 25		Approximately 20 to 25			Approximately 30			Approximately 20		Approximately 40
Max root depth (cm)	115		No data		30			150			60		60
Above ground tree height/ **max** root depth ratio	1.13		No data		8.57			1.0			12.9		4.25
Above ground tree height/ **effective** root depth ratio	3.25		4.60		10.28			5.0			32.25		6.38
# and size (mm) of 1° roots at base of tree	6 medium (5 to <20 mm); 3 small (2 to <5 mm) and 1 medium (5 to <20 mm) 2°		8 medium (5 to <20 mm); 5 small (2 to <5) 2°		13 medium (5 to <20 mm); >30 small (2 to <5 mm) 2°			6 medium (5 to <20 mm) and 7 small (2 to <5 mm); >20 2°			5 coarse (20 to <50 mm), 4 medium (5 to <20 mm); ~20 small (2 to <5 mm) 2° roots observed within 1 m grid		2 coarse (20 to <50 mm) and 9 medium (5 to <20 mm); 9 small (2 to <5 mm) 2°
Root orientation	Horizontal within the top 20cm, vertical at depths >20cm		Horizontal; some oblique in subsoil		Horizontal within the top 20 cm; few, small vertical roots below a 20 cm depth			Horizontal on Treatment 3 side of tree; mostly vertical on Treatment 12b side of tree with some oblique			Horizontal		1° horizontal, 2° oblique
Direction of horizontal roots	Distributed evenly around the tree; 3 1° roots into Treatment 3, 2 1° roots into Treatment 12b, 1 vertical		Distributed evenly around the tree, with largest root heading east along the border		Distributed evenly around the tree but longer roots towards Treatment 3; 4 headed to Treatment 12b, 5 to Treatment 3, 2 east, and 2 west			Distributed evenly around the tree			Distributed evenly around the tree		Distributed evenly around the tree
Max observed root length (m)	Trmt 3 - 2.13	Trmt 12b - 2.24	Trmt 3 - 1.53	Trmt 12b - 1.04	n/a	Trmt 3 - 3.4	Trmt 12b - 2.42	n/a	Trmt 3 - 9.95	Trmt 12b - 1.28	7.25		4.8

Tree Species	Spruce		Spruce		Pine			Pine			Aspen	Aspen
Exposed Root diameter at tree (mm)	Trmt 3 - 13.1	Trmt 12b - 12.73	Trmt 3 - 9.4	Trmt 12b - 6.44		Trmt 3 - 9.9	Trmt 12b - 17.98		Trmt 3 - 13.43	Trmt 12b - 8.18	22.35	17
Average depth of exposed root (cm)	Trmt 3 - 5	Trmt 12b - 3	Trmt 3 - <10	Trmt 12b - <10		No data	No data		No data	No data	25, but at ~6 m length root went vertical	5
Root diameter at midpoint (mm)	Trmt 3 - 2.59	Trmt 12b - 4.6	Trmt 3 - 2.39	Trmt 12b - 2.35		Trmt 3 - 2.08	Trmt 12b - 6.25		Trmt 3 – 3.0	Trmt 12b - 4.56	No data	5.18
Root diameter at end (mm)	Trmt 3 - 0.63	Trmt 12b - 3.26	Trmt 3 - 0.35	Trmt 12b - 0.92		Trmt 3 - 0.93	Trmt 12b - 1.24		Trmt 3 - 0.9	Trmt 12b - 1.84	4.84	3.75
Abundance fine (1<2 mm) roots	Top 20 cm abundant (>100), >20cm plentiful (10 to 100)		Plentiful (10-100)		Top 20cm plentiful (10 to 100), >20cm few (1)			Few (<10)			Plentiful (10 to 100)	Few (<10)
Abundance small (2 to <5 mm) roots	Top 20cm abundant (>10), >20cm few (1)		Plentiful (1-10)		Top 20cm abundant (>10), >20cm few (1)			Abundant (>10)			Abundant (>10)	Abundant (>10)
Abundance medium (5 to 20 mm) roots	Top 20cm abundant (>5), >20cm few ((1)		Abundant (>5)		Top 20cm abundant (>5), >20cm none			Plentiful (1 to 5)			Abundant (>5)	Abundant (>5)
Abundance coarse (20 to <50 mm) roots	None		None		None			None			5	2
Root Notes	Taproot emerges oblique and becomes vertical; peat depth was highly variable (0-3 to 0-14 cm); smaller primary roots had many small secondary roots		No taproot, but a mass of fine and small roots off the plug; roots clustered at the peat/subsoil interface; roots occupied the upper subsoil but were not deep		No taproot even though no root restriction present; roots dominantly horizontal			Small vertical tap root; roots mostly present in peat and upper subsoil; one root runs oblique into the subsoil and then below 20 cm depth switches to vertical; fewer thick roots at Treatment 12b side of tree			No taproot; roots primarily horizontal along the transition between peat and subsoil; for root length data, direction of root was not recorded	No taproot; for root length data, root traveled east along the border and at 4.8 m plunged deeper than 80 cm

Table B.1.4. Border between Treatment 5 (30 cm Peat) and Treatment 6 (30 cm Peat/30 cm Bm/90 cm Subsoil (>1m)) root observations.

Parameter	Jack Pine			Jack Pine		Jack Pine		Spruce			Spruce				Aspen		Aspen		
Tree #	27			32		33		28			30				29		31		
Tree Height (m)	1.3			1.87		0.92		1.44			1.68				2.05		3.77		
Basal Diameter (mm)	44			59		22.05		40			47				no data		48		
DBH (mm)	n/a			15		n/a		8			12				no data		32		
Tree Location	~2.7 m south of border of Treatment 5; well within Treatment 6			entirely w/in treatment 5		entirely w/in treatment 5 (North of border by ~ 10 m)		directly on border between treatments 5 and 6; OB ranges from 17 to 40 cm below sand w/ 1 m of tree; no obvious subsoil; admixing with Bm along border			Entirely w/in Treatment 6 (3 to 4 meters from border to Treatment 5)				Entirely w/in Treatment 5; ~ 2 m from border		Directly on border between Treatments 5 and 6		
Material	**Peat**	**Bm**	**Subsoil**	**Peat**	**Overburden**	**Peat**	**Overburden**	**Peat**	**Bm**	**Overburden**	**Peat**	**Bm**	**Subsoil**	**Overburden**	**Peat**	**Overburden**	**Peat**	**Bm**	**Overburden**
Depth (cm)	0 to 35	35 to 60-65	60-65 to >120	0-30	>30	0 to 31	>31	0 to 30	30 to 47-70	Ranged from starting at 47 on N side of tree to 70 on S side of tree	0 to 27-35	27-35 to 53-72	53-72 to 122-133	Started at 133	0 to 30	>30	0 to 25	25 to 36-39	>39 (directly below tree)
% roots in material	80	15	5	100	0	100	0	90	10	0	84	13	2	0	100	0	90	10	0
Effective Root Depth (cm)	35			20		30 (*i.e.*, peat)		30 (*i.e.*, peat)			~30 (*i.e.*, peat)				30 (*i.e.*, peat)		25		
Max root depth (cm)	~120			30 (depth of overburden)		30 (*i.e.*, no roots observed in OB)		Max rooting depth was depth of OB (which was variable on border); no roots observed w/in OB			~100				30 (no roots observed w/in OB)		no roots observed w/in OB; only fine/small roots w/in Bm		
Above ground tree height/ **max** root depth ratio	1.08			6.23		3.07		0.05			1.68				6.83		15.08		
Above ground tree height/ **effective** root depth ratio	3.71			9.35		3.07		0.05			5.6				6.83		15.08		

Parameter	Jack Pine	Jack Pine	Jack Pine	Spruce	Spruce	Aspen	Aspen
# and size (mm) of 1° roots at base of tree	5-10 (5.01 to 7.73 mm); >10 (2-5 mm)	2 coarse (20-50 mm); >5 medium (5 to <20 mm); 1-10 small (2 to <5 mm); >100 fine (1<2 mm)	>10 (2.39 to 3.72); 10 to 100 fine (1<2 mm) 2° roots from 1° roots	2 clusters of 1° roots; 1 at the soil surface (horizontal, medium (5 to 12.48 mm) evenly distributed roots); 2nd at the bottom of plug (~14 cm from soil surface; oblique, plentiful (1-5), medium (5-20 mm), plentiful (10-100) fine (1<2 mm), plentiful (1-10) small (2 to <5 mm)	1 (20 to<50 mm); 7 (5 to <20 mm); 3 (2 to <5 mm)	3 coarse (20 to <50 mm); 7 (5 to <20 mm)	3 (20 to<50 mm); 7 (5 to <20 mm)
Root orientation	~1/2 of 1° roots are oriented horizontal in a north direction (i.e, they stay w/in the peat); ~1/2 the 1° roots are oriented vertically into the Bm and Subsoil (~1/2 of those change orientation to horizontal w/in the Bm material)	majority of medium roots - horizontal w/in 5-10 cm of the soil surface; few small vertical roots; 1 medium vertical root changes to horizontal @~25 cm	Horizontal		Mostly horizontal, 1 vertical changed to horizontal within the Bm material	vertical root directly below base of tree ~12 cm and branched into 2, 2° roots growing in horizontal directions; mainly horizontal	Horizontal (1 oblique coarse root (growing towards Treatment 6 - changes to horizontal at peat/Bm interface)
Direction of horizontal roots (distribution around tree)		~70% of medium roots are on west side of tree within 5-10 cm of the soil surface	Evenly distributed around the tree	Evenly distributed around the tree, particularly larger diameter 1° roots	Evenly distributed around tree; no obvious direction/rooting pattern in a given direction	No obvious direction; relatively evenly distributed around tree	2 coarse roots growing towards Treatment 6; 1 coarse root growing towards Treatment 5
Max observed root length (m)	1.04	2.82	1.07	1.38; 1.43; 1.7	1.72	2.4; 1.73; 1.75	(Treatment 6) 8.2; (Treatment 5) 5.01 m
Exposed Root diameter at tree (mm)	5.66	8.32	2.11	4.56; 9.6; 12.48	1.83	12.2; 14.53; 11.78	(Treatment 6) 29.5; (Treatment 5) 13.37
Average depth of exposed root (cm)	10-15 (within peat)	8-10	5	2 cm in S direction towards Treatment 6; close to surface; close to surface in NW direction towards Treatment 5	2-3	10; near surface w/in 10 cm	(Treatment 6)~30 cm - border between peat and Bm ; (Treatment 5) ~5 cm
Root diameter at midpoint (mm)	n/a	n/a	0.7	n/a	n/a	n/a	(Treatment 6) 11.37
Root diameter at end (mm)	2.63	1.29	0.54	0.95; 2.54; 2.16	1.96	4.7; 6.32; 4.5	(Treatment 6) 3.07; (Treatment 5) 4.37
Abundance fine (1<2 mm) roots	n/a	Abundant (>100) 1°	Abundant (>100) 1° near base of root plug; plentiful (10-100) everywhere else	Plentiful (10-100)	Abundant (>100) 2°	Plentiful (10 to 100) 1° and 2°	Few (10) 1°; abundant (>100) 2° and 3°
Abundance small (2 to <5 mm) roots	Abundant (>10)	Plentiful (1-10) 1°	Abundant (>10)	Plentiful (1-10)	Few (<5) 1° and 2°	Few (<5)	Few (<5) 1°; abundant (>10) 2° and 3°

