Assessment of a Red Pine Plantation near Hunt Club Road, Ottawa

Prepared for The City of Ottawa

Prepared by FSmith Consulting Inc., Peterborough, Ontario

May 22nd, 2023

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Preamble

As requested by the City of Ottawa this report is intended to provide a professional forestry evaluation of the subject lands including a site survey and inventory (in appendix), the results of the condition and health assessment and an evaluated list of management options that address to varying degrees the City's management objectives. Following a review of the draft report the City, a proposed management plan was developed based on the City's preferred option.

This report summarizes the current forest condition determined through field observations and office research that provides a basic history and assessment of the plantation's development, health and potential for management.

This opinion represents the evidence, opinions, and conclusions of a registered professional forester (RPF#1491) acting under the framework of the Professional Foresters Act (2000) and the scope of practice regulated by the Ontario Professional Foresters Association. The study and report was supported by others working under the supervision of RPF # 1491, including Eric Boysen and Sylvia Ho. The report is limited to the bounds of the property for which the evaluation was conducted. I hereby verify that this report has been prepared without prejudice and represents my professional opinion.

Signed,

Ken A. Elliott, RPF # 1491, May 21, 2023

Fraser Smith, RPF # 2371, May 22, 2023

1.0 Assessment of the Hunt Club Road Red Pine Plantation

1.1 Background to the Study and Assessment

The City of Ottawa has requested a critical evaluation of an eight-hectare red pine plantation in Ottawa's urban area. The City will use the evaluation to inform a decision on whether to acquire the plantation for conservation and community use. The evaluation will include:

- A Survey and inventory the forest
- An Assessment of the condition and overall health of the forest
- Identification of management actions necessary to:
    - i. Ensure the future health of the forest
    - ii. Diversify the canopy and understory of the forest
        - o Improve the quality of the forest as wildlife habitat; and
        - o Make the plantation safe for recreational walking.

Figure 1. ***Map of the proposed assessment area***

1.2 Previous and Proposed Development of the Hunt Club Road Red Pine Plantation

Portions of the original plantation were cleared to permit development of the current Lowe-Martin printing facility (sometime between the 1991 and 2008 aerial photos) in the northwest corner of the property. A 2021 proposal (https://devapps.ottawa.ca/en/applications/D02-02-21-0040/details) to clear an area on the eastern boundary adjacent to the Otto's BMW facility caused some public concern (https://www.facebook.com/groups/savehuntclubforest) that resulted in the current request for a critical assessment of forest management options. Most relevant to this current assessment, McKinley Environmental Solutions prepared a Combined Environmental Impact Statement and Tree Conservation Report as part of the development proposal (http://webcast.ottawa.ca/plan/All_Image%20Referencing_Zoning%20Bylaw%20Amendment%20Application_Image%20Reference_2021-05-13%20-%20Environmental%20Impact%20Statement%20and%20Tree%20Conservation%20Report%20-%20D02-02-21-0040.PDF

1.3 The Property and Red Pine Plantation

The plantation to be assessed is located along Hunt Club Road, near the Ottawa International Airport in the City of Ottawa (see green boundary in Figure 1). It is bounded on the west by The Lowe-Martin print shop at 400 Hunt Club Road, and Otto's BMW at 660 Hunt Club Road on the east. Access is via Billy Bishop Private road, and by numerous foot paths connecting local housing areas.

The property is currently owned by the Federal Government. The northern portion of the red pine plantation is controlled by the Ottawa International Airport Authority, while the southern portion is part of the former Canadian Forces Base Uplands and is currently administered by Canadian Forces Support Unit (Ottawa) - Uplands Site.

1.3.1 Ottawa International Airport Authority: The northern portion (4.73 hectares) adjacent to 400 Hunt Club Road is leased by Transport Canada to the Ottawa International Airport Authority (Roll # 0614 116 401 90450 0000)(see Figure 3). As part of its responsibility to Transport Canada, the Airport Authority must prepare a Master Plan outlining development and management plans. The original Master Plan was developed in 1998 and must be updated every ten years. The most recent version of the Plan dates from 2018, and can be found here: https://yow.ca/en/corporate/airport-authority/airport-master-plan A copy of the Executive Summary of the 2018 plan can be found here: https://yow.ca/sites/yow.ca/files/site-specific/2018_ottawa_airport_master_plan_-_executive_summary_-_eng.pdf

While the Master Plan's main focus is on the development and management of airport services (Terminal buildings, runways, security, etc), it does reference environmental responsibility and planning, including:

> ENVIRONMENTAL AREA: The 'Environmental Area' designation contains those lands which, through studies conducted, are known to be ecologically important or are being reserved for environmental purposes. This designation is specifically the means through which compliance with provincial natural heritage and federal wildlife protection legislation (such as the Species at Risk Act) will be achieved. There will be no development of land identified as being environmentally significant. To protect areas of ecological importance, development proposed

within 30 metres should be supported by Environmental Impact Statements (EISs) that identify appropriate mitigation measures for implementation.

ENVIRONMENTAL AREA (GREENBELT LINKAGE): The Greenbelt Linkage is part of land reserved for environmental purposes which will form part of a potential future link between the Greenbelt lands to the west of the airport and the Leitrim Wetland. The Greenbelt Linkage and boundaries are subject to boundaries being established by an Ontario Land Surveyor and an agreement between the airport and the National Capital Commission (NCC).

The corridor of land running parallel to Hunt Club Road, including the red pine plantation, has been designated as Commercial Development lands (see Figure 2). It is not known if the plantation area was assessed for environmental significance as part of the Master Plan process.

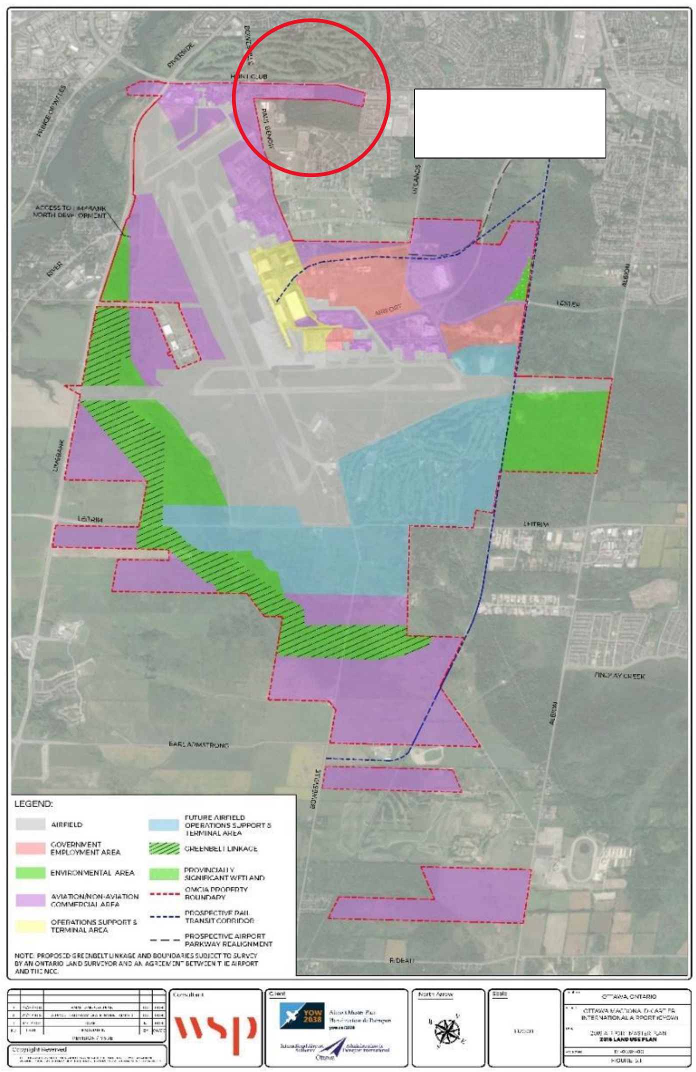


Figure 2. Map ***extracted from the YOW.ca Master Plan, 2018***
Hunt Club Red Pine Plantation designated as Commercial Development Area

1.3.2 Canadian Forces Support Unit (Ottawa) – Uplands Site. The southern portion (2.11 hectares) of the red pine plantation is administered by the Canadian Forces Support Unit (Roll # 0614 600 030 00100 0000). This Support Unit provides support to a variety of housing, training and well-being needs of Forces members. However, there is no indication that the plantation area and adjacent hardwood forest have been assessed nor included in services offered. See https://www.canada.ca/en/department-national-defence/services/bases-support-units/canadian-forces-support-unit-ottawa/services.html#operations

See maps below for more detail of the property controlled by respective responsible agencies:

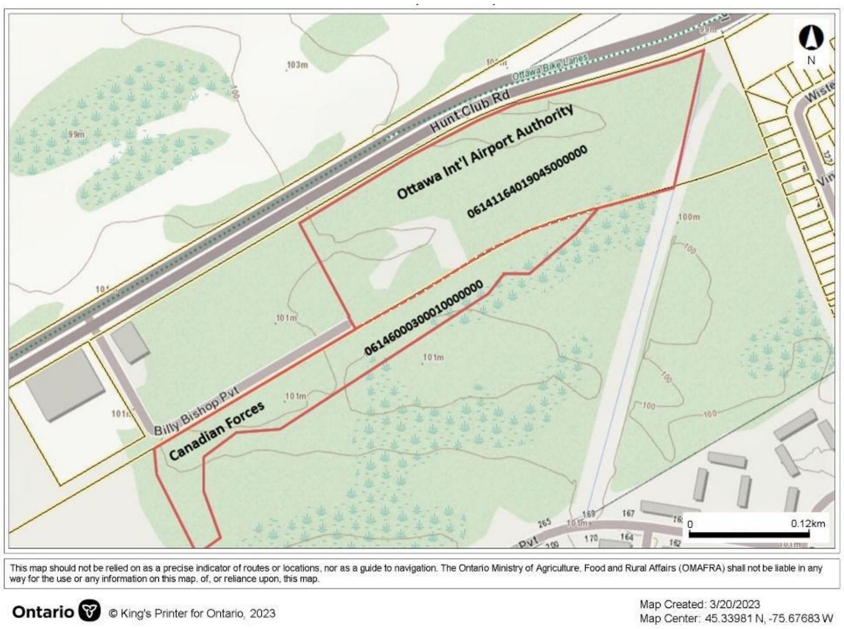


Figure 3. ***Topographic(top) and aerial views(bottom) of the ownership of the red pine plantation. Assessed area outlined by solid red line. Ownership division shown by dashed red line.***

Staff from the City of Ottawa confirmed that only the **4.73 hectare** portion of the red pine plantation controlled by the Ottawa International Airport Authority will be included in the final assessment and report on the red pine plantation (email March 10 Copestake – Boysen). Of this area, approximately **4.17 hectares** are red pine plantation, with the remaining 0.56 hectares occupied by the former sand pit and access roads.

1.4 Forest Assessment – approach and measurements

Prior to making any critical assessment of the health, growth and future management options for the plantation, FSmith Consulting Inc. conducted a forest inventory and assessment on March 7 and 8, 2023. Snow depths averaged 50 cms at the time of sampling which prevented an assessment of ground cover vegetation.

Eight (8) 200 m² circular fixed-area plots were established across the entire plantation area. The centre point of each plot locations was flagged for future reference. Geo-reference points were also recorded.

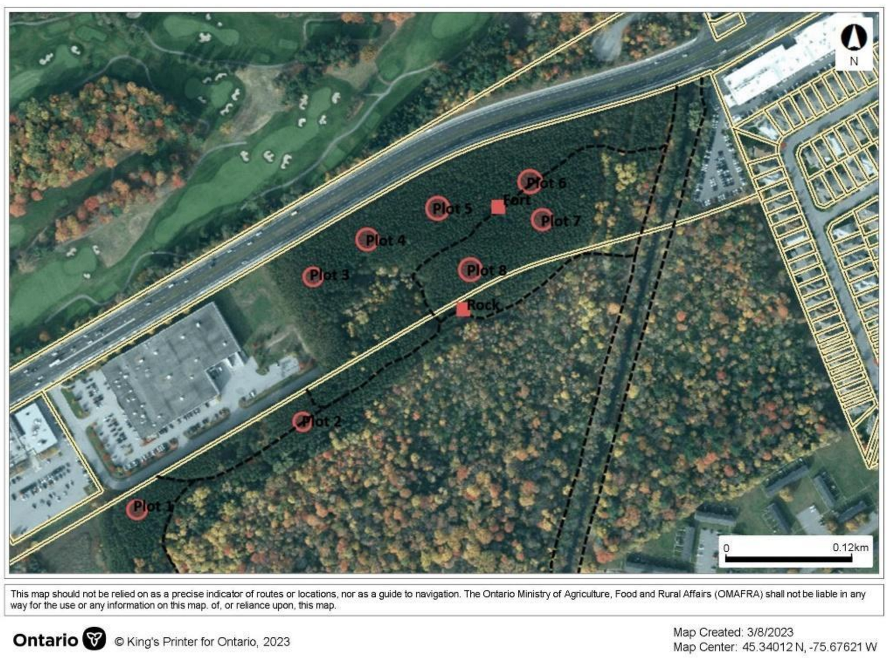


Figure 4. ***Map showing location of circular sample plots***

Within each plot, all trees with a Diameter at Breast Height (DBH) greater than 10 cms were assessed for:

- Species
- Diameter
- Alive / dead
- Notes on general stem form, health, wildlife use, or other pertinent characteristics

In addition, each plot was assessed for:

- Original planting density and spacing
- Shrub layer and invasive species assessment
- Average height of trees within the plot

Existing access trails were mapped using GPS tracking. Tree damage caused by the May, 2022 Derecho wind event was noted. Existing cultural items were also noted (ie constructed forts, water well testing locations, etc).

In addition to the assessment plots described above, a single tree was destructively sampled to allow for a more detailed stem analysis. A recently blown over tree was selected to ensure that no live tree was destroyed. This tree was assessed for:

- Diameter at each 1.0 m interval from the base of the tree, to the tip of the tree
    - A cross section ("cookie") was removed at each interval for further analysis)
- Diameter at Breast height (1.3 m)
- Total Height
- Height of live crown (from the growing tip to the lowest live branch)
- A soil sample was also taken because the root plate had tipped over for this tree

Figure 5. ***Photos of the Stem Analysis tree***

Left: measuring total and live crown heights.
Right: Cookies taken from the 1.0 m and 2.0 m heights. Diameter @ 1.0 m = 25.7 cm; Diameter @ 2.0 m = 25.0 cm
See Appendix 1 for data and photos of all cookies

A supplemental forest assessment was conducted on April 10, 2023 to determine whether the ice storm of Wednesday April 5th, 2023 had any impact on the plantation. No additional tree or crown damage was noted.

1.5 Forest Assessment – statistics and analysis

As per the City of Ottawa request, the following criteria were assessed and analyzed:

1.5.1 Site Survey and Inventory

1.5.1.1 <u>Site factors and suitability</u> – Site Index for Red Pine = 18.5 m (medium-well suited for red pine).

The site is mostly level. It appears to have been used for agricultural purposes until the 1940's or 50's. Some sand extraction has occurred in the centre of the property. Soils are moderately well-drained fine sands, with no limitations to rooting depth for red pine. Site index for red pine was calculated as SI 18.5 (ie projected 18.5 m of total height at age 50). This index is used to calculate the volume of wood per stem. Overall, this is a suitable site for red pine.

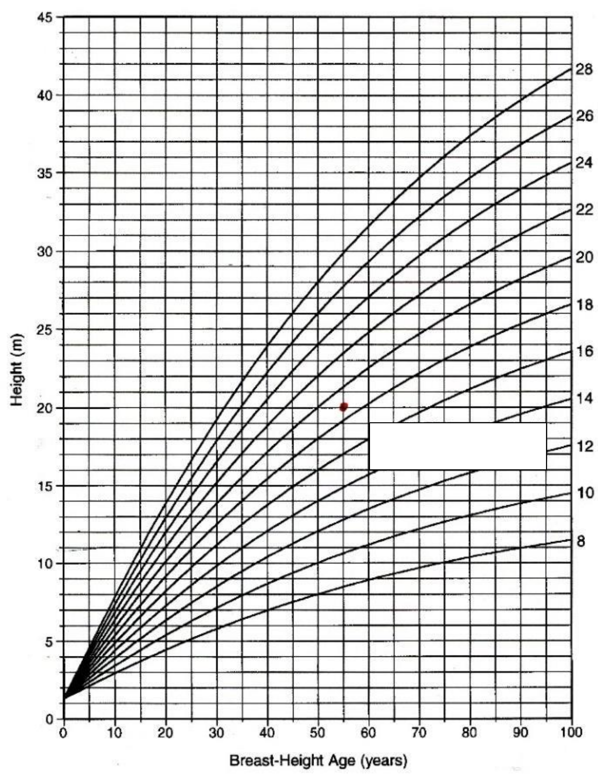


Figure 6. ***Site Index = 18.5 m (Breast height age = 55, Average Height = 20.0 m)***
Source: Beckwith et al, 1983

1.5.1.2 <u>Soil profile and free carbonates</u>

A soil sample taken from the Stem Analysis tree was sent to A&L Canada Laboratories in London, Ontario. This analysis shows that this is a low nutrient, slightly alkaline site with no particular issues regarding calcium content. The salt level is a very high which could either be from run-off from the Hunt Club Road, or the result of the glacial salt-water from the historical Champlain Sea. There was no indication of any red pine pocket decline, which can be a symptom of sites that are too high in carbonates to support long term red pine growth. See Appendix 2 for a more detailed discussion of red pine health issues, and Appendix 3 for the complete soils analysis lab results.

F*igure 7. Photo showing tipped over root plate of Stem Analysis tree, exposing the soil profile*

1.5.1.3 <u>Stand composition</u> – Red pine 95% Others 5%

Red pine was the only species recorded in any of the assessment plots. Other species with DBH > 10 cms were noted, including jack pine, Scots pine, white spruce (all planted), burr oak, red maple, elm, poplar. Minor occurrences of young seedlings of sugar maple and burr oak were noted in the understory.