Parameter	Jack Pine	Jack Pine	Jack Pine	Spruce	Spruce	Aspen	Aspen
Abundance medium (5 to 20 mm) roots	Plentiful (1-5)	Abundant (>5) 1°	None	Plentiful (1-5)	Abundant (5 to <20) 1°	Abundant (>5)	Abundant (>5) 1°
Abundance coarse (20 to <50 mm) roots	None	Two 1°	None	n/a	1 (20 to < 50 mm) 1°	3	3
Tap Root (Presence/Absence)	None	one root extending horizontally from base of tree in a N direction (90 degrees to majority of roots) that is larger in diameter - could be considered a tap root; did not extend vertical, remained completely horizontal w/in peat; few roots observed below 20 cm; maximum root length was observed for a root growing south towards Treatment 6	None	None	Vertical root extending from base, branched at 20 cm into 2 roots at Bm interface	None; however vertical root under base of tree for ~12 cm	None
Root Notes	few 2° extending from 1° roots; at 90 cm deep the 1° root branches into secondary roots which change from vertical to horizontal		Roots extending from entire length of the 16 cm plug	larger diameter 1° roots were closer to the surface in the peat; majority of 1° roots were distributed in peat or at interface between peat and Bm	oblique 2° and 3° roots into subsoil material; majority of root area was w/in the Bm material; some 2° roots extending to deeper depths; no 1° roots below Bm material	Exposed root #1 changed directions 90° at ~1 m from tree (initially growing N towards Treatment 5, turned and grew E along the border; root cloned itself at ~1.34 m from the tree	OB depth variable w/in 1 m of tree (N - towards Treatment 5 - 30 cm deep; S - towards Treatment 6 - 70 cm deep); Root w/in Treatment 6 - root branched at 4.5 m, abundant 3° roots which branched several times; Root w/in Treatment 5 - branched at 2.9 m and did 90° turn, abundant fine 3° roots along entire length

Table B.1.5. Border between Treatment 5 (30 cm Peat) and Treatment 9 (20 cm LFH/30 cm Bm/100 cm Subsoil (>1m)) root observations.

Parameter	Aspen		Aspen		Pine		Pine		Pine		Spruce		Spruce	
Tree #	52		58		53		54		56		55		57	
Tree Height (m)	5.18		4.35		2.72		0.96		2.34		0.76		1.45	
Basal Diameter (mm)	79		47		69.5		34.56		64.62		23.66		35.31	
DBH (mm)	49		24		40		5.08		30.68		4.14		5.02	
Tree description	directly on border (~2 m N of peat w/in LFH); relatively large aspen compared to others in either treatment		directly on the edge of Treatment 5		tree located ~ 1 m N of Treatment 5 on border w/in the same trench as Tree 52		South, on the Treatment 5 side of the border; Same trench as Tree 55 and 56		directly on border; OB directly below tree is 30 cm deep; ~ 70 cm S of the LFH/BM ; Same Trench as Tree 54 and 55		Within Treatment 5 on south side of border; Same trench as Tree 54 and 56		Tree located ~3 m N of Treatment 5 w/in Treatment 9 in the same profile trench as Tree 58	
Treatment	**9**	**5**	**9**	**5**	**9**	**5**	**9**	**5**	**9**	**5**	**9**	**5**	**9**	**5**
Material	**LFH**	**Peat**	**LFH**	**Peat**	**LFH**	**Peat**	**LFH**	**Peat**	**LFH**	**Peat**	**LFH**	**Peat**	**LFH**	**Peat**
Depth (cm)	0 to 9	n/a w/in 1 m of tree	0 to 10	n/a w/in 1 m of tree	0 to 10	n/a w/in 1 m of tree	n/a	0 to 20	n/a	0 to 30	n/a	0 to 21	0 to 10	n/a
% roots in material	*		*		*			100		100		100	5	
Material	**Bm**	**Overburden**	**Bm**	**Overburden**	**Bm**	**Overburden**	**Bm**	**Overburden**	**Bm**	**Overburden**	**Bm**	**Overburden**	**Bm**	**Overburden**
Depth (cm)	9 to 30/44	starts at 30 to 45 cm	10 to 30	begins at 30 on S side of tree and 50 on N side of tree	10 to 30	begins at 30 cm on S side of tree and 45 cm on N side of tree	n/a	>20	n/a	>30	n/a	>21	10 to 29 cm	>85
% roots in material	*		*		*			0		0		0	75	0
Material	**Subsoil**		**Subsoil**		**Subsoil**		**Subsoil**	-	**Subsoil**	-	**Subsoil**	-	**Subsoil**	-
Depth (cm)	n/a		20 to 40		n/a		n/a		n/a		n/a		29 to 85 cm	
% roots in material			*										20	
Effective Root Depth (cm)	Roots grew at different depths N and S of tree and did grow deeper w/in Treatment 9		Roots grew at different depths N and S of tree and did grow deeper w/in Treatment 9		~25		20 (*i.e.*, depth of peat)		30 (*i.e.*, depth of peat)		21 (*i.e.*, depth of peat)		~30	
Max root depth (cm)	Roots were exposed to subsoil w/in Treatment 9 where they changed from vertical to horizontal to oblique and grew towards the surface		Near tree (w/in 1 m of tree) ~20 cm; Further than 1 m from tree ~70 cm (w/in Treatment 9); near surface (<15 cm) in Treatment 5		Roots observed to approximately 2 cm w/in OB (*i.e.*, 35 cm)		20 (*i.e.*, depth of peat)		30 cm for roots growing w/in treatment 5 and 40 cm for roots growing w/in treatment 9		21 (*i.e.*, depth of peat)		~45	
Above ground tree height/ **max** root depth ratio	7.4		6.21		7.77		4.8		5.85		3.62		3.22	

Parameter	Aspen		Aspen		Pine		Pine		Pine		Spruce		Spruce	
Above ground tree height/ **effective** root depth ratio	No data		No data		10.88		4.8		7.8		3.62		4.83	
# and size (mm) of 1° roots at base of tree	7 coarse 1°; (23.44 to 39.64 mm); plentiful (1-5) medium (5 to <20 mm)		15 coarse 1°; abundant (>5) medium (5 to <20 mm); abundant (>10) small (2 to <5 mm)		4 coarse 1°; abundant (>5) medium (5 to <20 mm); abundant (>10) small (2 to <5 mm)		9 medium (2.85 to 14.22 mm); larger roots growing from top of plug, smaller roots growing from bottom		7 coarse 1°; abundant (>5) medium (5 to <20 mm)		10 small to medium (3.97 to 11.29)		1 coarse 1° (20.6); 7 medium (4.33 to 7.9); majority of roots growing from mid or bottom of root plug	
Direction of horizontal roots	2 coarse 1° roots growing N directly into Treatment 9; 1 coarse 1° root grew directly into Treatment 5; 1 coarse 1° root directly below tree; remainder 1° roots growing west along border		9 - 1° roots growing in direction of Treatment 9; 5 - 1° roots growing in direction of Treatment 5; larger diameter roots growing into Treatment 9		No obvious preferential direction; slightly less roots growing on Treatment 5 side of tree than Treatment 9 (*i.e.*, higher density growing into Treatment 9)		Relatively equally distributed		half of coarse 1° roots growing into Treatment 5 and half into Treatment 9; 5 to 6 medium roots growing N into Treatment 9		~ similar number and size of 1° roots headed north and south; few roots headed east/west along the boundary		Largest 1° roots growing S towards Treatment 5; no obvious roots growing N further into Treatment 9	
Root orientation	Horizontal within 1 m of tree, oblique to interfaces; vertical within Treatment 9 Bm		Horizontal or oblique		4 to 5 vertical roots directly under tree; horizontal at interfaces		Horizontal in peat, does not enter OB		Within Treatment 5: 80% of roots w/in 30 cm of surface are horizontal w/in peat initially, then oblique towards surface		Primarily horizontal		oblique in upwards direction away from the base of the tree and back towards soil surface; horizontal at LFH interface; 4 roots vertical/oblique into Bm - change to horizontal at Bm/Subsoil interface	
Max observed root length (m)	Into Trmt 9 - 5.08	Into Trmt 5 - 12.2	Into Trmt 9 - 6.9	Into Trmt 5 - 8.92	Into Trmt 9 - 1.56	Into Trmt 5 - 1.51	Into Trmt 9 - 2.23	Into Trmt 5 - 1.72	Into Trmt 9 - 3.6	Into Trmt 5 - 2.68	Into Trmt 9 - 2.05	Into Trmt 5 - 1.54	Into Trmt 9 - 3.64	Into Trmt 5 - 1.94
Exposed Root diameter at tree (mm)	32.71	39.64	15	16.49	13.78	8.35	5.59	14.22	15.4	20.13	5.69	6.06	18.85	2.84
Average depth of exposed root (cm)	branched into 3 2° roots - 1 = 8.2 mm and stayed w/in 10 cm of surface; 1 = 14.16 mm grew - almost vertical ; 1 = 11.19	branched 3 times (@ 4 m, 6 m and 9 m) into 2° roots; Root was oblique from tree to peat treatment where is changed to horizontal at approximately	oblique along transition between Bm/subsoil to 4.95 m; 90° turn and branched into three 2° roots and grew	horizontal following interface between peat/OB and then upwards to 3 cm below ground surface for the majority of its length	3 to 5 cm near the tree to 35 cm at tend (w/in Bm (*i.e.*, did not travel along the LFH interface))	At 1 m root branched into 2° roots (at peat and sand interface); one 2° root grew into OB (~2 cm deep); one 2° root grew into peat and branched at	starts at 5 cm, gradually down to 20 cm; Root initially growing in NE direction and transitions to straight E along the peat/LFH border	5 cm, gradually down to 15 cm	oblique; grew from surface to interface between the Bm and subsoil and continued on the interface horizontally	Stayed horizontal w/in 10 cm of surface; branched at 1.0 m (2° was 5.39 mm diameter at the branch)	~ 10 cm	~ 5 cm	branched at 1.17 m (10.18 mm before branch); LFH/Bm interface	no major branching; grew along border; ~ 10 cm
Root diameter at midpoint (mm)											0.98			