Figure 8. ***Photo showing the low species diversity / dominance of red pine in the plantation***

1.5.1.4 <u>Stand age</u> – 60 years old

No planting records were found for this plantation. However, there are other ways of determining the age, including:

- Stem analysis. Breast height age was counted as 55 years in 2023. It likely took 5 years from time of planting to reach this height which indicates a total age of 60 years old, or a 1962 planting date.

Figure 9. ***Photo of 1.0m cookie with pins inserted at 10-year increments from the centre of the tree. Note the rapid decline of diameter growth after Age 20***

- 1953 aerial photography shows the site to be an open field, with an active sand extraction pit in the centre. Interpretation of 1978 aerial photograph of the site shows the plantation to be 22 years old at that time. This suggests a planting date of 1956. This would indicate 66 years old in 2022. However, this seems like an over-estimate, given the results from the Stem Analysis shown above. See Appendix 4 for historical aerial photographs of the plantation area.

Figure 10. ***1978 aerial photography of the plantation with Forest Resource Inventory interpretation: Stand description Pr10 – 22 yrs old – 9 m height – 100% stocking – Site Class 1***

- The McKinley Environmental Solutions study estimated plantation age to be 55 years in 2020, or a planting date of 1965. However, they based this on a 1965 aerial photo in which you could clearly see the planted trees, meaning it is unlikely that they had just been planted as seedlings and more likely that they were 2 to 3 years old.

1.5.1.5 <u>Basal area</u> – average for all plots = 50 m²/ha

- Basal area measures the total cross-sectional area of solid wood (or stocking), in m²/ha
- It can be estimated using a wedge prism, or calculated by measuring the DBH of all stems in a fixed-area plot, and expanding that number to a per hectare basis
- For the purposes of this study we used the data from the six, 200 m2 fixed-area plots on the Ottawa International Airport Development lands. The calculated Basal Area of all live stems to be 49.90 (~50) m²/ha, with plots ranging from a low of 27 to a high of 58 m²/ha

1.5.1.6 <u>Density</u>

- **Density – number of live stems per hectare = 1,575 per hectare in 2022**
- **Initial planting spacing = 1.6 x 1.8 m** (nominal) = 3,470 stems per hectare at time of planting. Assume 10% initial planting mortality = **3,100** stems per hectare when plantation reached Free-to-Grow status
- Mortality = 3,100 – 1,575 = 1,525 stems per hectare (45%) have died naturally and mostly disintegrated / rotted since the plantation reached Free-to-grow status. The mortality seems to be randomly and uniformly distributed across the stand. Currently, there are approximately 197 dead standing trees per hectare.

1.5.1.7 <u>Diameter at Breast Height (DBH)</u>

- **Quadratic Mean Diameter** (**DBH_q**) is the diameter of the tree of average per tree basal area **= 20.08 cm** (this number is required for the Density Management Diagram tool, see Figure 23. In Section 2)
- **Arithmetic Mean Diameter = 19.85 cm**
- **Diameter Range = 13.9 cm to 27.4 cm DBH**

Figure 11. ***Photo showing a tree with Diameter at Breast Height = 20.3 cm, which closely approximates the Quadratic Mean Diameter (*****DBH_q*****) of 20.08 cms***

1.5.1.8 Average tree height = 20.0 m

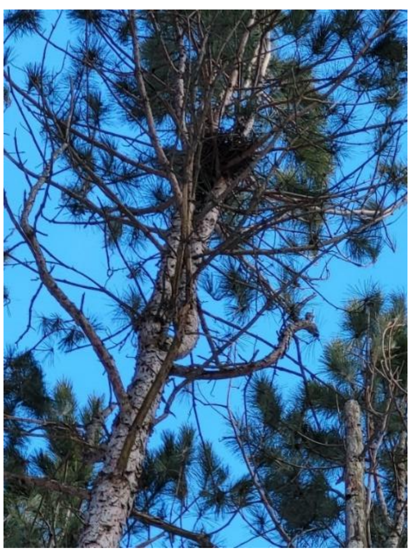
- Average tree height was measured through Stem analysis, and verified by using a Suunto Clinometer on random trees throughout the plantation area
- There was no difference in tree height across the plantation because of the uniform site conditions, species and planting date.
    - **Merchantable height –** based on a 15 cm average stump height, and a minimum top diameter of 13 cm **= 14.85 m**

1.5.1.9 Stand Volume

- **Total Stand Gross Volume** = 449 m3/ ha x 4.17 ha = **1872 m3**
- **Total Stand Merchantable Volume** = 336 m3/ha x 4.17 ha = **1400 m3**

1.5.1.10 Evidence of wildlife trees and wildlife use.

- There was little evidence of use of the plantation area by wildlife.
- On-site observations in March 2023 included:
    - Black-capped chickadee, blue jay, American crow, red-breasted nuthatch, hairy woodpecker
    - Red squirrel and cone feeding sites
    - Deer and fox tracks
    - Stick nest (likely crow) adjacent to main access trail between Plots # 2 and # 8
    - Small feeding cavities on dead and dying red pine throughout



a) ***Observed stick nest – unknown user***

b) ***Hairy woodpecker feeding on a declining red pine***

c) ***Observed woodpecker feeding cavities*** **d)** ***Sign on Lowe-Martin property adjacent to plantation***

Figure 12. ***Photos showing evidence of wildlife used within the Hunt Club Road Plantation.***

See Appendix 5 for all plot related data.

1.5.2 Condition and health of the plantation

1.5.2.1 Evidence of disease

- There were no diseases of red pine noted.
- The plantation was assessed for the following diseases of red pine:
    - Sclerroderris canker (needle fungus and stem canker)
    - Armillaria root rot
    - Heterobasidion (Annosus) root rot
    - Red pine pocket decline (a general health decline complex caused by root diseases, nutrient deficiency, insects, and site factors such as high pH / calcareous soils)
- See Appendix 2 for more information on some of these red pine health issues.

1.5.2.2 Evidence of stress

- There were several signs and indication of individual tree and overall plantation stress.
- The plantation was assessed for any evidence of stress from abiotic damaging agents, including:
    - Drought – nothing noted
    - Winter damage (salt spray, drying winter winds)
        - Several trees on the edge of the plantation adjacent to Hunt Club Road in the NE corner of the property exhibited signs of stress (red foliage) caused by the proximity to the road, hydro corridor and other infrastructure uses
        - Several trees adjacent to Billy Bishop Private road exhibited similar crown stress, likely due to exposure to road salt from the snow banks at the end of the road.

Figure 13. ***Photo showing blown-down, tipped-over, and red (dead/dying) foliage in the crowns***

- Blown down and tipped over trees
    - The Derecho wind of May 2022 caused small areas of the plantation to either tip over into the adjacent trees, or to blow down / snap off completely
    - There is little salvage opportunity for these trees, as Blue-stain fungus begins to degrade and decay the wood very quickly

Figure 14. ***Photos of snapped tress (left) and tipped over trees (right)***

Figure 15. ***Photo from stem analysis tree showing blue stain decay***

- Quality and decline issues

During the assessment of each plot we also took note of any defects, health issues or indicators of decline. This included issues such as double tops, declining or dead tops, crook, lean, wildlife damage, and heavy knots (see Figures 31 and 32 in Section 3). Of the 240 trees assessed in the 8 plots, 60 (25%) of them had one or more of these quality or health indicators.

- Crown volume and live crown height
    - Because the remaining live trees are growing in very close proximity, they compete for growing space and sunlight at the height of the live crown
    - Branches are frozen and brittle in winter, and can be sheared off by adjacent trees
    - This mechanical competition reduces both the current volume of the crown, but also reduces potential crown expansion as the terminal buds are sheared off or damaged
    - Current live crown height is approximately 20% of total height, with crown diameters of ~2 m. Individual red pine trees require a live crown ration of between 25 and 30% of total height in order to sustain growth.

Figure 16. ***Photo of sheared-off branches and branch tips blanketing the plantation floor***

Figure 17. ***Photo of sheared-off needles***

Figure 18. ***Photos showing the small live crowns, and limited room for crown expansion***

- Stand Density and Stem Diameter
  - Most trees are exhibiting signs of stress and low growth because of the Current Stand Density – number of live stems per hectare = 1,575 per hectare in 2022
  - Initial planting spacing = 1.6 x 1.8 m (nominal) = 3,470 stems per hectare at time of planting. We assumed 10% initial planting mortality, leaving 3,100 stems per hectare when plantation reached Free-to-Grow status. The site was likely planted using a mechanical tree planter attached to a farm tractor.
  - Mortality due to all causes, including competition from adjacent trees = 3,100 – 1,575 = 1,525 stems per hectare. 45% of the original trees have died naturally and mostly disintegrated / rotted since the plantation reached Free-to-grow status. Currently, there are approximately 197 dead standing trees per hectare.
  - The DBHq for the stand is 20.08 cm, which is small for trees aged 60 years. The Diameter range is between 13.9 cm and 27.4 cm DBH.

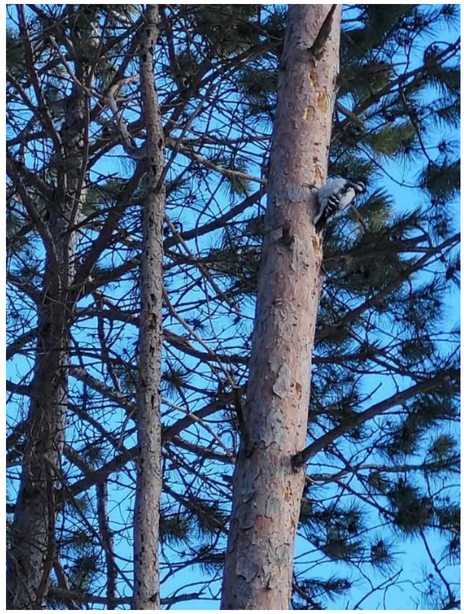


Figure 19. ***Photo of dead and dying trees with woodpecker activity***

Figure 20. ***Photo of Risk Warning and No Trespassing signs installed at various entry points by the Ottawa International Airport Authority. These signs are largely ignored by forest users.***

1.5.2.3 Fire risk assessment

- Current fire risk is **Low**
  - Very sparse fuel load on the ground (needles and fallen branches / some blown down trees)
  - Once shrub layer greens up in spring risk diminishes
- Risk increases to **High** immediately following any harvesting activity until needles fall off of the residual tops and branches
  - Risk can be mitigated by ensuring that the slash (tops and branches) is compacted by logging equipment during harvest operations
  - Signage to public warning of fire danger may also mitigate issues
  - Risk should return to **Low** once slash begins to decompose
- The greatest causal risk factor is from human activity, including careless smoking, camp fires, etc


Figure 21. ***Remains of a campfire within the boundaries of the plantation***

2.0 Future trajectory of the plantation

The current plantation can be analysed using a Density Management Diagram (DMD) which are graphs that relate the average tree size (stem diameter, basal area, or volume) and the stand volume (yield) to the stand density, but may also include the height of the dominant trees and other parameters. DMDs are used to identify optimal conditions for growth and for when density-related mortality is likely to begin. They can be used to guide the development of commercial thinning prescriptions and help to compare alternative thinning strategies (the timing and intensity of thinnings) in terms of their ability to achieve various management objectives. DMDs are also used to estimate the average dimensions (e.g., length and diameter) of extracted forest products. The maximum density lines in DMDs are based on the -3/2 self-thinning power law, which describes self-thinning trends in most species, and therefore applies best to thinning-from-below (ie smallest and weakest trees die out first).

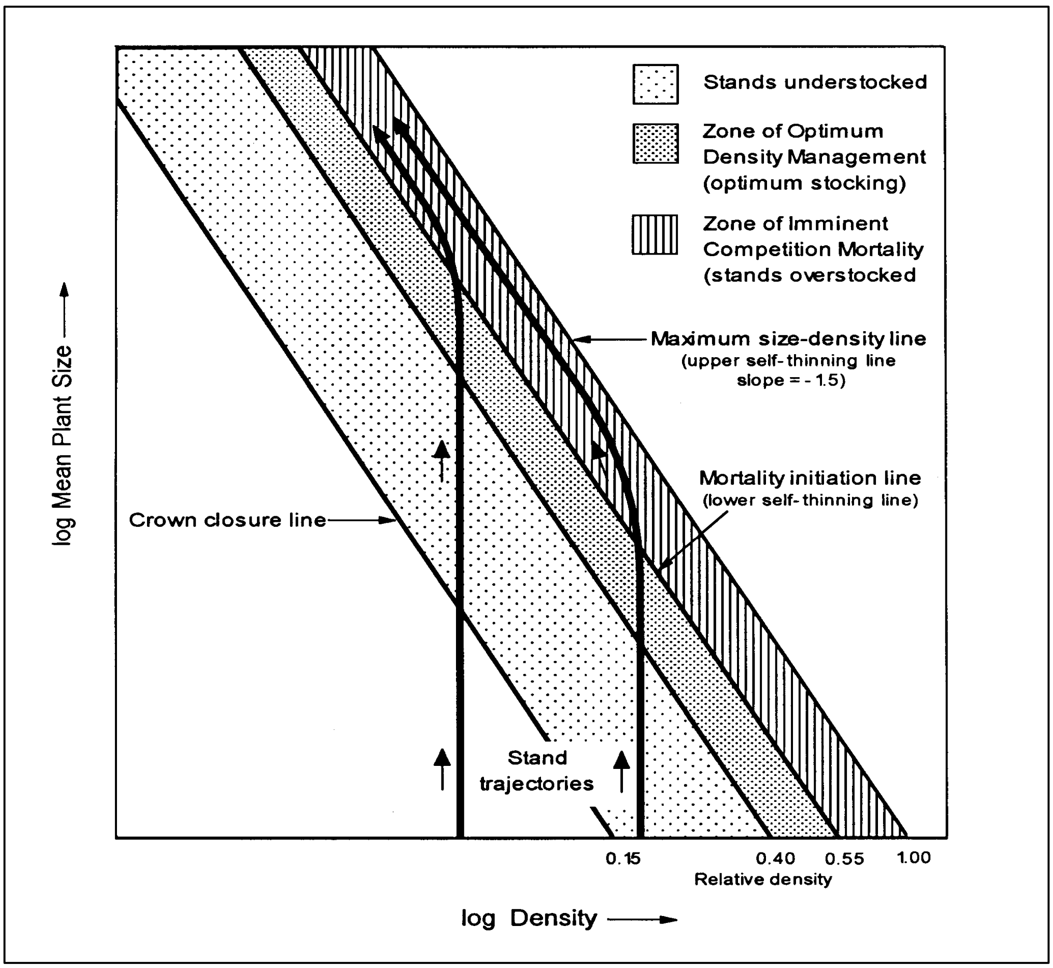


Figure 22. ***A typical presentation of a density-management diagram (Smith and Woods 1997). The Zone of Imminent Mortality (a.k.a. "overstocked") region indicates conditions where mortality occurs due to competition among the trees. The "mortality initiation line" represents the point at which natural self-thinning begins. The line for "maximum size–density" indicates the maximum mean plant size for a given density, and has a slope of -3/2, or otherwise known as the self-thinning power law.***

The Red Pine DMD for plantations (Smith and Woods 1997) is constructed using the following parameters: DBH_q, top height, initial planting density, current stand density, and the mean tree volume. All parameters except mean tree volume can be easily calculated or assessed in the field. The mean tree volume can then be read directly from the diagram. The future density, DBH_q, and stand basal area, plus approximations of the mean tree volume and total stand volume, can be estimated using these parameters.

DMDs are most useful when developing a "crop plan" before a plantation is established. For instance, a user can select an initial plantation density that will produce a desired DBH_q and top height that meet the minimum requirements for the target wood products in your local market.

2.1 Density Management Diagram for the Hunt Club Road Red Pine Plantation

This DMD shows the original and current stand conditions at the plantation. Parameters include:

- Initial plantation density at Free-to-Grow = 3100 stems / ha
- Current plantation density = 1575 stems / ha
- Stand age = 60 years, Site Index = 18.5 m, Stand Height = 20.0 m
- DBHq = 20.08 cm
- Stand Density Index (SDI) = 1575/2400 = 0.65. SDI represents the ratio of the actual density to the maximum density.

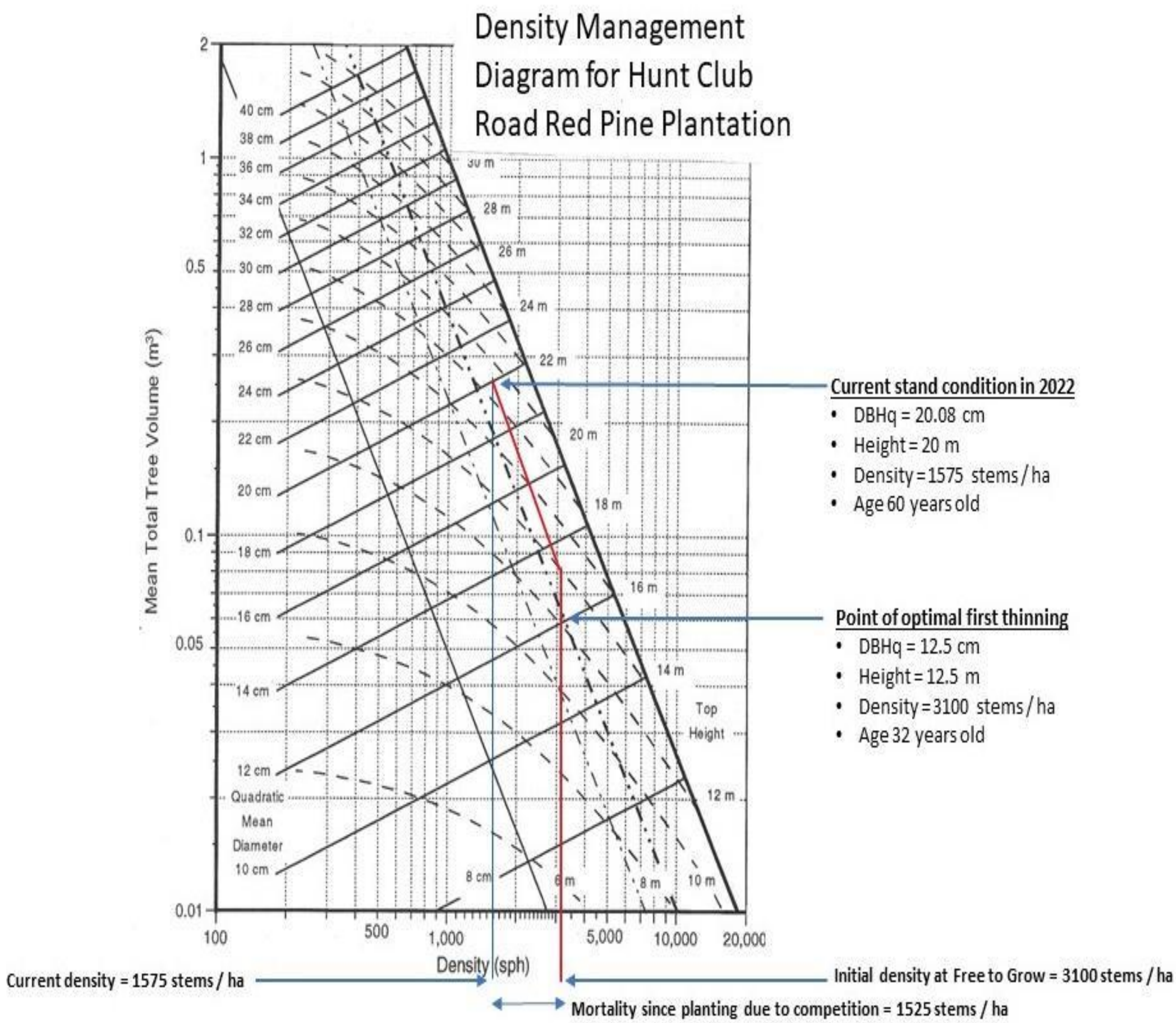


Figure 23. Sample d*ata plotted in a density management diagram for the Hunt Club Rd. red pine Plantation*

2.2 Initial Analysis of Density Management Diagram for the Hunt Club Road Red Pine Plantation

From the DMD for the Hunt Club Road red pine plantation, it can be determined that:

- The stand grew well from establishment to about Age 32, at which point it entered into the Zone of Imminent Mortality
    - DBHq at that time is calculated to have been 12.5 cm, with an average stem height of 12.5m
    - All stems would continue to grow beyond this point until competition began to reduce the density of surviving stems

- Shorter trees with smaller crowns would begin to die from competition for growing space from their neighbours
- This mortality trend would follow the -3/2 self-thinning power law described above for the next 28 years, and continues at present day
- Since the initiation of competition within the Zone of Imminent Mortality, 1525 stem / ha, or 45% of the original surviving trees at Free-to-Grow have died. While there are approximately 197 dead standing trees per hectare, most of the trees that have died have fallen to the ground and have since decayed
- This mortality trend can be expected to continue
- Initial summary:
    - The plantation is severely over-stocked
    - The surviving trees are in a high-stress condition due to competition and other natural factors
    - If thinning were to occur, the potential for any growth recovery of remaining trees is low, or would be delayed for many years, due to the small crown volumes
    - The risk of residual trees breaking, bending or otherwise falling over is currently high, and would increase proportionally with the amount and pattern of any thinning operation.

3.0 Management considerations and options

While the trees are currently exhibiting a high degree of stress from a variety of factors, this does not mean that some type of management intervention is not warranted. Prior to making any forest management decisions about the future of the plantation, there are a number of factors to consider, including:

- Biological and tree health considerations
- Operational considerations
- Social considerations, and
- Financial considerations.

Each of these factors will be discussed in detail below.

3.1 Biological and tree health considerations

3.1.1 Red pine condition

- The stand is severely over-stocked, and has been for close to 30 years. As a result, all remaining live stems have a low Diameter at Breast Height for their age, and the crowns of these trees are too small to sustain more volume growth
- Optimal growth occurs on dominant stems with greater than 25 to 30 % live crown height
- From the current inventory, the largest trees are 27 cm DBH, and only 20% of inventoried trees have diameters greater than 22.5 cm DBH. These dominant and co-dominant trees have the greatest potential for future growth, and may also be the most stable from a breakage point-of-view
- The remaining 80 % of live trees are at greatest risk of any exposure due to thinning, and can not be relied upon to stand or survive if the canopy is opened by natural or mechanical means
- The largest tree in the plantation (on CFB lands) provides evidence of the growth potential of red pine on this site with proper management

Figure 24. ***Diameter of one of the largest trees in the plantation – open grown with live crown > 50% of total height (example of the potential for many of the residual trees on this site, if thinning had occurred earlier)***

Figure 25. ***General view of current tree condition – many small undersized trees with low crown volume***

3.1.2 Invasive species

- Both European and glossy buckthorn exist in the understory across the plantation. Some buckthorn saplings are suppressed because of low light condition, but many are growing vigorously and bearing fruit, which can be spread by feeding birds
- Seeds of both buckthorn species are likely abundant in the soil, and would respond vigorously to site disturbance
- A small quantity of Tatarian honeysuckle was also noted
- These shrub species will continue to be a management problem and will require vigilance and careful management consideration, prior to any thinning operation or disturbance-based intervention
- There was no evidence of Dog-strangling vine based on a winter-only assessment, but it may occur along the various pathways

Figure 26. ***Photos showing abundance and condition of advanced European buckthorn regeneration***

3.1.3 Insect and disease potential

- There is currently low incidence of both insects and diseases in the plantation
- The greatest future risk is from *Heterobasidion* root rot. This risk can be mitigated by applying fungicides at the time of thinning or any tree removal

3.1.4 Soils / Site suitability

- The site is moderately-well suited for red pine, and there is no reason to believe that the current or future health of the trees is limited by the site itself
- It is possible (probable) that the top-soil may have been removed from the site in the pre-planting period
- The soils are also suitable for a variety of other conifers (ie white pine, white spruce) and hardwoods (ie maples, oaks, poplar and birch)

3.1.5 Wildlife - current and future use

- The plantation does not offer a diverse or productive habitat for wildlife
- Small mammals and birds are currently using the plantation and the surrounding forest
- This plantation and adjacent hardwood forest represents one of the last remaining larger blocks of forest in the general area, and is surrounded by residential, commercial and industrial development
- Careful management may enhance the habitat in the future. Caution must be taken to reduce the current and future abundance of invasive shrubs and plants, which do not have much wildlife value

3.1.6 Biodiversity

- There is currently very low diversity within the plantation area
- The central portion of the plantation appears to be an old sand extraction pit where red pine trees were either never planted, or failed to survive initially
- This area has regenerated naturally to a variety of native and non-native species, including (see Figure 27):

  Hardwoods – red and burr oak, white birch, ash, poplar, beech

  Conifers – jack pine, Scots pine, white pine, hemlock
- Due to the constraints of a winter-only assessment, no survey of ground plants was conducted. However, the McKinley Environmental Solutions site survey for the site development proposal on the eastern edge of the property noted a number of other species. As reported, there were no significant or endangered plant or animal species found during their surveys.
- There is a source of native tree seed adjacent to the plantation that could enhance natural regeneration
  - The neighbouring hardwood stand south of the red pine contains burr oak, red oak, sugar maple, red maple, basswood, beech, white birch, elm and poplar. Some ash were noted, but these trees are likely going to be impacted by the Emerald Ash Borer in the future, and can not be relied upon as a seed source.

Figure 27. ***Photo from central sand pit area, with red oak, white birch, ash and other species present***

3.2 Operational considerations

Based on the authors' experience with red pine plantation management in Ontario, economically viable plantations have the following characteristics:

- **A minimum size of 4 ha:** Small adjacent blocks owned by different landowners can be managed and marketed collectively to provide a sufficient merchantable volume to make harvesting economical (i.e., at least 200 to 500 m^3, depending on local markets).
- **A market:** For commercial thinning, you must be able to sell the type of products the stand can produce. In addition, the future market must support the kind of products you intend to produce from the final crop trees.
- **Sufficient tree size:** Commercial thinning products require trees with an average diameter of 18 to 20 cm in DBH, with the potential to produce at least three 2.54-m logs (also known as "bolts"), each with a top diameter of at least 13 cm. For most conifers, this requires a total tree height of at least 12 to 14 m.
- **Wide spacing:** A spacing of 4.3 m between rows of trees is necessary to allow passage of most machinery without damaging the residual stems, especially in this plantation because of the tree height. To achieve this, the initial between-row spacing at the time of planting should have been at least 2.1 m, although 2.4 m would provide more flexibility. Where this width of access corridor is not possible due to tight initial spacing, a cross-row thinning can be conducted to allow access for the harvesting equipment.
- **Alternatives:** Smaller blocks can be commercially thinned using smaller equipment and more manual labour. The minimum amount of wood required to fill a standard tractor-trailer is 35 to 40 m^3, and the wood must be easily accessible (i.e., must be brought to a road large enough to accommodate such a large vehicle). It is important to plan for operational constraints such as room for turning the vehicle around, sufficient distance from phone and electrical lines to allow operation of its loader, sufficient distance from ditches, and the need to avoid compaction of a road caused by fully loaded trucks.

All forest harvest workers must have enough training and experience to perform their work without damaging the forest or any infrastructure such as roads and without endangering themselves or others. Care must be taken not to damage the residual stems with the harvesting equipment, and to avoid damaging the site by working under wet conditions when the soil is particularly vulnerable to damage.

How often a plantation can be, or will need to be thinned depends on several factors:

- **Density:** Thinnings must be conducted throughout the life of the plantation to maintain the desired density, and to avoid intra-tree competition and the onset of natural thinning. A normal "rule-of-thumb" is to reduce the density by no more than one-third of the standing trees, starting at age 30. Depending on the management history of the plantation, a more gradual progression towards a more favourable density for residual tree health and growth may be required.
- **Tree Quality:** For both pre-commercial and commercial thinning, the residual stems must have sufficient quality, and stem stability to survive and grow well. Early thinnings (i.e., the first and second thinnings before age 50) should focus on removal of the weakest or lowest-quality trees, on creating initial access corridors to the interior of the stand, or a combination of both objectives. Subsequent thinning will focus on retention of the highest-quality stems. Where plantations have been left un-thinned for too long, individual trees may have weak stems and may suffer from breakage following thinning.
- **Market conditions:** Whether commercial thinning is possible depends on the types of products demanded by local markets and by the distance to the nearest processing facilities; longer distances increase the cost of transporting the wood and therefore decrease its value.
- **Site characteristics:** The location and size of the site, as well as its proximity to adjacent plantations and markets, will determine the economics of thinning.
- See Appendix 6 for the Recommended Management Scenarios for Red Pine

Most commercial thinning operations now use systems of heavy equipment, such as a single-grip harvester that fells and delimbs the trees, and then cuts them into logs of the desired length (also known as a "cut-to-length processor"). These harvesters work with a forwarder that carries the logs rather than dragging the trees along the ground to a landing, where they will be processed and loaded onto trucks.

Figure 28. ***(Left) A single-grip harvester fells and processes a mature red pine. (Right) A forwarder brings the products to the landing and loads them onto a haul truck.***

For the Hunt Club Road Red Pine plantation, the following site-specific information will need to be considered:

- All rows are oriented in an East-West pattern, paralleling Hunt Club Road
- Approximately 56 rows at the narrowest point
- Approximately 60 rows at widest
  - Variable distance between rows, but with an average 1.8 m
  - Removing only one row will make access corridors 3.6 m wide
  - Removing two rows will make access corridors 5.4 m wide
    - 4.3 m access corridors are needed to accommodate both the feller buncher and forwarder
- Landing and loading requirements
  - Harvested trees will need to move along existing main trails towards the dead end on Billy Bishop Private. There are no other viable landing and loading areas

3.3 Social considerations

- Any forest management operation in this plantation will be of high interest to the public because of the previous site development proposal, and the "Save Hunt Club Forest" campaign
- There are many access points into the plantation, from Billy Bishop Private road, Hunt Club Road, and from the CFB housing to the south and west.
- The existing trail network is used heavily by local residents as a natural area for walking dogs
- It appears that the area is also used for orienteering exercises, as many off-trail markers were found
- Following the Derecho wind event, there are many toppled over and leaning trees, which present a current safety hazard.
- Should any thinning operations occur, there should be ample information and warning provided to interested parties which explains both the rationale and benefits of the chosen management approach
- Access will need to be prevented during all operations, and until such time as the materials and machines have been removed from the site
- Following operations, the fire risk and public safety risk will increase for a period of time until the site exhibits new growth, and the slash from felled trees has rotted.

Figure 29. ***Photos of main access trail, and other cultural markers***

Figure 30. ***Photo of typical slash (branches, unmerchantable stems, etc) immediately following harvest which represents both a public safety and fire hazard risk***

3.4 **Financial considerations**

- There will be both costs, and benefits, associated with any chosen forest management option
- Benefits include:
  - Creating a healthier, more diverse, and safer forest
  - Value of the harvested wood. Depending on the volume and quality of the harvested material, it could be worth between $20 and $25 per metric tonne (approximately 1 m3).
    - Merchandising: Commercial thinning products require trees with an average diameter of at least 18 to 20 cm in DBH, with the potential to produce at least three 2.54-m logs (also known as "bolts"), each with a top diameter of at least 13 cm. Product merchandising and final value will be dependant upon the following (see photos below);
      - Stem crook caused by mechanical injury to the tree in the past
      - Double stems / double tops
      - Human-caused hazards such as nails, markers, water well test sites, proximity to hydro lines and fences, etc
    - **The maximum on the stump value of the plantation in 2023 if all trees were to be harvested would be Total Stand Merchantable volume x value = 1400 m3 x $20 / m3 = $28,000.00**
- Costs include:
  - Public consultation and communications
  - Trail and access point closures during operations
  - Security for the operators and their equipment
  - Restoration activities, such as invasive species control, follow-up planting with other native species, long-term monitoring of forest growth and response
- The cost of acquiring the land from the Federal Government has not been factored into management options, but will include the value of the land, legal and Land Registration fees, etc

Figure 31. ***Photos of stem crook at various heights along the length of the tree***

Figure 32. ***Photos of double stems and double tops, which reduce the value of the tree***

Figure 33. ***Photos of operational hazards such as nails in trees, water wells, hydro lines, fences***

4.0 Management Options

In our experience, plantations that have been allowed to grow in a stagnated state beyond the age of 30 years without any thinnings are often considered too difficult and costly to manage and with the uncertainty of very little growth response the owners most often decide to maximize their revenues by opting for a clearcut and replant scenario or simply leave them with no management and ultimately further decline and stand break-up.

In the proposal for this project the City of Ottawa requested that we consider options that would meet their follow objectives:

- Ensure the future healthy growth of the forest
- Diversity the canopy and understory of the forest in the mid to longer term
- Improve the quality of the forest's flora and fauna, including native wildflowers, birds, amphibians, reptiles and small mammals
- Make the forest safe for passive recreation by residents and visitors.

As well we have considered three other objectives for each option:

- Ease of implementation
- Volume of harvested red pine
- Value of harvested red pine

Based on these objectives and all the considerations discussed in Sections 1 to 3 we have developed 6 options that may be considered in deciding whether to pursue owning and managing this red pine plantation. Below we briefly describe each option and what aspects they are best suited to. We do provide an opinion on cost recovery from the sale of red pine products and comment without specifics on the operational costs (costs were not a requirement of the RFP). See also Appendix 6 for a full analysis of the pros and cons of each option against each management objective.

<u>Option 1 – Do nothing</u> – acquire land and let nature take its course, or do not acquire land

This option is a completely hands off approach that involves no thinning or invasive species control. Although it is likely to be the cheapest of all the options, public opinion would likely be negative because of the gradual decline of the health of the forest and increased incidence of invasive species. This would be seen as negligent and irresponsible management for any forest landowner. For safety and liability alone, the owner would either need to completely restrict public access or carry out a progressively more expensive and time-consuming hazard tree removal program.

Buckthorn Removal Pre-treatment

The pre-existing understory of buckthorn that is consistently established across the entire plantation is a forest management problem best addressed under the low light conditions that currently exist prior to any canopy disturbances. **Forest Management Options 2 to 6 would all follow this generic pre-treatment of buckthorn.** Below is a quick description of what this would entail:

Buckthorn is an invasive, perennial, woody shrub that actively increases growth through “root - suckering” that produces multiple stems from the existing root system following mechanical control. Options such as mowing, cutting, pulling, and tarping will generally result in a proliferation of the species rather than an effective control because the root system is largely unaffected and will be stimulated by disturbing the above ground stems. The primary means of controlling buckthorn is through chemical methods applied as part of a planned Integrated Pest Management (IPM) program.

To effectively control the root system of buckthorn plants, a systemic herbicide is applied to the plant during the active growing season (generally from May through October) by licensed forestry applicators. This application technique takes advantage of maintaining the vascular system to distribute the herbicide throughout plant tissues. As the systemic herbicide takes effect, the remaining stems with green foliage can be easily identified and addressed, while the dead stems can be bypassed and less herbicide is applied on site. This technique takes advantage of plant’s natural systems, reducing uncertainty and unnecessary herbicide usage by using live foliage as an indicator of whether effective control has occurred on each stem.

Two primary means of applying systemic herbicides are used for buckthorn: basal bark and/or foliar. Basal bark applications use an oil-based formulation generally containing triclopyr as an active ingredient. The herbicide is applied to individual stems towards the base of the plant, or through incisions made through the bark on larger and tougher stems. The oil-based herbicide can be applied over a greater part of the year, including winter months, however the best results are generally seen for those applications between May and September. This technique is the most labour-intensive. However, it allows for applications to individual stems, thereby reducing mortality on non-target species. Foliar applications deposit a herbicide, either water- or oil-based, to the foliage of the plant with a sprayer or mist-blower. The products available and active ingredients include a wide range of options, but those containing glyphosate are the most commonly used. Application must occur during the active growing season of the plant, avoiding peak stem flow in spring, and can be easily applied over a wide area where homogenous populations of buckthorn exist. Foliar applications are the least labor-intensive to implement, but have a lower success rate per application. Retreatments are often required, which allows for herbicide to be deposited over a broader area. A further application option of combining approaches, such as initial foliar application followed by individual stem applications, may also be considered.