Parameter	Aspen		Aspen		Pine		Pine		Pine		Spruce		Spruce	
	mmm - oblique and stayed w/in sand	26 cm and stayed at the transition between the peat and OB	vertical into subsoil			76 cm and entered into OB and became very fibrous								
Root diameter at end (mm)	1.17	1.9	1.66 (70 cm depth)	0.53	0.85	1.46	0.9	0.87	2.83	0.83	0.7	0.98	1.4	1.53
Abundance fine (1<2 mm) roots	Abundant (>100) 2° root hairs from 1° roots growing into Trmt 5		Abundant (>100) 1° and 2° directly under tree		Plentiful (10-100) 1°; Abundant (>100) 2°		Few (10) 1° and 2°		n/a		Plentiful (10-100) 1°		Abundant (>100) 2° roots on all 1° roots (more on vertical roots than horizontal roots and increases with depth)	
Abundance small (2 to <5 mm) roots	Plentiful (1-10) 1°; Abundant (>10) 2° w/in Trmt 5		Abundant (>10) 1° and 2° directly under tree		Abundant (>10) 1°; few (<10) 2° w/in 1 m of tree		Plentiful (1-10) 1° and 2°		Abundant (>10) 1° and 2°; More on treatment 5 side of tree than treatment 9		few (<10) 1° and 2°		Abundant (>10) 2°	
Abundance medium (5 to 20 mm) roots	Few (<10) 1° (most are coarse)		Abundant (>5) 1° directly under tree		Abundant (>5) 1° directly under tree		Abundant (>5) 1°		Abundant (>5) 1° and 2° on Treatment 5 side of tree		Plentiful (1 -5) 1°		Abundant (>5) 1°	
Abundance coarse (20 to <50 mm) roots	7 - (1°)		15 - (1°)		4 - (1°)		None		7 - (1°)		None		1 - 1°	
Root Notes	Of the 2 coarse 1° roots growing N into Treatment 9: 1 branched at 80 cm and sent 2° roots into deeper depths and 1 branched at 120 cm and stayed horizontal along the LFH interface until branching again; the horizontal coarse 1° root growing into Treatment 5 branched as soon as it encountered the peat (one 2° root horizontal along peat surface, one 2° root oblique to peat/OB interface; root below aspen branched into 2° roots and grew west primarily growing along interfaces;		Deeper roots growing into Trmt 9 (from vertical base under tree which is ~10 cm long) - however they change to oblique w/in 20 cm and grow back towards the surface of the soil; roots appear to be traveling along the transition of the BM and subsoil and/or LFH and BM		Overburden is a more friable and has more structure (sub-angular blocky) than observed elsewhere and thus roots observed growing ~ 2 cm w/in OB; high root biomass compared to other treatments and/or other trees w/in border		Few fine roots in comparison to other pine trees growing in other treatments; largest diameter root grows south from tree and branches into 2° roots w/in 30 cm of tree; medium root grows in north direction		Roots on Treatment 5 side of tree form 2° roots near the base of the tree (thus larger diameter 2° roots on treatment 5 side of tree); 1 coarse 1° root from bottom of plug growing north to Treatment 9 and decreases in depth into Bm/Subsoil and stays horizontal at 20-25cm; tap root changed from vertical to oblique and went down into the sand when it reached Trmt 9		Few fine 2° roots in comparison to other treatments; small and fine fibrous roots emerging from plug and grow along transition between Peat and OB.		Several vertical roots	

* Difficult to estimate due to volume of roots w/in each treatment

Table B.1.6. Aspen root observations for border between Treatment 5 (30 cm Peat) and Treatment 12b (150 cm Subsoil (>1m)).

Tree Species	Aspen				Aspen				Aspen			
Tree #	1				4				5			
Tree Height (m)	8.48				3.77				4.37			
Basal Diameter (mm)	83.8				42.5				58.04			
DBH (mm)	52.8				25.78				33.54			
Tree Location	Tree located on the border, closer to Treatment 5; south side of pit (Treatment 12b) had deeper overburden and thicker subsoil				Located entirely in peat treatment; overburden was sloping downwards on south (Treatment 12b) side of pit, subsoil depth increased on south side of pit				Tree was located approximately 1.5 meters south of the border, located entirely in Treatment 12b			
Material	**Windblown Subsoil**	**Peat**	**Subsoil**	**Overburden**	**Windblown Subsoil**	**Peat**	**Subsoil**	**Overburden**	**Windblown Subsoil**	**Peat**	**Subsoil**	**Overburden**
Depth (cm)	0 to 15	15 to 30	30 to >120	starts at 30 cm depth in Treatment 5, 120 cm depth in Treatment 12b	0 to 10	10 to 29	n/a	>29	n/a	n/a	0 to 150	Did not reach
% roots in material	No data	No data	No data		50	50					90	n/a
Effective Root Depth (cm)	Approximately 30				25				Approximately 30			
Max root depth (cm)	15 cm on north (Treatment 5) side of pit, 120 cm on south (Treatment 12b) side of pit				40				>120			
Above ground tree height/ **max** root depth ratio	56.53 (Treatment 5 side of tree); 7.07 (Treatment 12b side of tree)				9.73				3.67			
Above ground tree height/ **effective** root depth ratio	0.28				15.08				14.57			
# and size (mm) of 1° roots at base of tree	4 coarse (20 to <50 mm) and 2 medium (5 to <20 mm); 2 coarse 2° and 1 medium 2°				3 medium (5 to <20 mm) and 2 coarse (20 to <50 mm)				3 coarse (20 to <50 mm) and 4 medium (5 to <20 mm)			
Root orientation	Mainly horizontal, few vertical roots on Treatment 5 side of pit				Horizontal				Horizontal and oblique			

Tree Species	Aspen		Aspen		Aspen	
Direction of horizontal roots (distribution around tree)	Within Treatment 12b primary roots branch into secondary and tertiary roots more than w/in Treatment 5; no roots w/in the overburden		3 primary roots north towards Treatment 5; 2 primary roots south towards Treatment 12b		Largest diameter primary roots growing towards Treatment 5	
Max observed root length (m)	Treatment 5 - 7.93	Treatment 12b - 2.5	Treatment 5 - 11.9	Treatment 12b - 5.6	Treatment 5 - 13.47	Treatment 12b - 2.53
Exposed root diameter at tree (mm)	No data	No data	No data	No data	Treatment 5 - 40.99	Treatment 12b - 14.59
Average depth of exposed root (cm)	Treatment 5 - <10	Treatment 12b - ~10 cm, oblique (steadily went deeper)	Treatment 5 - 25	Treatment 12b - 20	Treatment 5 - 10	Treatment 12b - Max depth >120
Root diameter at midpoint (mm)	No data	No data	No data	No data	No data	No data
Root diameter at end (mm)	No data	No data	Treatment 5 - 11.78	Treatment 12b - 1.24	Treatment 5 - 1.78	Treatment 12b - 9.32
Abundance fine (1<2 mm) roots	Plentiful (10 to 100)		Few (<10)		Plentiful (10 to 100)	
Abundance small (2 to <5 mm) roots	Treatment 5 - few (1); Treatment 12b - plentiful (1-10)		None		None	
Abundance medium (5 to 20 mm) roots	Treatment 5 - abundant (>5); Treatment 12b - plentiful (1 to 5)		Plentiful (1 to 5)		Plentiful (1 to 5)	
Abundance coarse (20 to <50 mm) roots	Treatment 5 - 1; Treatment 12b - 3		2		3	
Root Notes	Roots almost exclusively at the surface (top 30 cm); w/in subsoil material, primary roots horizontal and vertical; no observable roots in overburden; secondary roots w/in subsoil material were smaller than secondary roots w/in the peat material and were oriented vertically in the subsoil material vs horizontally in the peat material; coarse fragments present in soil profile		No roots were observed w/in the overburden directly under the tree, all roots travelled horizontally above the overburden; windblown subsoil depths varied between 8 and 10 cm		The largest diameter root was growing north towards Treatment 5 and at ~2 m in length it turned 90 degrees out of the subsoil treatment and into the peat treatment for 10 more meters; given the length of the root extending into peat treatment it is difficult to estimate the area of roots horizontally within each material from a biomass perspective	

Table B.1.7. Jack pine root observations for border between Treatment 5 (30 cm Peat) and Treatment 12b (150 cm Subsoil (>1m)).

Tree Species	Jack Pine				Jack Pine				Jack Pine				Jack Pine			
Tree #	2				3				8				9			
Tree Height (m)	2.95				2.82				2.12				3.32			
Basal Diameter (mm)	83				85.17				63.86				140			
DBH (mm)	57				39.51				19.37				43.73			
Tree Location	Tree located closer to Treatment 5 than Treatment 12b				Tree located closer to Treatment 5 than Treatment 12b				Located entirely w/in Treatment 12b, 1.6 m from Treatment 5				Tree located directly on border between Treatment 5 and 12b			
Material	**Windblown Subsoil**	**Peat**	**Subsoil**	**OB**	**Windblown Subsoil**	**Peat**	**Subsoil**	**OB**	**Windblown Subsoil**	**Peat**	**Subsoil**	**OB**	**Windblown Subsoil**	**Peat**	**Subsoil**	**OB**
Depth (cm)	0 to 33	33 to 65	n/a	>65	0 to 10	10 to 28	n/a	>28	n/a	Not present w/in 1 m of tree	0 to 105	>105	n/a	0 to 15	15 to 42	>42
% roots in material	40	60	n/a	0	10	90	n/a	0		5	95		n/a	70	30	0
Effective Root Depth (cm)	Approximately 45				Approximately 25				No data				Approximately 25			
Max root depth (cm)	65				28				115				50			
Above ground tree height/ **max** root depth ratio	4.54				10.07				1.84				6.64			
Above ground tree height/ **effective** root depth ratio	6.56				11.28				No data				13.28			
# and size (mm) of 1° roots at base of tree	>10				>5				7 medium (5 to <20 mm) and 1 coarse (20 to <50 mm); 12 2° ~5 mm in diameter				5 coarse (20 to <50 mm), plentiful medium (1 to 5; 5 to <20 mm), plentiful small (1 to 10, 2 to <5 mm); total of 10 1° roots			
Root orientation	Horizontal primary roots and oblique secondary roots				Horizontal				Top half of subsoil mostly horizontal; bottom half vertical				Horizontal			

Tree Species	Jack Pine	Jack Pine		Jack Pine		Jack Pine	
Direction of horizontal roots (distribution around tree)	Several growing in each direction, with no preferred direction of root growth	Largest primary roots growing in the direction of Treatment 5		2 primary roots growing towards subsoil, 1 towards peat, 3 along the border; roots well distributed around the tree		7 primary roots travelling towards Treatment 5, 3 travelling towards Treatment 12b	
Max observed root length (m)	1.99	Treatment 5- 1.68	Treatment 5- 1.41	Treatment 5 - 1.95	Treatment 12b - 1.95	Treatment 5 - 3.1	Treatment 12b - 2.5
Exposed root diameter at tree (mm)	No data	Treatment 5- 32.9	Treatment 5- 22.3	Treatment 5 - 6.6	Treatment 12b - 9.2	Treatment 5 - 40	Treatment 12b - 13.1
Average depth of exposed root (cm)	30 to 60	Treatment 5- 10 to 25	Treatment 5- 10 to 25	No data	No data	Treatment 5 - 10	Treatment 12b - 10
Root diameter at midpoint (mm)	No data	No data	No data	No data	No data	Treatment 5 - 7.5	No data
Root diameter at end (mm)	2.95	Treatment 5- 4.38	Treatment 5- 2.68	Treatment 5 - 1.3	Treatment 12b - 1.8	Treatment 5 - 1	Treatment 12b - 1.05
Abundance fine (1<2 mm) roots	Plentiful (10 to 100)	Plentiful (10 to 100)		Plentiful (10 to 100)		None	
Abundance small (2 to <5 mm) roots	Abundant (>10)	Abundant (>10)		Abundant (>10)		Plentiful (1 to 10)	
Abundance medium (5 to 20 mm) roots	Abundant (>5)	Plentiful (3-5)		Abundant (>5)		Plentiful (1 to 5)	
Abundance coarse (20 to <50 mm) roots	None	1		1		5	

Tree Species	Jack Pine	Jack Pine	Jack Pine	Jack Pine
Root Notes	Larger roots w/in windblown subsoil, but more quantity of roots in the peat (smaller diameters); only larger (medium) primary roots are w/in the windblown subsoil material; largest root did not grow from the base of the tree, nor did it grow vertically; roots not growing into the overburden; direction not noted for root length measurements	Largest root did not grow vertically like a typical tap root, but horizontally from the base of the tree and up and away from the overburden; very few secondary roots present (fine when present)	Note that while tree is in Treatment 12b, the subsoil depth gradually decreases to meet the peat in Treatment 5; this is likely why 95% of roots are in subsoil and 5% in peat (roots grew horizontally into the peat); taproot observed with other primary roots growing vertical directly below the tree	Largest root from the tree base was 47 mm growing in the direction of Treatment 5, branches into secondary roots and then grows vertically to overburden where it forms tertiary roots but does not grow into the overburden; 90% of root mass in subsoil when considering the vertical profile [70% of roots are present in the peat; 30% are present in the subsoil material]; large number of secondary roots w/in 15 cm of tree; for horizontal root measurements, one root reached a depth of ~20 cm at its end and stayed at the transition between subsoil and peat; material depths were variable with a range between 0 to 15 cm for peat, 23 to 42 cm for subsoil, and 30 to 42 cm for overburden (largest depth values given above)

Table B.1.8. White spruce root observations for border between Treatment 5 (30 cm Peat) and Treatment 12b (150 cm Subsoil (>1m)).

Tree Species	Spruce				Spruce			
Tree #	6				7			
Tree Height (m)	1.36				0.75			
Basal Diameter (mm)	37.25				21.25			
DBH (mm)	5.91				n/a			
Tree Location	Tree located south of border entirely within Treatment 12b, Treatment 5 begins ~ 60 cm north of tree				tree located exclusively within Treatment 5; approximately 15 m N of border; recorded within a pit (hand excavated)			
Material	**Windblown Subsoil**	**Peat**	**Subsoil**	**Overburden**	**Windblown Subsoil**	**Peat**	**Subsoil**	**Overburden**
Depth (cm)	15 to 0	n/a	0 to 60	>60	n/a	0 to 34	n/a	>34
% roots in material	n/a	n/a	80 % of roots within 0 to 20 cm	n/a	n/a	100	n/a	0
Effective Root Depth (cm)	Approximately 25				25			
Max root depth (cm)	No data				No roots growing into overburden			
Above ground tree height/ **max** root depth ratio	5.44				3.0			
Above ground tree height/ **effective** root depth ratio								
# and size (mm) of 1° roots at base of tree	7 medium (5 to <20 mm)				7 ranging from fine (1 to <2 mm) to small (2 to <5 mm)			
Root orientation	Oblique and horizontal				Horizontal and oblique			
Direction of horizontal roots (distribution around tree)	Even distribution of primary roots growing towards each treatment, with the 2 largest primary roots growing north towards Treatment 5; secondary roots growing almost immediately away from the trunk of the tree				Horizontal roots growing north towards Treatment 5, fine-small oblique roots distributed around the tree			
Max observed root length (m)	Treatment 5 - 2.44		Treatment 12b - 0.62		Treatment 5 - 0.62			
Exposed root diameter at tree (mm)	Treatment 5 - 10.94		Treatment 12b - 7.96		Treatment 5 - 2.91			

Tree Species	Spruce		Spruce
Average depth of exposed root (cm)	Treatment 5 - 15	Treatment 12b - 15	Treatment 5 - 2
Root diameter at midpoint (mm)	No data	No data	No data
Root diameter at end (mm)	Treatment 5 - 1.11	Treatment 12b - 3.25	Treatment 5 - 1.29
Abundance fine (1<2 mm) roots	None		Plentiful (10 to 100)
Abundance small (2 to <5 mm) roots	Plentiful (1 to 10)		Abundant (>10)
Abundance medium (5 to 20 mm) roots	Plentiful (1 to 5)		None
Abundance coarse (20 to <50 mm) roots	None		None
Root Notes	Advantageous roots are growing approximately 10 cm above the root plug; tap root extending to a 30 cm depth where it changes from vertical to horizontal and travels north towards Treatment 5		Roots clearly avoiding overburden; roots mostly growing from bottom of plug; fine secondary roots directly at the base of the tree (abundant, >100)

B.2 SELECT TREATMENTS

Table B.2.1. Treatment 1 (30 cm Peat/120 cm Subsoil (>1m)) root observations.