The following options presented all include the recommendation for pre-treatment as a best practice to set back the buckthorn population to very low levels. Management of the overstory plantation will likely result in a short-term increase in buckthorn, that may require follow-up treatments. The existing condition of an overstory of red pine with an understory of very little other than buckthorn presents the opportunity for an extensive control project for the site with relatively little risk to other understory non-target species or the existing red pine stand and the advantage of low light which reduces growth response. It is unlikely that even successive treatments will entirely eliminate buckthorn stems and potentially germinating seeds, given the nature of the invasion and presence of buckthorn throughout the area, but an effective control of the majority of the population will allow for regeneration of desired species following harvest that would otherwise be out-competed by the existing population of buckthorn. If timed properly, multiple applications may be used to shorten the overall control period.

Option 2 – Very light thinning from below using crop tree approach (max 10%)

This option is a cautionary treatment based on keeping the disturbance level very low to avoid increasing the risk of windthrow and ice or snow damage that can result when more edges are created following row thinnings and other openings of the canopy. This method involves identifying the most dominant, wind-firm, large diameter red pine in the stand (ie “crop trees”). These trees are then provided with 2 or 3 -sided crown release by removing the 2 or 3 three trees next to or touching their crowns. Selections would be made in such a way as to only result in a 10% reduction in basal area in the first thinning. After 10 years additional crop trees could be selected and/or possibly some further release for the original crop trees. The second thinning would also only remove 10% of the BA. This would all have to be done with a very small tractor or horses and a chainsaw operator, and all but the very best trees would be felled and left on the ground. Operations would be slow, due in part because of the tree height, and due to felled trees getting hung up in adjacent trees.

This light thinning option will address the removal of most of the hazardous or defective trees and some of the other declining trees, however only a small percentage of the poor-quality trees will be removed. Although the thinning will target improving the conditions for trees with the best potential, overall growth will not improve much. Some new downed wood will result but there will be almost no other improvements to wildlife habitat. There will be negligible revenues from wood products and although hazard trees will be addressed at the two thinning stages, there will still be a lot of risky trees and annual hazard tree monitoring and removal will still be necessary.

Option 3 – Light row thinning – remove 2 rows for every 10 rows (2 and 8) – 5 access corridors would be created. Follow-up thinning required in 10 years

The main purpose for this light row thinning approach is to establish the access that would normally be created in earlier thinnings and begin to adjust the density through a light second thinning 10 years later. The intent is to be able to use larger equipment normally associated with plantation thinnings which increases the efficient and lowers the cost of operations. Given the narrow spacing, access row removals will require 2 rows to be removed next to each other. This will be done at intervals of 2 rows removed and 8 rows left (20% of basal area). The first thinning at age 62 will only be an access row removal. Then in year 72 a light thinning (20% of basal area) from below can be completed in the remaining 8 rows. Which should be able address the removal of the poorest quality trees.

Although the wide spacing of the thinned corridors and waiting 10 years to conduct selective thinning is intended to reduce the exposure of the plantation to environmental damage and allow for some acclimatization, the current high density and spindly/small crown conditions still leaves the plantation vulnerable to damage with limited growth response. The double row removal will provide 5 corridors where light will likely be sufficient for some natural regeneration but very little will likely develop in the 8 intervening rows.

The open corridors and new inputs of downed wood will increase the structural diversity and there will be a subsequent response of natural regeneration but limited to the corridors. This is problematic as these need to be used for access during the second and subsequent thinnings and will be subject to logging damage. This level of harvest will allow for most of the hazard trees to be addressed but more may develop since not all of the low vigour trees will be removed. This level of harvest will have more value than Option 2 but is still quite low. The 2nd thinning will be mostly poor quality trees that may be difficult to market.

Option 4 – Traditional row thinning to a max of 30% removal – 2 rows for every 8 rows plus light thinning from below – follow-up thinning in 10 years

This option follows a traditional row thinning and light thinning from below approach. Again, due to the narrow spacing and the advantages of using larger equipment, this approach will pair the row removals and will take 2 rows and leave 6 in-between (25% BA removal), creating approximately 7 access corridors and will add 5% basal area removal of the poorest quality trees. The follow-up thinning in 10 years will be a selective thinning and will allow for the removal of most of the poorest quality trees from below (20% BA removal).

The main purpose for this row thinning and selective tree removal is to establish access to the plantation and to quickly bring the plantation more in-line with ones that would have been thinned at least two or three times by this age. The inherent risk with this approach is the dramatic increase in vulnerability of the residual stand to wind, ice and snow damage. Although, stands thinned according to the proper timing, starting at age 30 can withstand 25 to 30% BA removals on a 10 year thinning cycle, it is likely that the spindly and small-crowned trees in this previously unthinned plantation will be at high risk of damage when the overall BA is reduced by approximately 50% over 10 years under this option. However, if it does withstand the initial shock, the dominant trees will receive more resources due to thinning and can hopefully begin to develop more crown and subsequent growth response.

As well, this treatment will provide more openings, more downed wood and more opportunities to for regeneration and wildlife to begin to utilized the increases in structural diversity. As with Option 3, responses will mostly be limited to the corridors. However, there is less space between them and there maybe options to limit access in a few of them during the second and subsequent thinnings, maintaining more of the diversity and growth. Most of the hazard trees should be removed by the end of the second thinning but more may develop since many low vigour trees will still remain. The first row removal and thinning should have reasonable marketability. However, the second thinning will be mostly low value trees that may be difficult to market

Option 5 – Restoration thinning – create canopy gaps

The authors have experience restoring red pine plantations and have found that the greatest success for quick response is through the creation of canopy gaps with planting, in addition to row removals. This treatment uses the light row removals of Option 3 (20% BA by taking 2 rows and leaving 8) and pairs this with the creation of 15 circular canopy gaps of 20m width (0.0314 ha per gap) for another 10% BA removal. The gaps need to be associated with open corridors but can be located in spots that have lower quality red pine. After 15 years another program of access creation (thinning) and gap creation can occur with the same BA removal targets. At this time the configuration could either be another double-row removal (middle 2 rows of 8 remaining) or a cross-row removal could be used. The cross-row allows for a slightly narrower corridor, breaks up the row appearance of the whole stand, allows regeneration to be mostly undisturbed in the original corridors and provides for some larger openings where double rows meet the cross-rows.

This option is focussed on moving the plantation towards a multi-layered and diverse forest with the highest level of structural and biological diversity of any of the options. This will require significant inputs from the landowner including site preparation, tree planting, monitoring, tending, hazard tree removals and potentially other follow-up treatments.

Similar to Option 4, this option creates some very open conditions in a previously unthinned stand and the risk of wind, ice and snow damage will be quite high even after the second thinning since the treatment does **not** have a focus on moving resources to the best crop trees. Poor trees will still remain and stability and growth may not be improved much.

Other than Option 6, this will have the highest value returns and both harvests will have a mix of poor quality and higher value trees, which should make each treatment equally attractive for operators.

Option 6 – Clearcut with standards

This option will realise the current stand's highest end value. In forestry terms and because there has been no thinning, a clearcut at this point recognizes the fact that the plantation has reached its economic rotation age. To retain the natural heritage value of mature pine trees in the future forest we recommend keeping the largest, most stable legacy crop trees at a rate of 25 per hectare for a total of approximately 104 to 120 trees across the site.

This approach would allow the owner to receive the highest end value for the wood fibre that has been grown on this site, while avoiding risky challenges of trying to practice forest management in a stand that has been neglected and left in a severely overstocked condition that is difficult to recover from. Using this ecological "restart" would allow the owners to create a restoration plan that best addresses the biological, recreation and safety issues noted previously.

All this considered, these types of "clearcut" operations often are not well received by the public and the heavy equipment and devastated appearance can create significant controversy in the short term. The safety concerns would require a complete exclusion of the public during the 3 or 4 week period of harvesting and then would require subsequent monitoring of the legacy trees for potential tree falls and breakage.

This option will provide the greatest source of revenue and would likely be easy to engage an operator because of the significant volumes.

The challenges of forest harvesting in an urban environment may affect the attractiveness of any harvesting, or of any option considered here.

5.0 Recommendations and Management Plan

Following a review of the draft report by the City of Ottawa we received direction on how to proceed with Section 5.0: "After a preliminary assessment of the options available, City staff have indicated that Option 6, as laid out, is the most viable option given public safety is the highest priority." All but Option 1 are silviculturally viable and each has their own risks and opportunities. Different landowners or different site locations may result in different priorities and could mean choosing one of the other options. We understand the City's concern for safety and would agree that if the City were to own this property **Option 6 – Clearcut with standards**, provides the greatest control over the risks and the future forest condition. The following is a high-level management plan that provides the basic steps that would need to be followed to achieve the principles described in Option 6 over a 20-year period.

Steps include:

1. **Buckthorn control**
2. **Marking and marketing**
3. **Harvesting**
4. **Site preparation**
5. **Planting**
6. **Tending**
7. **Monitoring and Assessment**
8. **Public outreach and education**

Each step in this crop plan is a project unto itself that requires a detailed assessment of the site, followed by a prescription that is specific to timing and the conditions that are on the site at the time. The RFP did not require an estimate of costs for managing the site under one of the proposed options. However, at each step proper management will incur a number of costs that include professional and technical services, equipment, operational contracting and materials such as planting stock and chemicals.

1. Buckthorn control

As noted in Section 4, buckthorn and other invasive species need to be fully assessed for treatment. There is an existing problem with buckthorn that if left untreated will impact on the future forest condition. We recommend following the direction in Section 4, by conducting a two-step chemical pre-treatment across the entire area to be managed. Doing this work while the overstory is still present will be more cost effective, since the existing buckthorn plants will not be as vigorous in the shade. The initial treatment should be foliar and depending on its efficacy the second treatment can be foliar and/or basal bark.

It would be best if harvesting occurred during the following year (presumable winter) and before leaf out. Assessments of buckthorn and other invasive species responses to the harvest should be made in the first few years following the harvest. Further control maybe necessary at the time of site preparation and/or tending. Monitoring until free-to-grow status of newly established trees, and a few times following, should assess the presence and impact of invasive species and determine if some form of further control may be needed.

2. Marking and marketing

The management direction for Option 6 is a clearcut with standards. Following a further assessment of the stand, a detailed tree marking prescription can be prepared to identify approximately 25 legacy trees per hectare (a total of 104 to 120 trees across the site). Our inventory indicates that these dominant trees should be at least 27 cm dbh and greater. Markers should select the healthiest and most windfirm legacy trees, while working to have them distributed across the site. An exception would be to find trees that currently have wildlife cavities in them. Only a few were found during our inventory but this could be set as a priority, especially along the southern edge which is close to the existing hardwood habitat on the neighbouring property. By marking the legacy trees with a ring of blue paint or some other retention colour, it will be made clear to the operator that these are to be retained and carefully operated around, with no damage to the stems or root systems.

Another consideration for wildlife habitat creation, would be to increase the number of potential cavity trees by picking approximately 40 to 50 trees from the 25 to 27 cm size class that are amongst those to be harvested and mark them for stubbing (where the operator cuts the tree off at a height that can be reached with the boom of the machine (3 to 5m)). These dead stubs or snags can then be used by wood borers and later cavity specialist birds and mammals. At these short heights these stubs are not much of a safety concern. When they rot and fall, they become part of the downed wood component of the site.

It would also be prudent to consider the future trail layout and to keep fewer of the legacy and stubbed trees in the vicinity of the trails to reduce the hazard tree situation over the long term.

Once the tree marking prescription is approved a tree marking contract can be established and this work can be completed and audited.

The harvesting approach should also be discussed and directed. A full-tree approach would bring the entire tree to the landing and allow for processing at the roadside and would keep most of the branches and tops in bunches at the road. The woody debris would then be organized away from the main planting site, making it easier to manage (chip, burn, etc.) but this also removes the nutrients in the needles and branches from the main site. This may be a concern since the soils analysis suggests this is a low nutrients site. The tree length and cut-to-length approaches leave the tops and branches on-site. Which is better for nutrient retention but creates a more difficult environment for planting and increases the fire risk in the early years.

An estimate of wood volumes should be calculated and the harvesting project and approach to selling the wood (tendered sales, auction, etc.) should be determined. To have control over which operator is best suited to the job and the value of the wood products we recommend marketing and advertising the wood volume along with the contract expectations to potential operators.

3. Harvesting

A contract should be drawn up and signed by the chosen operator. The contract should include all the pertinent requirements of the job: type of equipment to be used and logging method (tree-length, short wood, etc.), timing of operations, deadline for completion, access and landing requirements, safety and public notice considerations, etc. The harvesting job and contract require careful monitored by the landowner.

If the future planting includes red or white pine then some consideration should be given to applying a registered fungicide to the stumps to help prevent the spread of Heterobasidion root rot, which may be present but undetected, to the planted seedlings.

4. Site preparation

After the harvest is completed, field data should be collected to help determine the prescriptions for site preparation, tree planting/seeding and tending. A few factors will go into deciding on the type of site preparation and its intensity:

i. The amount and distribution of debris – will it hinder tree planting efforts or be a fire hazard?
ii. Tree species to be planted and deer population – oak, white pine and yellow birch are notorious favourites of deer and planting within logging debris can help reduce browsing pressure
iii. The amount of competing vegetation on the site – will mechanical site preparation be sufficient or will some sort of chemical treatment be necessary?
iv. Visual preference or ecological preference – the options include: even distribution of woody debris across the site, windrows or periodic piles
v. Safety – would any particular approach to site preparation create any concerns for increased fire risk or people being injured while trying to access the site?

Once decisions on these factors have been made then a site preparation prescription can be developed, an approach to contracting can be determined and implementation can proceed. Depending on landowner's needs, the site preparation can be completed in the same year as the harvest or the following year. Waiting longer than this can mean incurring further tending costs as the seed bank will begin to germinate and both native and non-native plants will grow and create challenges for tree planting and additional needs for chemical site preparation.

5. Planting

There are many options for the type of species to be planted and the configuration of the new forests in terms of spacing between trees and the planting pattern. As well, seeds can also be sown but we do not recommend relying on seeding alone, since there is less certainty of success. We strongly recommend a careful assessment of the site along with confirming the objectives for the future forest. A relevant current guide that should be consulted is the *Afforestation Guide for Southern Ontario* (OMNRF, 2019). Chapters 2 and 3 provide advice on establishment and early growth and competition control. The entire guide would be of use to those responsible for the tree establishment and tending prescriptions and the overall long-term management of the new forest.

Some important considerations include:

i. Tree species

We strongly recommend using native species that are best suited to the site. The species and its seed source should be considered in light of the current modelling around climate change and species less likely to survive in these areas, such as white spruce, should probably be avoided.

Based on the soil analysis, our assessment of the current red pine stand and Appendix 1 of the Afforestation Guide (OMNRF, 2019), we would recommend the following native species be considered: white pine, red oak, bur oak, white oak, red pine, black cherry, basswood and red maple. Although tending to protect the young planted trees from competition is a requirement for most plantations it is particularly relevant to the establishment of hardwood species. As well, hardwoods may require tree protection if the deer or rodent populations are high enough to damage the newly planted trees. A plantation that is not pure conifer also has a lower fire risk.

ii. Planting arrangement

The proportion of the various species and their configuration in rows or more random patterns needs to be thought of in terms of future requirements for tending or thinning. As well, the actual spacing between trees has an impact on survival, growth and the need for thinning. If thinning may not be as likely in this plantation due to the location in the city, future markets or the complexity of the species mix then a wider spacing should be consider at time of establishment. The Density Management Diagrams and crop planning considerations as mentioned in Section 2, can be used to help decide on the best spacing and total number of trees to be established. These are particularly useful in the case of pure species plantations.

iii. Planting stock, seed sourcing and nurseries

In determining the species, the prescription writer also needs to consider:

- where the tree species can be acquired from - local nursery or farther?
- what type of stock do the nurseries produce (how big and at what cost)?
- where is the seed sourced from and is it climate change appropriate?
- can the numbers by species be acquired in time to match the proposed planting date?

Once these factors and others have been settled the prescription writer can set the tree planting prescription and initial tending requirements. The owner can then proceed to order the trees and select the tree planting contractor. This can be done in the spring or the fall, so depending on how quickly all these factors come together it may take up to an additional year following site preparation.

6. Tending

The goal of tending is to maximize the survival of the newly planted trees and ensure they reach free-to-grow as soon as possible. A regular monitoring program provides the important information on the amount, type and intensity of competition and will be used to determine when to consider applying additional tending treatments. It is not unusual for three separate tending treatments to be required in the early years of establishing a plantation. Given this is a post-harvest type of plantation (rather than open field), it is likely that chemical tending will be the easiest to implement and most effective. The factors that will affect the tending options include:

- site preparation effectiveness
- tree species planted and their proportions
- arrangement and spacing of planation (rows?)
- size of the planting stock
- site productivity

- perennial versus annual weeds

Each year following plantation establishment the results of monitoring can help establish tending prescriptions, with contracts set and implemented.

7. Monitoring and Assessment

The established trees should be monitored and assessed at various times during the establishment period. Immediately following planting there should be an assessment of tree planting quality to assess whether the planting contract was achieved and whether any remedial action is required. In each of the first few years (number of years determined by response) the survival and growth should be assessed to determine needs for refill planting and/or tending. Eventually a free-to-grow assessment should be completed to confirm that the planted trees are free of competition, large enough to live on their own, and are distributed across the site such that it will meet the goals of the future forest condition. A free-to-grow assessment methodology should be identified and implemented sometime between years 5 and 10 following planting.

After the plantation is determined to be free-to-grow, monitoring and management activities will be reduced while the trees continue to grow. From years 10 to 20 of the management plan it is likely that monitoring may only be needed on a 5-year cycle. The first thinning is not usually necessary until year 25 to 30 or beyond if initial spacing is wide.

There will continue to be a need to annually (and following any major weather) monitor the large legacy red pine trees to determine their stability and whether any hazard tree removals are necessary to protect the public.