Parameter	Jack pine		Spruce		Aspen		Aspen (no test pit)	
Tree #	35		36		37		38	
Tree Height (m)	2.01		1.48		1.09		1.07	
Basal Diameter (mm)	68		47		31.3		47.4	
DBH (mm)	19		9		18.01		26.7	
Reclamation Material	**Peat**	**Subsoil**	**Peat**	**Subsoil**	**Peat**	**Subsoil**	**Peat**	**Subsoil**
Average Depth (cm)	25-28	>28	20	>20	27	>27	25	>25
% roots in material	95	5	85-90	10-15	95	5	>95	~5 (unconfirmed)
Effective Root Depth (cm)	25		20-23, within peat or at interface		27		10-15 (unconfirmed)	
Max root depth (cm)	90		65		~30-35		Cannot estimate (no test pit)	
Above ground tree height/ **max** root depth ratio	2.23		2.28		3.11		n/a	
Above ground tree height/ **effective** root depth ratio	8.04		6.43		4.04			
# and size of 1° roots at base of tree	Abundant (>15) medium (5-20 mm); plentiful (1-10) small		10-15 medium (5 to 20 mm); few small (2 to <5 mm); plentiful fine (1 to <2 mm)		5 (11.57 to 26.25 mm)		7 coarse (20.84 to 32.8 mm); 8-10 medium (15-20 mm)	
Root distribution around tree	Evenly distributed		Evenly distributed		Evenly distributed		Evenly distributed; Larger diameters E, S, and W	
Root orientation	Horizontal		Horizontal (plentiful fine vertical roots directly under the tree)		Horizontal		Horizontal; no vertical root below tree; one oblique root extending deeper dead ~30 cm from tree (dry/broke off)	
Max observed root length (m)	2.46		3.98		2.27		n/a	
Exposed Root diameter at tree (mm)	10.84		12.15		12.35		n/a	
Average depth of exposed root (cm)	<5		<5		5-10		n/a	
Root diameter at midpoint (mm)	n/a		n/a		6.21		n/a	
Root diameter at end (mm)	1.84		1.34		4.77		n/a	

Parameter	Jack pine	Spruce	Aspen	Aspen (no test pit)
Abundance fine (1<2 mm) roots	Few 2° roots extending from 1° roots	Abundant (10-100) 1° and 2° directly under tree; abundant root hairs (3°)	Abundant (10-100)	Plentiful (10-100)
Abundance small (2 to <5 mm) roots	Plentiful (1-10) 1° and few (<10) 2°	Few (<5) 1°; Abundant (>10) 2°	Plentiful (1-10) 1° and 2°	Few (<5)
Abundance medium (5 to 20 mm) roots	Abundant (>5) 1°; Few 2° roots within 60 cm of tree	Abundant (>5) 1°	Abundant (>5) 1° and 2°	Abundant (>5)
Abundance coarse (20 to <50 mm) roots	None	3	1	7
Root Notes	Peat had higher clay content compared to other peat treatments assessed; Vertical/oblique tap root branches into two 2° roots at ~16 cm, both of which change to horizontal and stay w/in the peat; deepest observed root is 90 cm (2° /3° with abundant root hairs)	No medium or coarse roots extend into the subsoil; most primary roots either shallow w/in peat or horizontal at the peat/subsoil interface	Largest 1° root extends vertical to 7 cm then oblique w/in peat; Aspen root grafted to a spruce located ~10 m to the southeast of tree; 2° roots do not penetrate into the subsoil horizon, they stay along interface	No test pit for this tree, hand dug to confirm root distribution around tree; very little (if any) branching into larger secondary roots w/in 40 cm of tree; one oblique root observed along peat/subsoil transition and then back into peat; few roots observed in secondary

Table B.2.2. Treatment 3 (10 cm Peat/140 cm Subsoil (>1m)) root observations.

Parameter	Aspen		Spruce		Jack pine	
Tree #	46		47		48	
Tree Height (m)	2.38		1.19		2.05	
Basal Diameter (mm)	31		40.5		55.2	
DBH (mm)	9		n/a		10.5	
Reclamation Material	**Peat**	**Subsoil**	**Peat**	**Subsoil**	**Peat**	**Subsoil**
Depth (cm)	0 to 10	>10	0 to 10	>10	0 to 7	>7
% roots in material	80	20	90	10 (on interface)	95	5
Effective Root Depth (cm)	20 (difficult to qualify)[1]		30 (although higher volume in Peat)		7 (Peat)	
Max root depth (cm)	80		45 (fine vertical roots from base of tree)		30	
Above ground tree height/ **max** root depth ratio	2.98		2.64		6.83	
Above ground tree height/ **effective** root depth ratio	11.9		3.97		29.29	
# and size (mm) of 1° roots at base of tree	7 medium (8.02 to 18.39); 1 coarse (22.94)		1 coarse; 4 medium (10 to 20 mm); 10 medium (5 to 10 mm)		2 coarse (20.10, 20.51); 5 medium (9.68 to18.47)	
Root distribution around tree	Evenly distributed		Evenly distributed		Majority heading northeast	
Root orientation	Mainly horizontal (see notes) and oblique		Horizontal (slightly oblique towards surface); vertical roots extend from base of tree		Horizontal	
Max observed root length (m)	6.11; 6.61		2.79		2.72	
Exposed root diameter at tree (mm)	14.17; 11.61		8.29		20.17	
Average depth of exposed root (cm)	3 to 8; 8		8		5 to 10	
Root diameter at midpoint (mm)	no data		4.23		4.73	
Root diameter at end (mm)	1.87; 1.06		1.11		1.29	
Abundance fine (1<2 mm) roots	Few (<10) 2°		n/a		Abundant (>100) 2°	
Abundance small (2 to <5 mm) roots	Plentiful (10 to 100) 2°		Few (<10) 1° and 2°		Plentiful (1 to 10) 1° and 2°	
Abundance medium (5 to 20 mm) roots	Abundant (>5) 1°; plentiful (1-5) 2°		Abundant (>5) 1°; few (1) 2°		Abundant (>5) 1°; few (1) 2°	

Parameter	Aspen	Spruce	Jack pine
Abundance coarse (20 to <50 mm) roots	1	1	2
Root Notes	1 oblique root into subsoil (16.4 mm root); One vertical below tree which changes to oblique for ~45 cm and at 35 cm below surface turns 90° to horizontal and grows back towards the surface in a south direction; medium 2° roots extend vertical from 1° roots and extend deeper into subsoil (~every 10 cm on the root); 2 root lengths measured - 1 growing south, 1 growing east - both ended up near each other south of tree	Few roots extend into subsoil. Some roots are oblique and sloping upwards to surface from mid-point of soil plug; majority of roots extend from bottom of root plug with the exception of the largest diameter primary root which is near the top of the plug; tree roots all w/in 15 cm on tree	Large 1° roots along peat/subsoil interface; exposed root depth was on average 5 cm, travelling down to 10 cm (slightly into subsoil) and then back up to the peat/subsoil interface

[1] Difficult to qualify effective rooting depth because it is challenging to estimate root area with the widely distributed roots.

Table B.2.3. Treatment 4 (30 cm Peat/30 cm Blended B/C) root observations.

Parameter	Aspen			Aspen			Jack pine			Jack pine			Spruce			Spruce		
Tree #	21			26			22			23			24			25		
Tree Height (m)	1.94			2.2			1.35			1.64			1.36			1.48		
Basal Diameter (mm)	33.75			27.65			30.42			41.89			38.32			49.39		
DBH (mm)	8.64			10			7.05			8.51			7.41			6.96		
Reclamation Material	**Peat**	**Blended B/C**	**OB**	**Peat**	**Blended B/C**	**OB**	**Peat**	**Blended B/C**	**OB**	**Peat**	**Blended B/C**	**OB**	**Peat**	**Blended B/C**	**OB**	**Peat**	**Blended B/C**	**OB**
Depth (cm)	0 to 32	32 to 62	>62	0 to 40	40 to 74	>77	0 to 38	38 to 69	>69	0 to 33	33 to 68	>68	0 to 27	27 to 59	>59	0 to 28	28 to 61	>61
% roots in material	90	10	0	95	5	0	90	10	0	95	5	0	90	10	0	90	10	0
Effective Root Depth (cm)	32 (*i.e.*, peat)			40 (*i.e.*, peat)			38 (*i.e.*, peat)			30 (*i.e.*, peat)			27 (*i.e.*, peat)			43		
Max root depth (cm)	50			65			70			60			60			60		
Above ground tree height/ **max** root depth ratio	3.88			3.38			1.93			2.73			2.27			2.47		
Above ground tree height/ **effective** root depth ratio	6.06			5.50			3.55			5.57			5.04			3.44		
# and size (mm) of 1° roots at base of tree	2 medium (14.44, 17.59), 2 coarse (20.62, 34.67)			abundant (>10) small (2 to 5 mm); abundant (>10) medium (8.26 to 13.81); 1 coarse			Abundant (>10) medium (8.17 to 10.08); 1 tap root			Abundant (>10) small (2 to 5 mm); Abundant (>15) medium (5.59 to 8.19)			6 medium (7.28 to 17.89); few (<10) small (2 to 5 mm)			Abundant (>10) medium size (6.41 to 7.20 mm); abundant (>10) small (2 to <5 mm)		
Root distribution around tree	Evenly distributed			Evenly distributed			Evenly distributed; though more growing west than east			Evenly distributed			Evenly distributed			Evenly distributed		
Root orientation	Three 1° horizontal roots close to soil surface heading south, east, and west respectively, while the other 1° extends vertically; 2° roots extend vertically into Blended B/C			Horizontal, vertical in B/C			Horizontal in peat; oblique and vertical in Blended B/C, and mostly secondary and tertiary roots in Blended B/C			Horizontal			Horizontal in peat; oblique and vertical in Blended B/C			Roots horizontal in peat; in Blended B/C roots primarily horizontal but with oblique branching		
Max observed root length (m)	8.60			2.3; 6.82			1.35			2.14			1.17			1.20		
Exposed Root diameter at tree (mm)	17.24			8.43; 15.92			6.39			2.95			7.18			6.02		
Average depth of exposed root (cm)	2 cm for most of length; 25 cm at end			n/a			~10			<10			~5			n/a		