8. Public Education and Outreach

If the City of Ottawa were to purchase this property and pursue the above management plan, there would be considerable public interest and a need to provide education and safety direction. We recommend that the City develop a Public Education and Outreach Plan that is directly matched to the activities outlined in the forest management plan. The site and this project provide a fantastic opportunity for citizens of Ottawa to learn about forestry and urban forestry. The City will need to look carefully at each step in the plan to determine how to provide notification, when and how long to restrict access, determine what other departments need to be involved, such as transportation, and consider how to deliver the messages about each of the forestry activities. There may be opportunities to engage local citizens and other volunteers with certain tasks.

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Appendix 1 – Stem Analysis Data

- A single selected blown-over tree was selected for stem analysis
- This tree was adjacent to Billy Bishop Private and may have received from growth benefit from the time a portion of the plantation was removed for development purposes
- As such, it may not be completely representative of the average tree in the centre of the plantation (ie DBHq of 20.08 cm)
- Data for the stem analysis tree:
    - DBH = 25.3 cm
    - Total height = 20.0 m
    - Live crown = 5.0 m (from 15.0 to 20.0 m)
    - Crown width = 2 to 3 m
    - Maximum merchantable height = 15.0 m (minimum merchantable diameter = 13.0 cm)

Height along stem	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Diameter	25.7	25.7	25.0	25.0	23.6	22.8	22.8	21.6	21.4	20.8	20.2	19.1	18.2	17.2	16.2	13.5	12.2	8.3


17.0
16.0
15.0m
14.0 M
13.0m

12.0 M
11.0M
10.0M


9.0M
8.0M
7.0M


6.0M
5.0M
4.0M


3.0M
2.0M
1.0M

Appendix 2 - Red Pine Health Issues

Scleroderris canker

This serious disease can girdle and kill jack pine and red pine in natural forests, plantations, and nurseries. Ontario has two known strains of this fungus. The North American strain infects young trees, but rarely kills trees taller than 2 m. The European strain is more virulent and can kill larger trees. The first indication of infection is a reddish-brown discoloration at the base of needles in May or June. The needles also bend downwards as the infection progresses. In summer, the needles and branch tips turn yellow to brown. The fungus then progresses along the branch and into the main stem, where it forms a canker that can kill the tree above that point. Because the fungus usually infects lower branches, pruning is an effective control measure.

Root diseases are sometimes called "diseases of the site" because they persist in the stumps and roots of dead or harvested trees for many years, possibly even for decades, and can transmit the disease to the new stand (Manion 1991). This problem may be less significant for former agricultural land, as there are few or no dead trees to spread the infection, but it becomes an important consideration for underplanting in coniferous plantations or when replanting the same species after a site has been harvested (see Section 4.5.2 for details). The source of infection is often apparent: dead trees with obviously decayed roots or fungal fruiting bodies on infected stumps. Both hardwoods and conifers are susceptible to root diseases, especially during their juvenile stage. For root diseases, a large food supply (i.e., roots and stumps) already colonized by the fungus provides ample energy for reproduction of the fungus. Although removal of all inoculum from a site is not possible, stump removal can reduce the potential inoculum significantly, and can thereby reduce the impact of root diseases to an acceptable level (Morrison and Mallett 1996). This technique will be most useful on easily accessible, high-productivity sites with few sources of infection.

Armillaria root rot

Armillaria root rot is caused by a number of similar species within the *Armillaria* genus. It can be recognized by the distinctive fruiting bodies (mushrooms) that appear in the fall as well as the "shoestring"-like black rhizomorphs that grow both under the bark of heavily infected trees and from infected roots, extending several meters into the surrounding soil. White mycelial fans are often observed growing between the wood and bark of declining trees.

Armillaria has a very wide host range. It infects nearly all conifers and hardwoods, as well as some herbaceous plants. The disease spreads through direct contact between roots and mycelium in the soil and via root grafts between infected and healthy trees, and abundant spores are produced by the fruiting bodies.

Infections in younger trees can cause swift decline and mortality, whereas the disease may begin as a butt or root rot in older trees and wait for other stress events (e.g., insect defoliation, drought) before it causes significant decline. Infected trees are susceptible to windthrow, which can create risks to workers during thinning operations. Stumps of killed or harvested trees can act as a source of inoculum for many years.

Management of Armillaria infections can be difficult, and complete eradication is unlikely once it is established. The most promising management options are reduction of the inoculum and favoring the establishment of more resistant species. Reduction of the inoculum typically means removal of stumps and may require letting a site sit fallow for some period of time. Choosing resistant species requires identification of the specific Armillaria species that is present on the site, as each species has somewhat different host preferences. For more information on the disease, see Whitney and Dumas (1994).

Heterobasidion root rot

This disease is also known as Annosus root rot (based on an older name for the pathogen). The fungus affects more than 150 hosts, but usually occurs on conifers. It is one of the most serious diseases in Ontario red pine plantations. The fungus produces fruiting bodies at the base of living trees and on infected stumps from previous thinning operations. In the fall, white and brown fruiting bodies form at the root collar of heavily infected trees. The fungal hyphae colonize the roots, kill them, and cause them to rot. The infection can kill young trees quickly, but can also kill larger trees after a few years of infection. Young trees exhibit symptoms such as a reduction in branch growth, chlorotic (yellowing) needles, and a "stress crop" of cones (i.e., a crop that occurs when a tree is dying and tries to reproduce one last time). Mature trees will typically show initial growth reduction, and weakened trees become increasingly susceptible to windthrow as the dead roots stop providing stability. Typically, infected trees die in groups in a circular pattern ("pockets") that results from transmission of the disease from an initially affected tree to healthy surrounding trees through root grafts.

Several strategies can mitigate the damage caused by this disease:

- **Control:** Control of the fungus is most practical during the initial infection. During thinning, freshly cut stumps can be treated with a number of registered fungicide products that prevent fungal germination and growth.
- **Careful logging:** Infection can also occur through wounds on roots and the lower stem, so minimizing damage to residual trees will reduce the frequency of infection.

Red pine pocket decline

A combination (complex) of health issues has caused unprecedented rates of decline and mortality in some of Ontario's oldest red pine plantations (i.e., >60 years). This "red pine pocket decline" has been attributed to a number of factors and causal agents:

- **Root diseases:** The presence of root diseases, including Armillaria root rot and Heterobasidion root rot. Refer to sections 5.4.1 and 5.4.2 for details.
- **Nutrient deficiency:** Unhealthy trees have a harder time resisting infections. A lack of iron is especially damaging. This can arise under alkaline soil conditions, which make iron insoluble and therefore unavailable to trees. This deficiency can be recognized by yellowing of the current year's growth, reduced overall growth, a thinning crown, and crown dieback. This deficiency is exacerbated by drought conditions. Plantations established on sites with alkaline upper (A and B) soil horizons are most likely to suffer early decline (i.e., <40 years).
- **Insects:** Bark beetles and scale insects, which may be only secondary pests, tend to attack trees that are already under stress.
- **Other predisposing site factors:** These include an alkaline soil C horizon. Red pine grows best on acidic sites, and when the roots reach soil with this higher pH, they cannot survive, effectively restricting the rooting depth.

Management options to address this issue include testing the soil pH before establishing red pine, and avoiding sites with higher pH in the upper soil horizons. Frequent monitoring of the plantation's health will detection and response to problems before they become serious. See Fact Sheet below for

“Modified management recommendations to establish and manage red pine plantations” developed by the County of Simcoe and OMNRF.

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MODIFIED MANAGEMENT RECOMMENDATIONS TO ESTABLISH AND MANAGE RED PINE PLANTATIONS *Based on the presence or future probability of red pine decline*

By Bob Hutchison[1], Graeme Davis[2], John McLaughlin[3]

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ESTABLISHING RED PINE PLANTATIONS

Before planting red pine, check the pH of the A, B, and C soil horizons. For the C horizon, sample at a depth of about 1.5 m.

1. If A and/or B horizons are alkaline (pH > 7):
   - Do not plant red pine

   Crop is likely to fail by 30 to 40 years of age due to nutrient deficiency.

2. If A and B horizons are acidic but the C horizon is alkaline:
   - Reasonable growth and longer rotations are possible but the stand will be predisposed to root disease, especially if the combined depth of the A and B horizons is <1 metre

   Armillaria root disease will reduce stand health but without post-thinning stump treatment Annosus root rot will also increase.

Sites with compacted soil (bulk density >1.4) will be more susceptible to root rot because red pine does not root well in dense soil – especially if it is alkaline.

Richer soils may result in more root disease and as such are not necessarily better red pine sites.

MANAGING YOUNG (<50 YEARS) RED PINE PLANTATIONS

Check the pH of the C horizon to determine if future decline is probable. (If the plantation is in reasonable health at this stage it is unlikely that the A or B horizons are alkaline.)

If the C horizon is alkaline:

- If not already present in the understory, consider options to establish desirable species as soon as possible
- Ensure that an aggressive thinning regimen is in place (i.e., consider light selection thinning in addition to row removal at first thinning)

RECOMMENDATIONS BASED ON LEVEL OF PLANTATION DECLINE

The recommendations provided below are applicable where a typical prescription for a healthy stand in the 50 to 70+ year age class would include a 25 to 35% reduction in suppressed or poorly formed stems and improved spacing (typical residual target basal area of 28-30 m ha^{-2}).

Management objectives include maximizing timber values and moving towards stand conversion.

1. Stand is relatively healthy but has occasional decline pockets and/or scattered individual mortality:
   - Mark as for regular selection cutting but with more emphasis on trees of smaller diameter class and poorer quality or declining health and that affect final stand spacing
   - Mark two live trees surrounding decline pockets or unhealthy stems
   - PLUS, when approaching decline pockets switch to marking from above and remove larger diameter trees (maintaining prescribed % reduction) within 50 to 75 m around the declining stems.

2. Stand has scattered decline pockets and/or scattered individual mortality throughout:
   - Mark entire stand from above for selection cutting but emphasize the removal of larger diameter classes and unhealthy trees with declining crowns regardless of diameter

   OR if marking from above seems unnecessary:
   - Mark all trees with thinning or declining crowns (some openings will be created and basal area may be substantially reduced)
   - Where basal area remains above the target, reduce it to 26 to 28 m^{2}ha^{-1} using spacing as the main criteria.

3. Stand exhibits severe decline throughout:
   - Remove overstory leaving only white pine (if present)
   - Consider retaining areas with little commercial value to minimize damage to regeneration and to provide wildlife habitat

For all scenarios, monitor stands biannually to check for continued spread of decline. If so further measures (marking and removal) may be necessary.

Complete overstory removal is a feasible option where adequate advanced regeneration is present. Where this is not the case, consider other approaches to ensure adequate regeneration following harvest.

In younger (30-50 years) stands, sampling soil may help to determine the likelihood of future decline problems. Where the C horizon is alkaline, decline is more likely and it is prudent to assume a younger rotation age and consider options to ensure adequate advanced regeneration.

For more information about management recommendations for red pine plantations, contact Graeme Davis, R.P.F, County of Simcoe [Graeme.Davis@Simcoe.ca; (705) 726-9300 ext.1177] or John McLaughlin [john.mclaughlin@ontario.ca; (705) 946-7419].

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Cette publication hautement spécialisée *Mortality in Southern Ontario Red Pine Plantations: Causes, Consequences, and Management Options* n'est disponible qu'en anglais en vertu du Règlement 411/97, qui en exempte l'application de la Loi sur les services en français. Pour obtenir de l'aide en français, veuillez communiquer avec le ministère de Richesses naturelles au information.ofri@ontario.ca.

Appendix 3 – Soil Sample Analysis Data

A & L Canada Laboratories Inc.

2136 Jetstream Road, London, Ontario, N5V 3P5

Report Number: C23103-10084
Account Number: 05585

Telephone: (519) 457-2575 **Fax:** (519) 457-2664

To: ERIC BOYSEN
364 GREER ROAD MABERLY, ON K0H 2B0
For:

Reported Date: Apr 17, 2023 **Printed Date:** Apr 17, 2023

SOIL TEST REPORT

Page: 1 / 1

Sample Number	Lab Number	Organic Matter	Phosphorus - P ppm Bicarb	Phosphorus - P ppm Bray-P1	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	pH	Buffer pH	CEC meq/100g	Percent Base Saturations % K	% Mg	% Ca	% H	% Na
1	00437	1.5	7 L	13 L	43 L	84 L	300 VL	56 VH	5.5	6.4	9.7	1.1	7.2	15.4	73.8	2.5

Sample Number	Sulfur S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Soluble Salts ms/cm	Saturation %P	Aluminum Al ppm	Saturation %Al	Nitrate Nitrogen NO3-N ppm	K/Mg Ratio	ENR	Field ID
1	32 VH	1.3 L	10 L	101 VH	0.5 M	0.3 VL		1 VL	1181	2.4 MT		0.15	27	

OE VL = VERY LOW, L = LOW, M = MEDIUM, H = HIGH, VH = VERY HIGH, G = GOOD, MA = MARGINAL, MT = MODERATE PHYTO-TOXIC, T = PHYTO-TOXIC, ST = SEVERE PHYTO-TOXIC

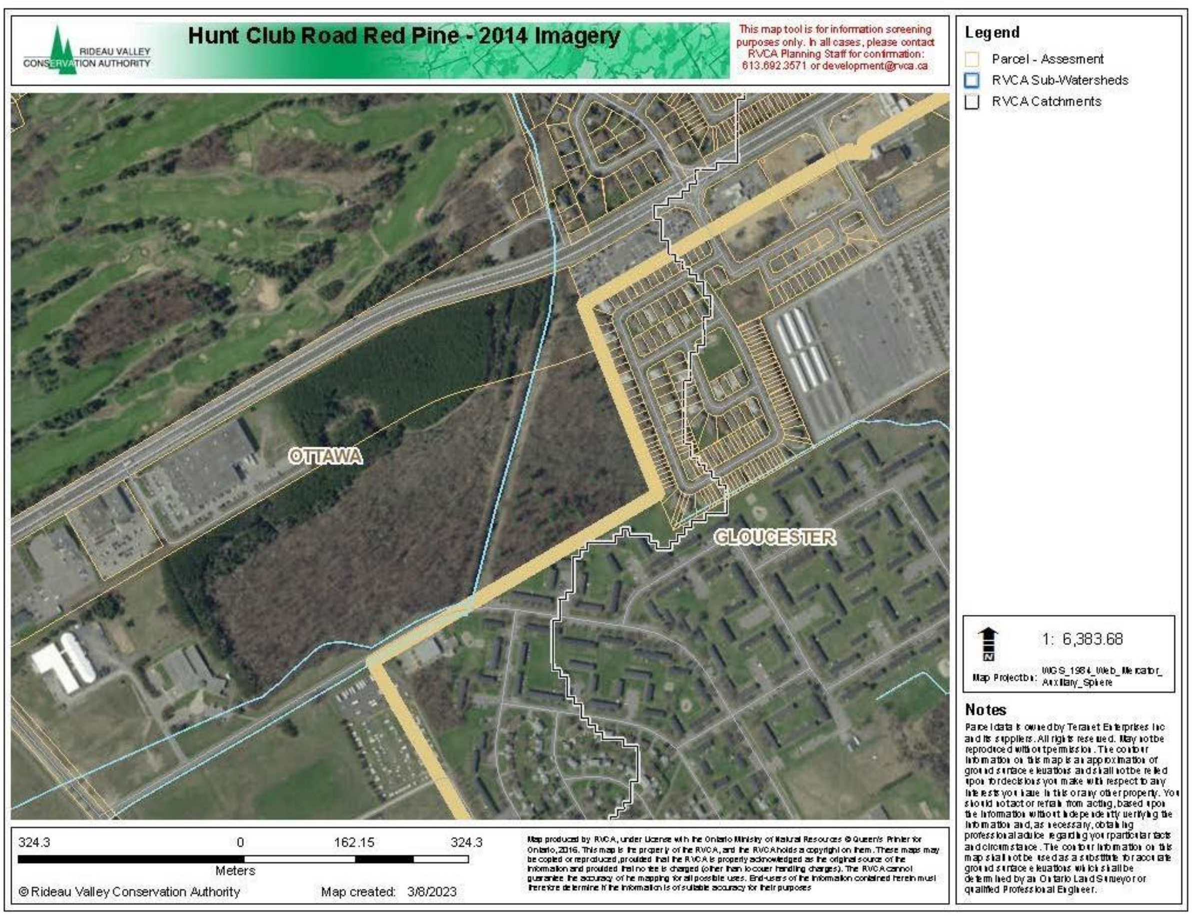
The results of this report relate to the sample submitted and analyzed. All results are released based on acceptable QC data.
* Crop yield is influenced by a number of factors in addition to soil fertility.
No guarantee or warranty concerning crop performance is made by A & L.
Results Authorized By: **Beth Wood, Agronomist**
A&L Canada Laboratories Inc. is accredited by the Standards Council of Canada for specific tests as listed on www.scc.ca and by the Canadian Association for Laboratory Accreditation as listed on www.cala.ca

Appendix 4 - Historical aerial photos of the Hunt Club Red Pine Plantation

1953 Aerial Photograph

1978 Aerial Photograph

1991 Aerial Photograph



2014 Satellite Imagery

Appendix 5 - Data from plots

Hunt Club Road March 2023

Red Pine Plantation

All plot areas are 200m2

Plot 1 DND Lands

	DBH	DBH^2	Basal Area	Vol/stem
	25.3	640.09	0.050272669	0.452307445
	32.1	1030.41	0.080928401	0.728119661
	27.1	734.41	0.057680561	0.518956882
	21.3	453.69	0.035632813	0.320591424
	23.9	571.21	0.044862833	0.403634701
	24.7	610.09	0.047916469	0.431108514
	29.6	876.16	0.068813606	0.619121828
	24.8	615.04	0.048305242	0.434606338
	27	729	0.05725566	0.515134008
	27.3	745.29	0.058535077	0.526645027
	30.2	912.04	0.071631622	0.644475748
	23.8	566.44	0.044488198	0.400264071
	19.2	368.64	0.028952986	0.260492456
	22.3	497.29	0.039057157	0.351400536
	16.4	268.96	0.021124118	0.190055477
	28.5	812.25	0.063794115	0.57396104
	22.9	524.41	0.041187161	0.370564369
	17.8	316.84	0.024884614	0.22388897
	19.2	368.64	0.028952986	0.260492456
	26.3	691.69	0.054325333	0.488769605
Total	489.7	12332.59	0.968601619	8.714590556
Count	20			
Average	24.49	24.83		
Density	1000			
BA/ha	48.43	Vol/ha	435.7295278	
Height(m)	20			