Parameter	Aspen	Aspen	Jack pine	Jack pine	Spruce	Spruce
Root diameter at midpoint (mm)	9.41	2.5; 12.44	2.09	2.17	2.4	2.91
Root diameter at end (mm)	4.46	1.08; 1.7	0.5	0.53	1.63	1.27
Abundance fine (1 to <2 mm) roots	Plentiful (10 to 100) 2°	Abundant (>100) 2°	Abundant (>100) 2°	Abundant (>100) 1° and 2°	Plentiful (10 to 100) 2°	Abundant (>100) 1° and 2°
Abundance small (2 to <5 mm) roots	Plentiful (1 to 10) 2°	Abundant (>10) 1° and 2°	Plentiful (1 to 10) 2°	Abundant (>10) 1° and 2°	Plentiful (1 to 10) 1° and 2°	Abundant (>10) 1°
Abundance medium (5 to 20 mm) roots	Plentiful (1-5) 1° and 2°	Abundant (>5) 1°	Abundant (>5) 1°	Abundant (>5) 1° and 2°	Abundant (>5) 1°	Abundant (>5) 1°
Abundance coarse (20 to <50 mm) roots	2	1	None	None	None	None
Root Notes	Vertical root splits into 2° roots directly below tree; Exposed 1° root growing in E direction which split into medium sized 2° roots; Roots stayed mostly in peat, small roots did go vertical.	Five 1° roots emerged from tree stem above the tree plug; three 1° roots emerged from bottom of plug; vertical root(s) directly below the tree changes to horizontal w/in the peat. Other smaller diameter vertical roots transition to horizontal deeper, w/in the Blended B/C material.	Secondary branching occurs w/in 30 cm of tree; tap root vertical w/in peat, transitions to oblique/horizontal and grows along the peat/Blended B/C interface.	High volume of root biomass; medium horizontal roots extend for meters away from tree in peat (unique observation given size of tree); medium tap root present; vertical 2° roots growing into Blended B/C; no roots observed in overburden	Medium sized tap root present; Most roots in Blended B/C or lower in peat grow along the peat and Blended B/C interface; root plug evident and 1° roots were observed above and below	Most 1° roots originate from bottom of the tree plug; roots are straddling the interface between peat and Blended B/C material

Table B.2.4. Treatment 6 (30 cm Peat/30 cm Bm/90 cm Subsoil (>1m)) root observations

Parameter	Aspen			Jack pine[1]			Spruce[1]			
Tree #	34			27			30			
Tree Height (m)	1.44			1.3			1.68			
Basal Diameter (mm)	23.38			44			47			
DBH (mm)	4.09			n/a			12			
Reclamation Material	**Peat**	**Bm**	**Subsoil**	**Peat**	**Bm**	**Subsoil**	**Peat**	**Bm**	**Subsoil**	**Overburden**
Depth (cm)	0 to 33	33 to 62	>60/62	35	60-65	>120	27-30	26-37	69	Starts at 1.3m
% roots in material	100	0	0	80	15	5	84	13	2	0
Effective Root Depth (cm)	30 (peat)			35			~30 (*i.e.*, peat)			
Max root depth (cm)	33			~120			~100			
Above ground tree height/ **max** root depth ratio	4.36			1.08			1.68			
Above ground tree height/ **effective** root depth ratio	4.80			3.71			5.60			
# and size (mm) of 1° roots at base of tree	8 small to medium (4.74; 6.27 to 15.29)			5-10 (5.01 to 7.73 mm); >10 (2-5 mm)			1 (20 to<50 mm); 7 (5 to <20 mm); 3 (2 to <5 mm)			
Root distribution around tree	Evenly distributed			~1/2 of 1° roots are oriented horizontal in a north direction (*i.e*, they stay w/in the peat); ~1/2 the 1° roots are oriented vertically into the Bm and subsoil (~1/2 of those change orientation to horizontal w/in the Bm material)			Mostly horizontal, 1 vertical changed to horizontal within the Bm horizon			
Root orientation	Primarily horizontal and roots remain w/in peat material; vertical roots directly below tree						Evenly distributed around tree; no obvious direction/rooting pattern in a given direction			
Max observed root length (m)	5.27			1.04			1.72			
Exposed root diameter at tree (mm)	10.34			5.66			1.83			
Average depth of exposed root (cm)	3-5			10-15 (w/in peat)			2-3			
Root diameter at midpoint (mm)	4.7			n/a			n/a			
Root diameter at end (mm)	1.05			2.63			1.96			

Parameter	Aspen	Jack pine[1]	Spruce[1]
Abundance fine (1<2 mm) roots	Few (<10) 1°	n/a	Abundant (>100) 2°
Abundance small (2 to <5 mm) roots	Plentiful (1 to 10) 1° and 2°	Abundant (>10)	Few (<5) 1° and 2°
Abundance medium (5 to 20 mm) roots	Abundant (>5) 1°	Plentiful (1-5)	Abundant (5 to <20) 1°
Abundance coarse (20 to <50 mm) roots	None	None	1 (20 to < 50 mm) 1°
Root Notes	Three 1° roots from top of tree plug, five 1° roots from bottom; roots from the top of plug stay ~2 cm from surface; 2 roots from the lower plug go vertical for ~12 cm then 90° turn to horizontal (1 - north, 1 - south); one turns oblique ~ 5 cm above Bm and grows back up towards surface (*i.e.*, did not go into Bm horizon)	few 2° extending from 1° roots; at 90 cm deep the 1° root branches into secondary roots which change from vertical to horizontal	Vertical root extending from base, branched at 20 cm into 2 roots at Bm interface; oblique 2° and 3° roots into subsoil material; majority of root area was w/in the Bm material; some 2° roots extending to deeper depths; no 1° roots below Bm horizon

[1] Jack pine and spruce data taken from trees assessed at the Treatment 5/6 border.

Table B.2.5. Treatment 7 (20 cm LFH/130 cm Subsoil (>1m)) root observations.

Parameter	Spruce		Aspen		Aspen		Jack pine	
Tree #	39		40 (2 stems)		42		41 (2 stems)	
Tree Height (m)	0.75		3.8; 2.9		2.95		2.75; 1.84	
Basal Diameter (mm)	22.9		46.7; 24.3		35		33.1; 52.3	
DBH (mm)	n/a		22.4; 9.6		14		20.5; 29.4	
Material	**LFH**	**Subsoil**	**LFH**	**Subsoil**	**LFH**	**Subsoil**	**LFH**	**Subsoil**
Depth (cm)	19	>19	21	>21	15 to 20	>15 to 20	20	>20
% roots in material	98	2	98	2	95	5	98	2
Effective Root Depth (cm)	19 cm (*i.e.*, LFH)		21 cm (*i.e.*, LFH)		20 cm (*i.e.*, LFH)		20 cm (*i.e.*, LFH)	
Max root depth (cm)	30		28		20 (directly under tree - horizontal roots may have extended deeper)		47	
Above ground tree height/ **max** root depth ratio	2.5		13.57		14.75		5.85	
Above ground tree height/ **effective** root depth ratio	3.95		18.10		14.75		13.75	
# and size (mm) of 1° roots at base of tree	2 from the top of the root plug (4.77, 8.92 mm); >10 from base of the plug (3.15 to 5.57 mm); Plentiful (1-10) fine and small roots emerging off plug		3 coarse (21.35 to 33.56); 5 medium (12.56 to 18.03); plentiful (10 to 100) fine (1<2 mm) roots at base of tree		1 coarse (26.73); 4 medium (13.84 to 16.49); abundant (>10) small (2 to<5 mm)		1 coarse (26.29); 10 medium (5.28 to 18.88); roots extend from top, mid and bottom of root plug	
Root distribution around tree	Majority of roots growing in south direction		Evenly distributed		Larger diameter primary roots mainly in north direction		Relatively evenly distributed	
Root orientation	Horizontal		Majority of 1° roots are horizontal; one 1° root is oblique to interface and transitions to horizontal		Primarily horizontal (95%)		Horizontal	
Max observed root length (m)	2.48		11.30		Root 1- 9.96; Root 2 - 2° roots (5.73 & 4.68)		3.55	
Exposed Root diameter at tree (mm)	8.48		17.12		20.88; 16.73		unconfirmed	

Parameter	Spruce	Aspen	Aspen	Jack pine
Average depth of exposed root (cm)	5	`10 to 15	8; 10 to15	5 to 10
Root diameter at midpoint (mm)	2.21	9.2	Root 1 - no data; Root 2 - 2° roots (6.61 &3.26)	6.37
Root diameter at end	1.23	3.8	Root 1 - 1.03 ; Root 2 - 2° roots (2.24 & 0.72)	2.42
Abundance fine (1<2 mm) roots	Plentiful (10-100) 2°	Plentiful (10 to 100) 1° roots at base of tree; plentiful (10 to 100) 2° roots on 1° roots	Abundant (>100) 1° and 2°	Few (<10) 1°; plentiful (10 to 100) 2°
Abundance small (2 to <5 mm) roots	Abundant (>10) 1° and 2° combined	Plentiful (1-10) 2°	Abundant (>10) 1°	Few (2 to <5) 1°; plentiful (1 to 10) 2°
Abundance medium (5 to 20 mm) roots	Abundant (>5) 1°	Plentiful (1 to 5) 2°	Plentiful (1-5) 1°	Abundant (>5) 1°
Abundance coarse (20 to <50 mm) roots	None	3	1	1
Root Notes	Root plug ~13 cm long; Most roots running south towards a small clearing. Roots in LFH, not subsoil. Small roots Abundant around plug base, plentiful otherwise.	Largest diameter 1° root splits into 2° roots w/in 10 centimeters of the tree, each ~15 mm; few fine roots entering subsoil	2 roots exposed; 2nd exposed root branched at 2.53 m and numerous times afterwards. Root 1 grew north and relatively straight; Root 2 grew south and stayed at LFH/subsoil interface; 95% of roots w/in LFH or at the LFH/subsoil interface	Root plug length 11cm; 5 roots extend vertically from base of plug; 1 coarse root transitions to horizontal, others all transition to horizontal w/in 40 cm; one vertical root exposed to LFH, then turned oblique to w/in 5 cm of surface, then grew in a south-west direction and turned straight south at 1.5 m; branched into 2° roots at 2.15 m; the 7.78 mm primary root comes out of the plug oblique, then horizontal ~5cm above subsoil horizon

Table B.2.6. Treatment 9 (20 cm LFH/30 cm Bm/100 cm Subsoil) root observations.