Plot 2 DND Lands

	DBH	DBH^2	Basal Area	Vol/stem
	23.6	556.96	0.043743638	0.393565209
	29.1	846.81	0.066508457	0.598382208
	20.6	424.36	0.033329234	0.299865936
	26.1	681.21	0.053502233	0.481364112
	19.3	372.49	0.029255365	0.263212986
	20.9	436.81	0.034307057	0.308663492
	21.1	445.21	0.034966793	0.314599193
	23.1	533.61	0.041909729	0.377065374
	26.8	718.24	0.05641057	0.507530658
	22.3	497.29	0.039057157	0.351400536
	19.9	396.01	0.031102625	0.279832947
	25.4	645.16	0.050670866	0.455890064
	22.3	497.29	0.039057157	0.351400536
	17.4	302.76	0.02377877	0.213939605
	21.6	466.56	0.036643622	0.329685765
	20.7	428.49	0.033653605	0.302784322
	23.1	533.61	0.041909729	0.377065374
	20.4	416.16	0.032685206	0.294071562
	19.5	380.25	0.029864835	0.268696442
	19.2	368.64	0.028952986	0.260492456
	20.3	412.09	0.032365549	0.291195574
	17.6	309.76	0.02432855	0.218886022
	20.9	436.81	0.034307057	0.308663492
	34.6	1197.16	0.094024946	0.845950383
	22.2	492.84	0.038707654	0.348256028
	27.1	734.41	0.057680561	0.518956882
	18.5	342.25	0.026880315	0.241844464
	27.2	739.84	0.058107034	0.522793888
	24.3	590.49	0.046377085	0.417258546
	20.3	412.09	0.032365549	0.291195574
	20.8	432.64	0.033979546	0.305716841
Totals	696.2	16048.3	1.260433482	11.34022648
Count	31			
Average	22.46	22.75		
Density	1550			
BA/ha	63.02	Vol/ha	567.0113238	
Height (m)	20			

PLOT 3 Ottawa Airport Lands

	DBH	DBH^2	Basal Area	Vol/stem
	20.1	404.01	0.031730945	0.285485995
	22.9	524.41	0.041187161	0.370564369
	18.8	353.44	0.027759178	0.249751665
	17.4	302.76	0.02377877	0.213939605
	17	289	0.02269806	0.204216363
	18.8	353.44	0.027759178	0.249751665
	16.7	278.89	0.021904021	0.197072323
	22.5	506.25	0.039760875	0.35773195
	22.5	506.25	0.039760875	0.35773195
	15.1	228.01	0.017907905	0.161118937
	17.9	320.41	0.025165001	0.226411643
	22.9	524.41	0.041187161	0.370564369
	18.7	349.69	0.027464653	0.247101799
	23.8	566.44	0.044488198	0.400264071
	17.4	302.76	0.02377877	0.213939605
	22.9	524.41	0.041187161	0.370564369
	18.9	357.21	0.028055273	0.252415664
	20.6	424.36	0.033329234	0.299865936
	24.7	610.09	0.047916469	0.431108514
	24.9	620.01	0.048695585	0.438118294

All Plots Combined both owners

Plot	DBH	DBH^2	Basal Area	Vol/stem
Plot 1	25.3	640.09	0.050272669	0.452307445
	32.1	1030.41	0.080928401	0.728119661
	27.1	734.41	0.057680561	0.518956882
	21.3	453.69	0.035632813	0.320591424
	23.9	571.21	0.044862833	0.403634701
	24.7	610.09	0.047916469	0.431108514
	29.6	876.16	0.068813606	0.619121828
	24.8	615.04	0.048305242	0.434606338
	27	729	0.05725566	0.515134008
	27.3	745.29	0.058535077	0.526645027
	30.2	912.04	0.071631622	0.644475748
	23.8	566.44	0.044488198	0.400264071
	19.2	368.64	0.028952986	0.260492456
	22.3	497.29	0.039057157	0.351400536
	16.4	268.96	0.021124118	0.190055477
	28.5	812.25	0.063794115	0.57396104
	22.9	524.41	0.041187161	0.370564369
	17.8	316.84	0.024884614	0.22388897
	19.2	368.64	0.028952986	0.260492456
	26.3	691.69	0.054325333	0.488769605
Plot2	23.6	556.96	0.043743638	0.393565209
	29.1	846.81	0.066508457	0.598382208
	20.6	424.36	0.033329234	0.299865936
	26.1	681.21	0.053502233	0.481364112
	19.3	372.49	0.029255365	0.263212986
	20.9	436.81	0.034307057	0.308663492
	21.1	445.21	0.034966793	0.314599193
	23.1	533.61	0.041909729	0.377065374
	26.8	718.24	0.05641057	0.507530658
	22.3	497.29	0.039057157	0.351400536
	19.9	396.01	0.031102625	0.279832947
	25.4	645.16	0.050670866	0.455890064
	22.3	497.29	0.039057157	0.351400536
	17.4	302.76	0.02377877	0.213939605
	21.6	466.56	0.036643622	0.329685765
	20.7	428.49	0.033653605	0.302784322
	23.1	533.61	0.041909729	0.377065374
	20.4	416.16	0.032685206	0.294071562
	19.5	380.25	0.029864835	0.268696442
	19.2	368.64	0.028952986	0.260492456
	20.3	412.09	0.032365549	0.291195574
	17.6	309.76	0.02432855	0.218886022
	20.9	436.81	0.034307057	0.308663492
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	27.1	734.41	0.057680561	0.518956882
	18.5	342.25	0.026880315	0.241844464
	27.2	739.84	0.058107034	0.522793888
	24.3	590.49	0.046377085	0.417258546
	20.3	412.09	0.032365549	0.291195574
	20.8	432.64	0.033979546	0.305716841
Plot 3	20.1	404.01	0.031730945	0.285485995
	22.9	524.41	0.041187161	0.370564369
	18.8	353.44	0.027759178	0.249751665
	17.4	302.76	0.02377877	0.213939605
	17	289	0.02269806	0.204216363
	18.8	353.44	0.027759178	0.249751665
	16.7	278.89	0.021904021	0.197072323
	22.5	506.25	0.039760875	0.35773195
	22.5	506.25	0.039760875	0.35773195
	15.1	228.01	0.017907905	0.161118937
	17.9	320.41	0.025165001	0.226411643
	22.9	524.41	0.041187161	0.370564369
	18.7	349.69	0.027464653	0.247101799
	23.8	566.44	0.044488198	0.400264071
	17.4	302.76	0.02377877	0.213939605
	22.9	524.41	0.041187161	0.370564369
	18.9	357.21	0.028055273	0.252415664
	20.6	424.36	0.033329234	0.299865936
	24.7	610.09	0.047916469	0.431108514
	24.9	620.01	0.048695585	0.438118294
	23.8	566.44	0.044488198	0.400264071
	17.3	299.29	0.023506237	0.211487596
	27.4	750.76	0.05896469	0.530510299
	24.2	585.64	0.045996166	0.413831386
	21.4	457.96	0.035968178	0.323608738
	23.7	561.69	0.044115133	0.396907573
	20.5	420.25	0.033006435	0.296961683
	16.7	278.89	0.021904021	0.197072323
	22.9	524.41	0.041187161	0.370564369
	23.2	538.24	0.04227337	0.380337076
	20.9	436.81	0.034307057	0.308663492
	23.3	542.89	0.042638581	0.38362291
	22.2	492.84	0.038707654	0.348256028
Plot 4	21.7	470.89	0.036983701	0.332745477
	21.1	445.21	0.034966793	0.314599193
	18.4	338.56	0.026590502	0.239236996
	18.4	338.56	0.026590502	0.239236996
	18.4	338.56	0.026590502	0.239236996
	20.7	428.49	0.033653605	0.302784322
	17.8	316.84	0.024884614	0.22388897
	16.8	282.24	0.02216713	0.199439537
	17.8	316.84	0.024884614	0.22388897
	19.8	392.04	0.030790822	0.277027622
	17.2	295.84	0.023235274	0.209049719
	18.8	353.44	0.027759178	0.249751665

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Plot	DBH	DBH^2	Basal Area	Vol/stem
Plot 3	20.1	404.01	0.031730945	0.285485995
	22.9	524.41	0.041187161	0.370564369
	18.8	353.44	0.027759178	0.249751665
	17.4	302.76	0.02377877	0.213939605
	17	289	0.02269806	0.204216363
	18.8	353.44	0.027759178	0.249751665
	16.7	278.89	0.021904021	0.197072323
	22.5	506.25	0.039760875	0.35773195
	22.5	506.25	0.039760875	0.35773195
	15.1	228.01	0.017907905	0.161118937
	17.9	320.41	0.025165001	0.226411643
	22.9	524.41	0.041187161	0.370564369
	18.7	349.69	0.027464653	0.247101799
	23.8	566.44	0.044488198	0.400264071
	17.4	302.76	0.02377877	0.213939605
	22.9	524.41	0.041187161	0.370564369
	18.9	357.21	0.028055273	0.252415664
	20.6	424.36	0.033329234	0.299865936
	24.7	610.09	0.047916469	0.431108514
	24.9	620.01	0.048695585	0.438118294
	23.8	566.44	0.044488198	0.400264071
	17.3	299.29	0.023506237	0.211487596
	27.4	750.76	0.05896469	0.530510299
	24.2	585.64	0.045996166	0.413831386
	21.4	457.96	0.035968178	0.323608738
	23.7	561.69	0.044115133	0.396907573
	20.5	420.25	0.033006435	0.296961683
	16.7	278.89	0.021904021	0.197072323
	22.9	524.41	0.041187161	0.370564369
	23.2	538.24	0.04227337	0.380337076
	20.9	436.81	0.034307057	0.308663492
	23.3	542.89	0.042638581	0.38362291
	22.2	492.84	0.038707654	0.348256028
Plot 4	21.7	470.89	0.036983701	0.332745477
	21.1	445.21	0.034966793	0.314599193
	18.4	338.56	0.026590502	0.239236996
	18.4	338.56	0.026590502	0.239236996
	18.4	338.56	0.026590502	0.239236996
	20.7	428.49	0.033653605	0.302784322
	17.8	316.84	0.024884614	0.22388897
	16.8	282.24	0.02216713	0.199439537
	17.8	316.84	0.024884614	0.22388897
	19.8	392.04	0.030790822	0.277027622
	17.2	295.84	0.023235274	0.209049719
	18.8	353.44	0.027759178	0.249751665
	18.9	357.21	0.028055273	0.252415664
	23.2	538.24	0.04227337	0.380337076
	20.2	408.04	0.032047462	0.288333718
	20.8	432.64	0.033979546	0.305716841
	22.4	501.76	0.03940823	0.354559177
	21.3	453.69	0.035632813	0.320591424
	20.5	420.25	0.033006435	0.296961683
	16.8	282.24	0.02216713	0.199439537
	21.3	453.69	0.035632813	0.320591424
	19.7	388.09	0.030480589	0.27423643
	23.4	547.56	0.043005362	0.386922877
	22.2	492.84	0.038707654	0.348256028
	26.2	686.44	0.053912998	0.485059792
	27.4	750.76	0.05896469	0.530510299
	21.8	475.24	0.03732535	0.335819322
	19.6	384.16	0.030171926	0.27145937
	27.4	750.76	0.05896469	0.530510299
Plot 5	22.2	492.84	0.038707654	0.348256028
	19.5	380.25	0.029864835	0.268696442
	25.9	670.81	0.052685417	0.474015149
	22.5	506.25	0.039760875	0.35773195
	18.5	342.25	0.026880315	0.241844464
	21	441	0.03463614	0.311624276
	16.4	268.96	0.021124118	0.190055477
	25.3	640.09	0.050272669	0.452307445
	14.6	213.16	0.016741586	0.150625467
	17.2	295.84	0.023235274	0.209049719
	19.2	368.64	0.028952986	0.260492456
	19.4	376.36	0.029559314	0.265947648
	20.5	420.25	0.033006435	0.296961683
	18	324	0.02544696	0.228948448
	15.2	231.04	0.018145882	0.163260029
	22.8	519.84	0.040828234	0.367335065
	18.6	345.96	0.027171698	0.244466065
	21	441	0.03463614	0.311624276
	24	576	0.04523904	0.407019463
	19.2	368.64	0.028952986	0.260492456
	18.5	342.25	0.026880315	0.241844464
	22	484	0.03801336	0.34200941
	21.5	462.25	0.036305115	0.326640185
	19.3	372.49	0.029255365	0.263212986
	19.9	396.01	0.031102625	0.279832947
	21.8	475.24	0.03732535	0.335819322
	21.1	445.21	0.034966793	0.314599193
	23	529	0.04154766	0.373807806
	18.1	327.61	0.025730489	0.231499386
	23	529	0.04154766	0.373807806
	17	289	0.02269806	0.204216363
Plot 6	22.4	501.76	0.03940823	0.354559177
	14.5	210.25	0.016513035	0.14856917
	18.6	345.96	0.027171698	0.244466065

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	23.8	566.44	0.044488198	0.400264071
	17.3	299.29	0.023506237	0.211487596
	27.4	750.76	0.05896469	0.530510299
	24.2	585.64	0.045996166	0.413831386
	21.4	457.96	0.035968178	0.323608738
	23.7	561.69	0.044115133	0.396907573
	20.5	420.25	0.033006435	0.296961683
	16.7	278.89	0.021904021	0.197072323
	22.9	524.41	0.041187161	0.370564369
	23.2	538.24	0.04227337	0.380337076
	20.9	436.81	0.034307057	0.308663492
	23.3	542.89	0.042638581	0.38362291
	22.2	492.84	0.038707654	0.348256028
Total	692	14802.36	1.162577354	10.45980663
Count	33			
Average	20.97	21.18		
Density	1650			
BA/ha	58.13	Vol/ha	522.9903316	
Height(m)	20			

PLOT 4	Ottawa Airport Lands			
	DBH	DBH^2	Basal Area	Vol/stem
	21.7	470.89	0.036983701	0.332745477
	21.1	445.21	0.034966793	0.314599193
	18.4	338.56	0.026590502	0.239236996
	18.4	338.56	0.026590502	0.239236996
	18.4	338.56	0.026590502	0.239236996
	20.7	428.49	0.033653605	0.302784322
	17.8	316.84	0.024884614	0.22388897
	16.8	282.24	0.02216713	0.199439537
	17.8	316.84	0.024884614	0.22388897
	19.8	392.04	0.030790822	0.277027622
	17.2	295.84	0.023235274	0.209049719
	18.8	353.44	0.027759178	0.249751665
	18.9	357.21	0.028055273	0.252415664
	23.2	538.24	0.04227337	0.380337076
	20.2	408.04	0.032047462	0.288333718
	20.8	432.64	0.033979546	0.305716841
	22.4	501.76	0.03940823	0.354559177
	21.3	453.69	0.035632813	0.320591424
	20.5	420.25	0.033006435	0.296961683
	16.8	282.24	0.02216713	0.199439537
	21.3	453.69	0.035632813	0.320591424
	19.7	388.09	0.030480589	0.27423643
	23.4	547.56	0.043005362	0.386922877
	22.2	492.84	0.038707654	0.348256028
	26.2	686.44	0.053912998	0.485059792
	27.4	750.76	0.05896469	0.530510299
	21.8	475.24	0.03732535	0.335819322
	19.6	384.16	0.030171926	0.27145937
	27.4	750.76	0.05896469	0.530510299
Total	600	12641.12	0.992833565	8.932607422
Count	29			
Average	20.69	20.88		
Density	1450			
BA/ha	49.64	Vol/ha	446.6303711	
Height(m)	20			

PLOT 5	Ottawa Airport Lands			
	DBH	DBH^2	Basal Area	Vol/stem
	22.2	492.84	0.038707654	0.348256028
	19.5	380.25	0.029864835	0.268696442
	25.9	670.81	0.052685417	0.474015149
	22.5	506.25	0.039760875	0.35773195
	18.5	342.25	0.026880315	0.241844464
	21	441	0.03463614	0.311624276
	16.4	268.96	0.021124118	0.190055477
	25.3	640.09	0.050272669	0.452307445
	14.6	213.16	0.016741586	0.150625467
	17.2	295.84	0.023235274	0.209049719
	19.2	368.64	0.028952986	0.260492456
	19.4	376.36	0.029559314	0.265947648
	20.5	420.25	0.033006435	0.296961683
	18	324	0.02544696	0.228948448
	15.2	231.04	0.018145882	0.163260029
	22.8	519.84	0.040828234	0.367335065
	18.6	345.96	0.027171698	0.244466065
	21	441	0.03463614	0.311624276
	24	576	0.04523904	0.407019463
	19.2	368.64	0.028952986	0.260492456
	18.5	342.25	0.026880315	0.241844464
	22	484	0.03801336	0.34200941
	21.5	462.25	0.036305115	0.326640185
	19.3	372.49	0.029255365	0.263212986
	19.9	396.01	0.031102625	0.279832947
	21.8	475.24	0.03732535	0.335819322
	21.1	445.21	0.034966793	0.314599193
	23	529	0.04154766	0.373807806
	18.1	327.61	0.025730489	0.231499386
	23	529	0.04154766	0.373807806
	17	289	0.02269806	0.204216363
Total		12875.24	1.01122135	9.098043875
Count	31			