Parameter	Jack pine			Jack pine			Aspen			Aspen			Spruce		
Tree #	16			19			17			20			18		
Tree Height (m)	2.76			1.28			5.42			4.23			1.37		
Basal Diameter (mm)	64			28			69			50.5			44.54		
DBH (mm)	39			n/a			38			30			6.82		
Reclamation Material	**LFH**	**Bm**	**Subsoil**	**LFH**	**Bm**	**Subsoil**	**LFH**	**Bm**	**Subsoil**	**LFH**	**Bm**	**Subsoil**	**LFH**	**Bm**	**Subsoil**
Depth (cm)	~0 to 11	~11 to 31	31->120	~0-5	~5 to 30	>30+	0 to 6/15	6-15 to 26-45	>26/45+	0 to ~14/17	14-17 to 44-47	44-47 to 132	0 to ~13	13 to 43	>43+
% roots in material	90		0	70	30	0	50	40	10	75	12	12	50	50	0
Effective Root Depth (cm)	30			15			25			30			30		
Max root depth (cm)	122			25-30			115			132			43		
Above ground tree height/ **max** root depth ratio	2.26			4.27			4.71			3.2			3.19		
Above ground tree height/ **effective** root depth ratio	9.20			8.53			21.68			14.10			4.57		
# and size (mm) of 1° roots at base of tree	10 medium (10.56 to 14.57)			6 medium (5.67 to 13.29)			4 coarse (25.45 to 39.76); 1 medium (18.7)			2 medium (13.84, 17.19); 2 coarse (21.43, 29.6)			9 medium (6.31 to 9.18)		
Root distribution around tree	Evenly distributed			Evenly distributed			Evenly distributed			One 1° root in north, south and east directions; One 1° root vertical directly below tree			Evenly distributed		
Root orientation	Primarily horizontal; 1 oblique into Subsoil			1° roots are horizontal; tap root vertical and then horizontal at interface of Bm to Subsoil and oblique			2 horizontal, 2 vertical to 20 cm then horizontal			Three 1° roots horizontal; One 1° root directly below tree vertical for ~15 cm then horizontal the boundary between LFH and Bm for ~30 cm and then vertical to the maximum observed depth			Mainly horizontal (at interface between LFH/Bm); oblique/random (*i.e.*, vertical and horizontal) at ~16 cm		
Max observed root length (m)	1.92			1.00; 1.20			2.79			3.93			2.40		
Exposed Root diameter at tree (mm)	16.08			8.68; 10.17			39.76			29.98			5.76		

Parameter	Jack pine	Jack pine	Aspen	Aspen	Spruce
Average depth of exposed root (cm)	10	<15 cm	at surface until 2.79 away from tree, then vertical to subsoil	no data	45
Root diameter at midpoint (mm)	no data	no data	no data	n/a	n/a
Root diameter at end	2.85	1.05	10.03	6.97	0.52
Abundance fine (1<2 mm) roots	n/a	n/a	Plentiful (10 to 100) 2°	Few (<10) 1°;	Plentiful (10 to 100) 1°
Abundance small (2 to <5 mm) roots	Few (<10) 1°	Plentiful (1 to 10) 1°	Plentiful (1 to 10) 2°	Plentiful (1 to 10) 1° and 2°	Abundant (>10) 1°; plentiful (1 to 10) 2°
Abundance medium (5 to 20 mm) roots	Abundant (>5) 1°	Abundant (>5) 1°	Plentiful (1 to 5) 1°	Plentiful (1 to 5) 1°	Abundant (>5) 1°; plentiful (1 to 5) 2°
Abundance coarse (20 to <50 mm) roots	None	n/a	4	2	None
Root Notes	90% of roots within 20 cm of surface; majority w/in 15 cm (w/in or just below LFH); vertical root from bottom of tree (could be tap root) extended to 1.22 m and transitioned to horizontal - was 0.67 mm at deepest depth and root was 1.67 m long.	2° roots explore deeper depths, primary roots remain closer to the surface (w/in 10 cm); two 1° roots oblique and grow into Bm material; tap root extended vertical to 26 cm where it did a 90° turn to horizontal for 5 cm and then oblique towards the surface in another 90° turn	Exposed and measured a second root: 4.9 m long, 1 m to 90° turn, 4.6 m to secondary branch; vertical root below tree changed to horizontal at Bm/Subsoil interface and gradually oblique into Subsoil; vertical 1° root changed direction at 1.15 m and horizontal w/in Subsoil; deepest root observed at 1.15 m - total length was 1.46 m.	Overburden at 1.35 m; Three 1° horizontal roots stay w/in 15 cm of soil surface (stay w/in LFH layer and boundary w/in Bm; One 2° root from 1° root growing in north direction close to surface travelled vertical to LFH/Bm boundary and then horizontal where it formed a 3° root at Bm/Subsoil interface and down to 0.8 m and branched several more times.	Two medium 1° roots at base of tree plug completely horizontal; 20% of 1° roots branch into 2° roots w/in 20 cm of tree

Table B.2.7. Treatment 10 (30 cm Peat/120 cm Blended B/C) root observations.

Parameter	Aspen		Jack pine		Spruce	
Tree #	50		51		49	
Tree Height (m)	1.9		1.7		1.4	
Basal Diameter (mm)	34.5		50.3		38.1	
DBH (mm)	9.4		9.4		4.6	
Reclamation Material	**Peat**	**Blended B/C**	**Peat**	**Blended B/C**	**Peat**	**Blended B/C**
Average Depth (cm)	0 to 25	>25+	0 to 25	>25	0 to 28	>28
% roots in material	90	10	75	25	90	10
Effective Root Depth (cm)	25		38		28	
Max root depth (cm)	1° roots extend below peat into blended B/C; max depth undetermined (estimated 45 cm)		40		36	
Above ground tree height/ **max** root depth ratio	4.22		4.25		3.89	
Above ground tree height/ **effective** root depth ratio	6.0		4.47		5.0	
# and size of 1° roots at base of tree	10-15 coarse and medium		4 coarse; >5 medium; >10 small; >100 fine		5 (9.12-13.35 mm) from top of plug; ~15 (3.44-8 mm) from bottom of plug	
Root distribution around tree	S, E, W (few extending N)		Evenly distributed		Evenly distributed	
Root orientation	Vertical, horizontal, & oblique; few surface horizontal 1° roots; plentiful vertical roots beneath tree		3 oblique 1° roots extend into Blended B/C w/in 20 cm of tree; 1 horizontal 1° roots extend along interface		1° roots from top of plug remained horizontal w/in peat and/or at Peat/Blended B/C interface; one vertical root extended into Blended B/C and did a 90° turn to remain ~2 cm below Peat w/in Blended B/C	
Max observed root length (m)	6.02		1.67; 1.39		3.34	
Exposed Root diameter at tree (mm)	17.9		13; 20.36		13.2	
Average depth of exposed root (cm)	5 cm to 3.4 m then oblique to Blended B/C		Root 1- near peat surface; Root 2 - branched at 38 cm ~10 cm into Blended B/B, most roots remain just below Peat		5	
Root diameter at midpoint (mm)	7.1		2.54; 11.33		3.5	

Parameter	Aspen	Jack pine	Spruce
Root diameter at end (mm)	1.4	1.27; 2.09	0.4
Abundance fine (1<2 mm) roots	Plentiful (10-100) 2°	Abundant (>100) 1° and 2°	Abundant (>100) 2°
Abundance small (2 to <5 mm) roots	Few (<5) 2°	Abundant (>10) 1° roots	Plentiful (1-10) 1° and 2°
Abundance medium (5 to 20 mm) roots	Abundant (>5) 1°; Plentiful (1-5) 2°	Abundant (>5) 1° roots	Abundant (>5) 1° and 2°
Abundance coarse (20 to <50 mm) roots	4	4	None
Root Notes	Most 1° roots stayed w/in the Peat horizon; vertical root directly below tree base extended vertically until the Peat and Blended B/C interface and then grew horizontally at interface	Base of root ball at interface; majority of roots grow w/in 12 cm on the base of tree; abundant fine roots in Peat and vertically into Blended B/C	Many roots off of plug base; ~25 cm from stem base to bottom of plug; Blended B/C harder to dig than other test pits

Table B.2.8. Treatment 11 (30 cm Peat/70 cm Blended B/C) root observations.