	18.9	357.21	0.028055273	0.252415664
	23.2	538.24	0.04227337	0.380337076
	20.2	408.04	0.032047462	0.288333718
	20.8	432.64	0.033979546	0.305716841
	22.4	501.76	0.03940823	0.354559177
	21.3	453.69	0.035632813	0.320591424
	20.5	420.25	0.033006435	0.296961683
	16.8	282.24	0.02216713	0.199439537
	21.3	453.69	0.035632813	0.320591424
	19.7	388.09	0.030480589	0.27423643
	23.4	547.56	0.043005362	0.386922877
	22.2	492.84	0.038707654	0.348256028
	26.2	686.44	0.053912998	0.485059792
	27.4	750.76	0.05896469	0.530510299
	21.8	475.24	0.03732535	0.335819322
	19.6	384.16	0.030171926	0.27145937
	27.4	750.76	0.05896469	0.530510299
Plot 5	22.2	492.84	0.038707654	0.348256028
	19.5	380.25	0.029864835	0.268696442
	25.9	670.81	0.052685417	0.474015149
	22.5	506.25	0.039760875	0.35773195
	18.5	342.25	0.026880315	0.241844464
	21	441	0.03463614	0.311624276
	16.4	268.96	0.021124118	0.190055477
	25.3	640.09	0.050272669	0.452307445
	14.6	213.16	0.016741586	0.150625467
	17.2	295.84	0.023235274	0.209049719
	19.2	368.64	0.028952986	0.260492456
	19.4	376.36	0.029559314	0.265947648
	20.5	420.25	0.033006435	0.296961683
	18	324	0.02544696	0.228948448
	15.2	231.04	0.018145882	0.163260029
	22.8	519.84	0.040828234	0.367335065
	18.6	345.96	0.027171698	0.244466065
	21	441	0.03463614	0.311624276
	24	576	0.04523904	0.407019463
	19.2	368.64	0.028952986	0.260492456
	18.5	342.25	0.026880315	0.241844464
	22	484	0.03801336	0.34200941
	21.5	462.25	0.036305115	0.326640185
	19.3	372.49	0.029255365	0.263212986
	19.9	396.01	0.031102625	0.279832947
	21.8	475.24	0.03732535	0.335819322
	21.1	445.21	0.034966793	0.314599193
	23	529	0.04154766	0.373807806
	18.1	327.61	0.025730489	0.231499386
	23	529	0.04154766	0.373807806
	17	289	0.02269806	0.204216363
Plot 6	22.4	501.76	0.03940823	0.354559177
	14.5	210.25	0.016513035	0.14856917
	18.6	345.96	0.027171698	0.244466065
	19	361	0.02835294	0.255093795
	19.5	380.25	0.029864835	0.268696442
	19	361	0.02835294	0.255093795
	16.9	285.61	0.022431809	0.201820883
	24.2	585.64	0.045996166	0.413831386
	21.5	462.25	0.036305115	0.326640185
	16.6	275.56	0.021642482	0.194719242
	21	441	0.03463614	0.311624276
	17.5	306.25	0.024052875	0.216405748
	23.1	533.61	0.041909729	0.377065374
	19.5	380.25	0.029864835	0.268696442
	21.1	445.21	0.034966793	0.314599193
	20.4	416.16	0.032685206	0.294071562
	19.4	376.36	0.029559314	0.265947648
	13.8	190.44	0.014957158	0.13457081
	23.8	566.44	0.044488198	0.400264071
	15	225	0.0176715	0.158991978
	13.5	182.25	0.014313915	0.128783502
	18.5	342.25	0.026880315	0.241844464
	15.5	240.25	0.018869235	0.169768101
	16.7	278.89	0.021904021	0.197072323
	21.3	453.69	0.035632813	0.320591424
	16.6	275.56	0.021642482	0.194719242
	25.8	665.64	0.052279366	0.470361867
	19.2	368.64	0.028952986	0.260492456
	23	529	0.04154766	0.373807806
	18.3	334.89	0.026302261	0.23664366
	24.5	600.25	0.047143635	0.424155265
Plot 7	18	324	0.02544696	0.228948448
	17	289	0.02269806	0.204216363
	19.3	372.49	0.029255365	0.263212986
	19.1	364.81	0.028652177	0.25778606
	13.9	193.21	0.015174713	0.136528178
	23.6	556.96	0.043743638	0.393565209
	20	400	0.031416	0.282652405
	20	400	0.031416	0.282652405
	20	400	0.031416	0.282652405
	18.5	342.25	0.026880315	0.241844464
	19	361	0.02835294	0.255093795
	20.3	412.09	0.032365549	0.291195574
	23	529	0.04154766	0.373807806
	22.5	506.25	0.039760875	0.35773195
	18	324	0.02544696	0.228948448
	22	484	0.03801336	0.34200941
	17.1	292.41	0.022965881	0.206625974
	23.2	538.24	0.04227337	0.380337076
	12.5	156.25	0.012271875	0.110411096
	22	484	0.03801336	0.34200941

	19	361	0.02835294	0.255093795
	19.5	380.25	0.029864835	0.268696442
	19	361	0.02835294	0.255093795
	16.9	285.61	0.022431809	0.201820883
	24.2	585.64	0.045996166	0.413831386
	21.5	462.25	0.036305115	0.326640185
	16.6	275.56	0.021642482	0.194719242
	21	441	0.03463614	0.311624276
	17.5	306.25	0.024052875	0.216405748
	23.1	533.61	0.041909729	0.377065374
	19.5	380.25	0.029864835	0.268696442
	21.1	445.21	0.034966793	0.314599193
	20.4	416.16	0.032685206	0.294071562
	19.4	376.36	0.029559314	0.265947648
	13.8	190.44	0.014957158	0.13457081
	23.8	566.44	0.044488198	0.400264071
	15	225	0.0176715	0.158991978
	13.5	182.25	0.014313915	0.128783502
	18.5	342.25	0.026880315	0.241844464
	15.5	240.25	0.018869235	0.169768101
	16.7	278.89	0.021904021	0.197072323
	21.3	453.69	0.035632813	0.320591424
	16.6	275.56	0.021642482	0.194719242
	25.8	665.64	0.052279366	0.470361867
	19.2	368.64	0.028952986	0.260492456
	23	529	0.04154766	0.373807806
	18.3	334.89	0.026302261	0.23664366
	24.5	600.25	0.047143635	0.424155265
Plot 7	18	324	0.02544696	0.228948448
	17	289	0.02269806	0.204216363
	19.3	372.49	0.029255365	0.263212986
	19.1	364.81	0.028652177	0.25778606
	13.9	193.21	0.015174713	0.136528178
	23.6	556.96	0.043743638	0.393565209
	20	400	0.031416	0.282652405
	20	400	0.031416	0.282652405
	20	400	0.031416	0.282652405
	18.5	342.25	0.026880315	0.241844464
	19	361	0.02835294	0.255093795
	20.3	412.09	0.032365549	0.291195574
	23	529	0.04154766	0.373807806
	22.5	506.25	0.039760875	0.35773195
	18	324	0.02544696	0.228948448
	22	484	0.03801336	0.34200941
	17.1	292.41	0.022965881	0.206625974
	23.2	538.24	0.04227337	0.380337076
	12.5	156.25	0.012271875	0.110411096
	22	484	0.03801336	0.34200941
	16.5	272.25	0.021382515	0.192380293
	16.4	268.96	0.021124118	0.190055477
	15.9	252.81	0.019855697	0.178643386
	18.1	327.61	0.025730489	0.231499386
	18	324	0.02544696	0.228948448
	16.5	272.25	0.021382515	0.192380293
	14	196	0.01539384	0.138499678
	19.5	380.25	0.029864835	0.268696442
	14.7	216.09	0.016971709	0.152695895
	19.1	364.81	0.028652177	0.25778606
	19.5	380.25	0.029864835	0.268696442
	18.4	338.56	0.026590502	0.239236996
	16.9	285.61	0.022431809	0.201820883
	19	361	0.02835294	0.255093795
	21.1	445.21	0.034966793	0.314599193
	25.1	630.01	0.049480985	0.445184604
	20.3	412.09	0.032365549	0.291195574
Plot 8	17.4	302.76	0.02377877	0.213939605
	23.8	566.44	0.044488198	0.400264071
	16.7	278.89	0.021904021	0.197072323
	16.9	285.61	0.022431809	0.201820883
	18.7	349.69	0.027464653	0.247101799
	21.2	449.44	0.035299018	0.317588242
	26.8	718.24	0.05641057	0.507530658
	16.4	268.96	0.021124118	0.190055477
	22.6	510.76	0.04011509	0.360918856
	19.8	392.04	0.030790822	0.277027622
	16.6	275.56	0.021642482	0.194719242
	17.7	313.29	0.024605797	0.22138043
	21.6	466.56	0.036643622	0.329685765
	17.9	320.41	0.025165001	0.226411643
	19.1	364.81	0.028652177	0.25778606
	18.4	338.56	0.026590502	0.239236996
	18.3	334.89	0.026302261	0.23664366
	25.4	645.16	0.050670866	0.455890064
	15.6	243.36	0.019113494	0.171965723
	16.7	278.89	0.021904021	0.197072323
	14.8	219.04	0.017203402	0.154780457
	21.1	445.21	0.034966793	0.314599193
	23.7	561.69	0.044115133	0.396907573
	17.2	295.84	0.023235274	0.209049719
	15.7	246.49	0.019359325	0.174177478
	20.2	408.04	0.032047462	0.288333718
	15.6	243.36	0.019113494	0.171965723
	20.5	420.25	0.033006435	0.296961683
Totals	3752.3	76241.99	5.988045895	53.87495457
Count	189			
Average	19.85344	20.08474		

Average	20.20	20.38		
Density	1550			
BA/ha	50.56	Vol/ha	454.9021938	
Height(m)	20			

PLOT 6	Ottawa Airport Lands			
	DBH	DBH^2	Basal Area	Vol/stem
	22.4	501.76	0.03940823	0.354559177
	14.5	210.25	0.016513035	0.14856917
	18.6	345.96	0.027171698	0.244466065
	19	361	0.02835294	0.255093795
	19.5	380.25	0.029864835	0.268696442
	19	361	0.02835294	0.255093795
	16.9	285.61	0.022431809	0.201820883
	24.2	585.64	0.045996166	0.413831386
	21.5	462.25	0.036305115	0.326640185
	16.6	275.56	0.021642482	0.194719242
	21	441	0.03463614	0.311624276
	17.5	306.25	0.024052875	0.216405748
	23.1	533.61	0.041909729	0.377065374
	19.5	380.25	0.029864835	0.268696442
	21.1	445.21	0.034966793	0.314599193
	20.4	416.16	0.032685206	0.294071562
	19.4	376.36	0.029559314	0.265947648
	13.8	190.44	0.014957158	0.13457081
	23.8	566.44	0.044488198	0.400264071
	15	225	0.0176715	0.158991978
	13.5	182.25	0.014313915	0.128783502
	18.5	342.25	0.026880315	0.241844464
	15.5	240.25	0.018869235	0.169768101
	16.7	278.89	0.021904021	0.197072323
	21.3	453.69	0.035632813	0.320591424
	16.6	275.56	0.021642482	0.194719242
	25.8	665.64	0.052279366	0.470361867
	19.2	368.64	0.028952986	0.260492456
	23	529	0.04154766	0.373807806
	18.3	334.89	0.026302261	0.23664366
	24.5	600.25	0.047143635	0.424155265
Total	599.7	11921.31	0.936299687	8.423967353
Count	31			
Average	19.35	19.61		
Density	1550			
BA/ha	46.81	Vol/ha	421.1983677	
Height(m)	20			

PLOT 7	Ottawa Airport Lands			
	DBH	DBH^2	Basal Area	Vol/stem
	18	324	0.02544696	0.228948448
	17	289	0.02269806	0.204216363
	19.3	372.49	0.029255365	0.263212986
	19.1	364.81	0.028652177	0.25778606
	13.9	193.21	0.015174713	0.136528178
	23.6	556.96	0.043743638	0.393565209
	20	400	0.031416	0.282652405
	20	400	0.031416	0.282652405
	20	400	0.031416	0.282652405
	18.5	342.25	0.026880315	0.241844464
	19	361	0.02835294	0.255093795
	20.3	412.09	0.032365549	0.291195574
	23	529	0.04154766	0.373807806
	22.5	506.25	0.039760875	0.35773195
	18	324	0.02544696	0.228948448
	22	484	0.03801336	0.34200941
	17.1	292.41	0.022965881	0.206625974
	23.2	538.24	0.04227337	0.380337076
	12.5	156.25	0.012271875	0.110411096
	22	484	0.03801336	0.34200941
	16.5	272.25	0.021382515	0.192380293
	16.4	268.96	0.021124118	0.190055477
	15.9	252.81	0.019855697	0.178643386
	18.1	327.61	0.025730489	0.231499386
	18	324	0.02544696	0.228948448
	16.5	272.25	0.021382515	0.192380293
	14	196	0.01539384	0.138499678
	19.5	380.25	0.029864835	0.268696442
	14.7	216.09	0.016971709	0.152695895
	19.1	364.81	0.028652177	0.25778606
	19.5	380.25	0.029864835	0.268696442
	18.4	338.56	0.026590502	0.239236996
	16.9	285.61	0.022431809	0.201820883
	19	361	0.02835294	0.255093795
	21.1	445.21	0.034966793	0.314599193
	25.1	630.01	0.049480985	0.445184604
	20.3	412.09	0.032365549	0.291195574
Total	698	13457.72	1.056969329	9.509642307
Count	37			
Average	18.86	19.07		
Density	1850			
BA/ha	52.85	Vol/ha	475.4821154	
Height(m)	20			

	16.5	272.25	0.021382515	0.192380293
	16.4	268.96	0.021124118	0.190055477
	15.9	252.81	0.019855697	0.178643386
	18.1	327.61	0.025730489	0.231499386
	18	324	0.02544696	0.228948448
	16.5	272.25	0.021382515	0.192380293
	14	196	0.01539384	0.138499678
	19.5	380.25	0.029864835	0.268696442
	14.7	216.09	0.016971709	0.152695895
	19.1	364.81	0.028652177	0.25778606
	19.5	380.25	0.029864835	0.268696442
	18.4	338.56	0.026590502	0.239236996
	16.9	285.61	0.022431809	0.201820883
	19	361	0.02835294	0.255093795
	21.1	445.21	0.034966793	0.314599193
	25.1	630.01	0.049480985	0.445184604
	20.3	412.09	0.032365549	0.291195574
Plot 8	17.4	302.76	0.02377877	0.213939605
	23.8	566.44	0.044488198	0.400264071
	16.7	278.89	0.021904021	0.197072323
	16.9	285.61	0.022431809	0.201820883
	18.7	349.69	0.027464653	0.247101799
	21.2	449.44	0.035299018	0.317588242
	26.8	718.24	0.05641057	0.507530658
	16.4	268.96	0.021124118	0.190055477
	22.6	510.76	0.04011509	0.360918856
	19.8	392.04	0.030790822	0.277027622
	16.6	275.56	0.021642482	0.194719242
	17.7	313.29	0.024605797	0.22138043
	21.6	466.56	0.036643622	0.329685765
	17.9	320.41	0.025165001	0.226411643
	19.1	364.81	0.028652177	0.25778606
	18.4	338.56	0.026590502	0.239236996
	18.3	334.89	0.026302261	0.23664366
	25.4	645.16	0.050670866	0.455890064
	15.6	243.36	0.019113494	0.171965723
	16.7	278.89	0.021904021	0.197072323
	14.8	219.04	0.017203402	0.154780457
	21.1	445.21	0.034966793	0.314599193
	23.7	561.69	0.044115133	0.396907573
	17.2	295.84	0.023235274	0.209049719
	15.7	246.49	0.019359325	0.174177478
	20.2	408.04	0.032047462	0.288333718
	15.6	243.36	0.019113494	0.171965723
	20.5	420.25	0.033006435	0.296961683
Totals	4938.2	104622.9	8.217080995	73.92977161
Count	240			
Average	20.57583	20.8789		
Density	1500			
BA/ha	51.35676			
Vol/ha	462.0611			

Density	1575
BA/ha	49.90038
Vol/ha	448.958

PLOT 8	Ottawa Airport Lands			
	DBH	DBH^2	Basal Area	Vol/stem
	17.4	302.76	0.02377877	0.213939605
	23.8	566.44	0.044488198	0.400264071
	16.7	278.89	0.021904021	0.197072323
	16.9	285.61	0.022431809	0.201820883
	18.7	349.69	0.027464653	0.247101799
	21.2	449.44	0.035299018	0.317588242
	26.8	718.24	0.05641057	0.507530658
	16.4	268.96	0.021124118	0.190055477
	22.6	510.76	0.04011509	0.360918856
	19.8	392.04	0.030790822	0.277027622
	16.6	275.56	0.021642482	0.194719242
	17.7	313.29	0.024605797	0.22138043
	21.6	466.56	0.036643622	0.329685765
	17.9	320.41	0.025165001	0.226411643
	19.1	364.81	0.028652177	0.25778606
	18.4	338.56	0.026590502	0.239236996
	18.3	334.89	0.026302261	0.23664366
	25.4	645.16	0.050670866	0.455890064
	15.6	243.36	0.019113494	0.171965723
	16.7	278.89	0.021904021	0.197072323
	14.8	219.04	0.017203402	0.154780457
	21.1	445.21	0.034966793	0.314599193
	23.7	561.69	0.044115133	0.396907573
	17.2	295.84	0.023235274	0.209049719
	15.7	246.49	0.019359325	0.174177478
	20.2	408.04	0.032047462	0.288333718
	15.6	243.36	0.019113494	0.171965723
	20.5	420.25	0.033006435	0.296961683
Total	536.4	6813.45	0.535128363	4.814595071
Count	28			
Average	19.16	15.60		
Density	1400			
BA/ha	26.76	Vol/ha	240.7297535	
Height(m)	20			

Appendix 6 - Recommended management scenarios for red pine plantations

(excerpt from OMNRF, 2019)

Red pine	
Establishment phase	
● Recommended spacing: 2.4 m × 2.1 m = 1984 trees/ha or 2.4 m × 1.8 m = 2314 trees/ha (a higher density for more intensively managed sites) ● Minimum between-row spacing: 2.1 m (e.g., 2.1 m × 1.8 m) ● Minimum 85% survival, or requires refill ● A crop plan can help determine the best initial spacing so that the first thinning occurs when the trees achieve a desired minimum diameter. ● Consider including 5 to 10% white pine, red oak, or both, planted in groups of 10 to 25 trees, to increase future diversity and provide regeneration options.	
Management phase	
Initial thinning	● Often after 25 to 30 years. ● Don't delay thinning past 35 years, because this produces trees with weak stems and thin crowns that are susceptible to bending and breakage. ● Average DBH of marked trees at the first thinning should be 16 to 18 cm (≥90% of stems ≥14 cm). They should have sufficient merchantable height to provide three usable logs (i.e., 8 m of straight bole to a 12 cm top to produce three 2.54-m logs). ● If planted at higher densities, pre-commercial thinning may be required. ● The first thinning should establish access rows and should include a light selection thinning from below to remove poor-quality stems in the residual rows. Typically, every fourth or fifth row is completely removed. ● The first thinning should remove 25 to 33% of BA, and the minimum residual basal area should be 26 m^2/ha. ● You may need to remove two adjacent rows if the initial spacing is too narrow for the thinning equipment. ● Select between 250 and 300 crop trees/ha, and prune lower branches to height of 3.0 m during the first thinning (here and for subsequent pruning, leave at least 33% of the live crown) if utility poles are the desired final product. ● Maintain or release acceptable (AGS) crop trees of other species to meet wildlife, regeneration, and diversity needs.
Subsequent thinnings	● After the first thinning, focus on thinning from below. Typical removal is 25 to 33% of basal area during each thinning. ● Return 9 to 12 years after the first thinning (exceptionally, as soon as 7 years or as late as 15 years), depending on the site quality, number of trees, and forest management objectives. ● After the second thinning, residual trees should all be of acceptable quality. ● You may still need to remove a few trees with v-forks, recently damaged trees, and declining trees. Start looking more at crown health than tree size for crop tree selection. ● Prune lower branches of crop trees to a height of 5.1 m. Prune lower branches of future utility poles to height of 7.4 m. ● Develop a long-term objective for natural or artificial regeneration when you plan the second thinning. ● Typical pathways are natural regeneration of hardwoods, white pine, or both; artificial regeneration of white pine, red oak, or both; and re-establishment of red pine. ● Time these thinnings to coincide with a seed crop to permit cone collection and increase the financial return from the plantation. ● At maturity (between 60 and 80 years), switch from thinning to improve stem quality to thinning designed to maximize the financial return, accounting for market demand.