Parameter	Spruce		Jack Pine		Aspen	
Tree #	43		44		45	
Tree Height (m)	1.37		1.71		3.15	
Basal Diameter (mm)	39.59		51		35.22	
DBH (mm)	5.73		10		21.5	
Material	**Peat**	**Blended B/C[1]**	**Peat[1]**	**Blended B/C**	**Peat**	**Blended B/C[2]**
Depth (cm)	0 to 29	29 to 70	0 to 27	27 to 95	0 to 32	32 to 89/95
% roots in material	95	5	90	10	98	2
Effective Root Depth (cm)	30		20		30	
Max root depth (cm)	40		45		35	
Above ground tree height/ **max** root depth ratio	3.43		3.8		9.0	
Above ground tree height/ **effective** root depth ratio	4.57		8.55		10.50	
# and size (mm) of 1° roots at base of tree	Abundant (>10) medium (5 to <20 mm); abundant (>10) small (2 to <5 mm)		2 coarse; abundant (>10) medium (5 to <20 mm); abundant (>10) small (2 to <5 mm)		10 to 15 medium (6.8 to 12.2); abundant (>10) small (2 to <5 mm)	
Root distribution around tree	Evenly distributed		Evenly distributed		Evenly distributed around the tree, secondary roots travel at Peat and B/C interface	
Root orientation	Horizontal w/in peat and at the Peat/ Blended B/C interface and vertical roots w/in Peat to interface, 90° turn to horizontal at interface		Mainly horizontal w/in peat; 1 medium 1° oblique root that extends vertically into Blended B/C; 2 medium 2° oblique roots extend into Blended B/C		variable; horizontal, oblique; tree roots demonstrated unique pattern with multiple bends near the tree	
Max observed root length (m)	1.76		1.80		6.83	
Exposed Root diameter at tree (mm)	16.03		23.06		11.16	
Average depth of exposed root (cm)	5		4 to 5		5 (8 to 10 after root formed secondary roots)	
Root diameter at midpoint (mm)	7.79		n/a		n/a	

Parameter	Spruce	Jack Pine	Aspen
Root diameter at end (mm)	2.45	0.82	1.1
Abundance fine (1<2 mm) roots	Abundant (>100) 2°	Plentiful (10 to 100) 2°	Abundant (>100) 2°
Abundance small (2 to <5 mm) roots	Abundant (>10) 1° and 2°	Abundant (>10) 1°	Abundant (>10) 1°
Abundance medium (5 to 20 mm) roots	Abundant (>5) 1°	Abundant (>5) 1° (15 to 20 mm size); abundant (5) 1° (10-20 mm size)	Abundant (>5) 1°
Abundance coarse (20 to <50 mm) roots	None	2	None
Root Notes	n/a	2 distinct size classes of 1° roots w/in the medium category (5 to 10 mm; 10 to 20 mm); in general many roots were 5 mm or less 30 cm from the tree; fine and small ends of roots were oriented along the interface between the Peat and Blended B/C; fairly large diameter roots in general for the size of the tree	large rock directly below tree in Blended B/C; one primary root was oblique directly out of the top of the root plug for ~30 cm and changed to horizontal (90° turn) and traveled along the interface between Peat and Blended B/C; one vertical root directly under aspen (~15 cm) - changed to horizontal at the interface and grew along interface; very few roots observed in Blended B/C

[1] Overburden at 70 cm; Blended B/C had higher clay content compared to Blended B/C in Cell 29 (Treatment 10); Peat is friable (looks loose) - different than Peat within Cells 3, 5 and 6.
[2] Overburden started at 89 to 95 cm.

B.3 TREATMENT COMPARISONS

Table B.3.1. Comparison of key parameters for Treatment 6 (30 cm Peat/30 cm Bm/90 cm Subsoil (>1m)), Treatment 9 (20 cm LFH/30 cm Bm/100 cm Subsoil (>1m)), Treatment 1 (30 cm Peat/120 cm Subsoil (>1m)) and Treatment 7 (20 cm LFH/130 cm Subsoil (>1m)).

Parameter	Treatment 9			Treatment 6			Treatment 1			Treatment 7		
	Aspen[1]	Pine[1]	Spruce	Aspen	Pine[2]	Spruce[2]	Aspen	Pine	Spruce	Aspen[1]	Pine	Spruce
Tree Height (m)	5.42	2.76	1.37	1.44	1.3	1.68	1.09	2.01	1.48	2.95	2.75; 1.84	0.75
Basal Diameter (mm)	69	64	44.54	23.38	44	47	31.3	68	47	35	2.75; 1.84	22.9
Effective Rooting Depth (cm)	25	30	30	30	35	30	27	25	20	20	20	19
Maximum Rooting Depth (cm)	115	122	43	33	120	100	35	90	65	20	47	30
Height/ **MRD** ratio	4.71	4.27	2.26	4.36	1.08	1.68	3.11	2.23	2.28	14.75	5.85	2.5
Height/**ERD** ratio	21.68	8.53	9.2	4.80	3.71	5.6	4.04	8.04	6.43	14.75	13.75	3.95
Root distribution around tree	Even	Even	Even	Even	Horizontal and vertical	Even	Even	Even	Even	Primarily north direction	Even	Primarily south-west direction
Max observed root length (m)	2.79	1.92	2.4	5.27	1.04	1.72	2.27	2.46	3.98	9.96	3.55	2.48
Root Diameter at end (mm)	10.3	2.85	0.52	1.05	2.63	1.96	4.77	1.84	1.34	1.03	2.42	1.23
Average depth of exposed root (cm)	no data	10	45	3 to 5	10 to 15	2 to 3	5 to 10	<5	<5	5 to 10	5 to 10	5
Abundance fine (1<2 mm) roots	Plentiful 2°	n/a	Plentiful 1°	Few 1°	n/a	Abundant 2°	Abundant	n/a	Abundant	Abundant 1° and 2°	Few 1°; plentiful 2°	Plentiful 2°
Abundance small (2 to <5 mm) roots	Plentiful 2°	Few 1°	Abundant 1°; plentiful 2°	Plentiful 1° and 2°	Abundant	Few 1° and 2°	Plentiful	Few 2°; plentiful 1°	Few 1°; Abundant 2°	Abundant 1°	Few 1°; plentiful 2°	Abundant 1° and 2°
Abundance medium (5 to 20 mm) roots	Plentiful 1°	Abundant 1°	Abundant 1°; plentiful 2	Abundant 1°	Plentiful	Abundant 1°	Abundant	Abundant	Abundant	Plentiful 1°	Abundant	Abundant
Abundance coarse (20 to <50 mm) roots	4	None	None	None	None	1	1	None	3	1	1	None

[1] Treatment 9 data displayed for aspen 17 and jack pine 16; Treatment 7 data displayed for Aspen 42.

[2] Treatment 6 data for jack pine and spruce taken from 5/6 border inspection area data.

Table B.3.2. Comparison of key parameters for Treatment 4 (30 cm Peat/30 cm Blended B/C), Treatment 5 (30 cm Peat), Treatment 10 (30 cm Peat/120 cm Blended B/C) and Treatment 11 (30 cm Peat/70 cm Blended B/C).

Parameter	Treatment 4			Treatment 5			Treatment 10			Treatment 11		
	Aspen[1]	Pine[1]	Spruce[1]	Aspen[2]	Pine[2]	Spruce[2]	Aspen	Pine	Spruce	Aspen	Pine	Spruce
Tree Height (m)	1.94	1.35	1.36	2.05	0.92	0.75	1.9	1.7	1.4	3.15	1.71	1.37
Basal Diameter (mm)	33.75	30.42	38.32	n/a	22.05	21.25	34.5	50.3	38.1	35.22	51	39.59
Effective Rooting Depth (cm)	32	38	27	30	30	25	25	38	28	30	20	30
Maximum Rooting Depth (cm)	50	70	60	30	30	25	~45	40	36	35	45	40
Height/ **MRD** ratio	3.88	1.93	2.27	6.83	3.07	3	4.22	4.25	3.89	6	3.8	3.43
Height/**ERD** ratio	6.06	3.55	5.04				6	4.47	5	10.5	8.55	4.57
Root distribution around tree	Even	Even	Even	Even	Even	Even to north	south, east, west	Even	Even	Even	Even	Even
Max observed root length (m)	8.6	1.35	1.17	2.4; 1.73; 1.75	1.38; 1.43; 1.7	0.62	6.02	1.67; 1.39	3.34	6.83	1.8	1.76
Root Diameter at end (mm)	4.46	0.5	1.63	4.7; 6.32; 4.5	0.95; 2.54; 2.16	1.29	1.4	1.27; 2.09	0.4	1.1	0.82	2.45
Average depth of exposed root (cm)	2 (25 at end)	10	5	10 cm	2 to 10 cm	2 cm	5 cm	10 cm	5 cm	5 to 10	4 to 5	5 cm
Abundance fine (1<2 mm) roots	Plentiful 2°	Abundant **2°**	Plentiful 2°	Plentiful 1° and 2°	Abundant 1°; Plentiful 1° and 2°	Plentiful 1° and 2°	Plentiful 2°	Abundant 1° and 2°	Abundant **2°**	Abundant **2°**	Plentiful 2°	Abundant **2°**
Abundance small (2 to <5 mm) roots	Plentiful 2°	Plentiful 2°	Plentiful 1° and 2°	Few 1° and 2°	Abundant 1°	Abundant 1°	Few **2°**	Abundant 1°	Plentiful 1° and 2°	Abundant 1°	Abundant 1°	Abundant 1° and 2°
Abundance medium (5 to 20 mm) roots	Plentiful 1° and 2°	Abundant 1°	Abundant 1°	Abundant 1°	none	none	Abundant 1°; Plentiful 2°	Abundant 1°	Abundant 1° and 2°	Abundant 1°	Abundant 1°	Abundant 1°
Abundance coarse (20 to <50 mm) roots	2	none	none	3	none	none	4	4	none	none	2	none

[1] Treatment 4 - Aspen #21; pine #22; spruce #24.

[2] Treatment 5 - Spruce #7 (Treatments 5/12b border area data); aspen #29 (Treatments 5/6 border area data); Pine #33 (Treatments 5/6 border area data).