	● Most red pine stands will eventually be converted to other species. If they will be regenerated to red pine, new planting stock will be required. ● In areas with competition from invasive species (buckthorn; dog-strangling vine), openings will tend to exacerbate their invasion.
Final harvest	● The potential harvest (rotation) age depends on the site and stand quality and on its regeneration status. ● Establish high-quality hardwoods or white pine to prevent establishment of invasive species, or to control existing invasives prior to the final harvest. ● To improve species diversity, minimize competition from invasive species and other species that are not part of your restoration objectives.
Other considerations	
Maximizing growth and quality	● Regular thinnings will provide more uniform growth, reduce competition, and allow poor-quality trees and those that would normally die to be removed and marketed early and utilized. Removing trees with defects through selective thinning early in the stand's development allows good growth and maximizes quality and value. ● Use DMDs or stocking guides to manage stand density within the range that will provide the best growth. ● Red pine is a good self-pruner. If pruning operations are necessary or desirable, focus on the high-quality crop trees (approximately 250 to 300 per hectare). ● Red pine has low genetic diversity, and individual trees tend to not differentiate themselves, leading to stagnant stands if regular thinning is not implemented. ● During the final thinning, consider the impact of skidding tree-length products; consider an alternative such as forwarding shorter products if high-quality regeneration has become established. Most of the high-end products, such as utility poles and wood suitable for building log homes, will come from the dominant and co-dominant trees that have been selected for low accumulated knot diameters, straightness, low taper, no forks, uniform growth, and few or no defects. ● Once all the trees have achieved acceptable quality, begin removing the high-value products when market conditions are favourable. ● As stands mature, watch for stress indicators in the crowns (e.g., tufting of needles, short needles, browning needles, thinning of the leaves or canopy). Trees with these types of symptoms are usually growing slowly and will not normally recover. Where possible, they should be removed.
Critical pest management issues	Heterobasidion root disease Red pine pocket decline (various insects and diseases) Red-headed pine sawfly
References (for further reading)	Horton and Bedell (1960) OMNR (1986) Smith and Woods (1997) Woods and Penner (2000) Gilmore and Palik (2006) Burgess et al. (2011)

Improving forest health and value

Although stand tending can improve the health of a forest, it will have the greatest impact when your goals for a plantation are to produce a monetary return on the investment. Pruning is a good investment when the goal is to provide knot-free timber. Regular thinning is generally a good investment because it will provide more consistent and uniform growth, reduce competition, and allow removal and utilization of poor-quality trees and those that would normally die, thereby adding this volume to the total harvest.

Pruning

Pruning is the removal of live or dead branches from standing trees to produce knot-free sawlogs, while maintaining at least one-third of the tree's height in live branches to sustain growth. To avoid damaging the tree, ensure that all pruning tools are sharp and well maintained. To accelerate healing of the wound, we recommend a technique in which the cut is as close as possible to the bark (without damaging the bark) and perpendicular to the branch to ensure that water runs off of the exposed wood. No paint or other substance should be applied over the wound. The selection and pruning of crop trees can add significant value to plantations, particularly on the most productive sites, and where active management practices such as regular thinning are being carried out. Before you identify and select crop trees, we recommend that you define the thinning regime and pattern, since this will reduce the risk of removing crop trees in a future thinning. A crop tree should be a dominant or co-dominant tree, with a well-developed leader and a full, round, finely branched crown, and it should have a straight, injury-free stem. The ultimate value of pruning will depend on the amount of usable, clear wood the tree produces. The larger the diameter of the tree when it is pruned, the longer it will take to produce the desired amount of clear wood.

Although red pine is relatively good at self-pruning at all ages, there may be economic benefits to pruning selected crop trees to produce clear, knot-free lumber. Between 250 and 350 crop trees/ha should be pruned when the plantation's average tree diameter is between 10 and 15 cm. The trees may be 15 to 20 years old at this time. Pruning can be conducted in conjunction with thinning. At the first thinning, prune the tree's branches to a height of about 3.0 m. Do not remove branches at heights greater than half of the total tree height at this growth stage. At the second thinning, more branches can be removed to bring the total branch-free height to 5.1 m. If you plan to grow high-quality utility poles, prune the branches to a height of 7.4 m. Pruning can be done at any time of the year, and if properly done, will not harm the tree. However, careless pruning can injure the tree and reduce its health. Pruning is easily done by forest landowners or volunteers who have little to no forest management experience once they have been trained on proper techniques.

Appendix 7 – Detailed Management Options Analysis

	Appendix 7. Forest Management Options for the Hunt Club Road Red Pine Plantation - Evaluated Against the City of Ottawa Objectives											
	Option 1		**Option 2**		**Option 3**		**Option 4**		**Option 5**		**Option 6**	
All Options except #1 require invasive species control treatments prior to any tree cutting, with potential follow-up	**Do nothing** - no thinning nor invasive species control		**Very Light Thinning from Below - 10% BA removal** yr 62; another 10% BA removal yr 72		**Light row thinning** - 20 % BA removal in yr 62; 20% BA selective removal in yr 72		**Traditional Row Thinning with selection - 30 % BA removal** in yr 62: another 20% BA in yr 72		**Restoration Thinning - create canopy gaps - 30 % BA removal** in yr 62: another 30%BA removal in yr 77 (5 -10% of each removal in gaps - planted)		**Clearcut with Standards** - retain 25 dominant trees/ha (27 cm dbh and greater) approx. 120 trees total	
City of Ottawa Objectives	**Pros**	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
i. The future healthy growth of the forest	allows natural processes	stand growth will continue to stagnate	will allow for the felling of most of the dead and some of the declining trees and create some access for future thinnings	insufficient density adjustment to allow for much growth response	creates access and removes dead, dying and low-quality trees	won't likely see much in the way of growth response - potentially only after second thinning	creates access and removes dead, dying and low-quality trees	growth may still be slow due to stand stagnation from lack of thinning and the retention of low crown volume trees	creates access and removes dead, dying and low-quality trees, provides additional light from sides of gaps	growth may still be slow due to stand stagnation from lack of thinning and the retention of low crown volume trees	retains legacy trees and creates an open condition suited to a new restoration plan that meets the City's current needs	forest conditions are mostly lost until the restored forest grows
		mortality rates will increase and more breakage patches from wind, ice and snow	will remove the weakest trees but not open the canopy too quickly and should have least amount of breakage and damage from wind, ice and snow	may still see further red pine decline, since will still be below needed space for light and growth and many poor-quality trees remain	improves stand quality by creating space and removing 20% of the poorest quality trees	may still see further red pine decline, since will still be below needed space for light and growth and many poor-quality trees remain	improves stand quality by creating space and removing 20% of the poorest quality trees	this amount of opening in a previously unthinned 60-year-old plantation will likely result in some blowdown and breakage	improves stand quality by creating space through row removals and gap creation	row removals and gap creation remove good and poor-quality trees equally	species composition and spacing of the new forest can be designed using density managemen t planning to maximize the growth potential	requires all silviculture steps associated with a forest renewal project after clear cutting, including site preparation, planting and tending.

		continue to lose trees and wood volume to natural mortality			should begin to see a reduction in mortality due to high densities	opening of sufficient size to begin to see additional breakage and damage from wind, ice, and snow	may begin to see growth responses on trees with the highest live crown volumes		increased light should allow some growth responses on trees with the highest live crown volumes that are closest to stand openings	this amount of opening in a previously unthinned 60-year-old plantation will likely result in some blowdown and breakage		
ii. Diversifying the canopy and understory of the forest in the mid to long-term	allows canopy to naturally break up through wind, ice and snow, which will accelerate over time	understory will very slowly establish and be released in natural disturbance patches	will begin to increase structural diversity by creating openings in the canopy	this is a light treatment, creating minimal structural diversity	slight increase in structural diversity by creating openings in the canopy	slightly more structural diversity than Option 2 but gradual over the 10 years	increase in structural diversity by creating a more open canopy	more structural diversity than Option 3 but not what could be achieved with canopy gaps like in Option 5	row removals and canopy gaps creates a maximum amount of structural diversity compared to all other options		retention of legacy trees in the high canopy provides habitat conditions not found in open fields	initially there will be some high canopy trees and single regeneration layer with limited structural diversity
		no control over timing or location of patches	will create downed wood on the forest floor - most felled trees will be left on the ground		creates downed wood - 30% of row removals 70% of selection removals will be left on ground (unmerchantable)		creates downed wood - 25% of row removals 70% of selection removals will be left on ground (unmerchantable)		creates both linear and patchy downed wood at about 25% of the volume cut to be left on ground (unmerchantable)		tops and branches left over from harvesting and site preparation will leave downed wood scattered across the site	diversity will need to be created through a new restoration plan with long period of succession

		understory is primarily buckthorn and other invasives which respond vigorously to canopy openings, few native seedlings	some light will reach the forest floor but likely only shade tolerant species will be able to germinate and grow	understory is primarily buckthorn and other invasives which respond vigorously to canopy openings, few native seedlings	although still a fairly light thinning after second treatment, native trees from neighbouring seed sources of shade and mid-tolerant trees should begin to germinate and grow	existing understory of invasive shrubs will respond to canopy openings and will need to be treated before and after thinnings	although still a fairly light thinning after second treatment, native trees from neighbouring seed sources of shade and mid-tolerant trees should begin to germinate and grow	existing understory of invasive shrubs will respond to canopy openings and will need to be treated before and after thinnings	the canopy gaps create a more suitable habitat for natural regeneration and will also be supplemented by native plantings	existing understory of invasive shrubs will respond to canopy openings and will need to be treated before and after thinnings	diversity can be a focus of the new restoration plan	a new restoration plan must be created and functional but is not always easy to achieve
iii. Improving the quality of the forest for urban flora and fauna (e.g., native wildflowers, birds, amphibians and reptiles, small mammals)	uses natural processes	some limited connections to existing source populations and seed trees/plants in neighbouring forests/trees	light will be able to reach the forest floor in limited areas	some limited connections to existing source populations and seed trees/plants in neighbouring forests/trees	more light will be able to reach the forest floor than in Option 2	some limited connections to source populations and seed trees/plants in neighbouring forests/trees	slightly more light will be able to reach the forest floor than in Option 3	some limited connections to source populations and seed trees/plants in neighbouring forests/trees	considerably more light will reach the forest floor in the created gaps, these can be supplemented with native species plantings	natural regeneration is still limited by the connection to local seed sources	Establishing habitat for certain urban flora and fauna can be part of restoration plans	The forest condition will be lost for 20 to 25 years until the new forest becomes established
	protects an existing 60-year-old stand of red pine	does not add native species through planting or other methods	improves quality of red pine by removing dead and declining trees	does not add native species through planting or other methods	removes all dead and declining trees and up to 70 to 80% of poorest quality trees	does not add native species through planting or other methods	removes all dead and declining trees and up to 75 to 85% of poorest quality trees	does not add native species through planting or other methods		the row removals and canopy gaps will not selectively remove poorer quality trees		Habitat for most forest flora and fauna will need to recover following the establishmen t of forest conditions
		continues to allow the stand to decline in quality, no control of invasive species	some openings and downed wood will create new habitat	does not create patches	increased openings and downed wood will create more new habitat than Option 2	does not create patches	increased openings and downed wood will create slightly more new habitat than Option 3	does not create patches	the canopy gaps and row removals will provide a wider range of habitat conditions for more species			

iv. Make the forest safe for passive recreational use by residents	no logging operations	leaves relatively stagnant stand to random mortality and breakage events	The trees most vulnerable to breakage and decline will be removed and hazard trees along trails can be targeted	May not remove all vulnerable trees and others may decline or break	The most obvious trees vulnerable to breakage and decline will be removed and hazard trees along trails can be targeted	opening of sufficient size to begin to see new breakage and damage from wind, ice and snow	The most obvious trees vulnerable to breakage and decline will be removed and hazard trees along trails can be targeted	opening of sufficient size creates risk of new breakage and damage from wind, ice and snow	The most obvious trees vulnerable to breakage and decline will be removed and hazard trees along trails can be targeted	opening of sufficient size creates risk of new breakage and damage from wind, ice and snow	most of the hazard trees that can fall on forest users will be eliminated	the legacy trees will be quite exposed and some may fall due to wind, ice and snow
	no herbicide used	would require an active hazard tree removal program for trails and along neighbouring properties to ensure safety	Low key tree felling and removal operation with small equipment or horses		commercial logging operations with heavy equipment involving a few weeks work each operation	monitoring for new hazard trees should be implemented	commercial logging operations with heavy equipment involving a few weeks work each operation	monitoring for new hazard trees should be implemented	commercial logging operations with heavy equipment involving a few weeks work each operation	monitoring for new hazard trees should be implemente d		significant periods of heavy equipment operations will be associated with the harvest and eventual site preparation operations
v. Ease of Implementation	very easy to implement	may result in significant monitoring and hazard tree removal	Most trees will not be merchantabl e and can be felled and left on the ground	Narrow single row removals at long intervals will limit access to only small equipment or horses and increase risk of hang-ups	Access thinning based on double row removals should make for easy commercial operations	Low volumes of small diameter, poor quality wood may be difficult to attract buyers	Access thinning based on double row removals should make for easy commercial operations	Low volumes of small diameter, poor quality wood may be difficult to attract buyers	Access thinning based on double row removals and canopy gaps should make for easy commercial operations		Very easy to implement with only a few legacy trees to work around	
		as more trees blow down and hazards increase, may face public complaints regarding		Chainsaw and small equipment will make hang-up removal slow	Processor or feller-buncher will eliminate any hung-up tree problems		Processor or feller-buncher will eliminate any hung-up tree problems		Processor or feller-buncher will eliminate any hung-up tree problems			

		the state of the declining forest and safety concerns										
vi. Volume harvested	no need to accommodate harvesting equipment	no volume	Thinning 1 = maybe one truck load of very small timber; Thinning 2 = another truck load - still quite small timber	very minimal merchantable timber	Thinning 1: 20% x 336m3/ha = 67.2 m3 x 4.17ha = 280.2 m3 ; Thinning 2: same as 1= 280.2 m3 ; **Total volume = 560.4 m3**	minimal merchantable timber	Thinning 1: 30% x 336m3/ha = 100.8 m3 x 4.17ha = 420.3 m3 ; Thinning 2: 20% x 336m3/ha = 67.2 m3 x 4.17ha = 280.2 m3 ; **Total volume = 700.5 m3**	minimal merchantable timber	Thinning 1: 30% x 336m3/ha = 100.8 m3 x 4.17ha = 420.3 m3 ; Thinning 2: same as 1 = 420.3m3 ; **Total volume = 840.6m3**	improved marketable volumes	336 m3/ha reduced by 2% for the legacy trees retained; 336 x 0.98= 329.3 x 4.17ha = **1373.2 m3**	
vii. Value of harvest volume	no costs associated with planning or implementing thinning operations	no income from wood products	some income - 35m2 x $20 = $700 X two thinnings = **$1400**	limited value; costs associated with invasive species control, prescription writing, tree marking, tendering, monitoring operations and public safety	Thinning 1: 317.9 m3 x $20 = $5604 ; Thinning 2: assume 10% lower value since few good trees $5604 x 0.90 = $5044; Total for two thinnings = **$10,648**	limited value; costs associated with invasive species control, prescription writing, tree marking, tendering, monitoring operations and public safety	Thinning 1: 420.3m3 x $20 = $8406 ; Thinning 2: assume 10% lower value since few good trees 280.2 x $20 = $5604 x 0.90 = $5044; **Total for two thinnings = $13,450**	limited value; costs associated with invasive species control, prescription writing, tree marking, tendering, monitoring operations and public safety	Thinning 1: 420.3m3 x $20 = $8406; Thinning 2: assume 10% lower value since few good trees 4720.3 x $20 = $8406 x 0.90 = $7565; **Total for two thinnings = $15,971**	limited value; costs associated with invasive species control, prescription writing, tree marking, tendering, monitoring operations, tree planting and public safety	1373.2 m3 x $20 = **$27,464**	highest value return; costs associated with invasive species control, prescription writing, tree marking, tendering, monitoring operations, restoration planning, site preparation, tree planting, tending and public safety

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