MANAGEMENT OF
ICE STORM
DAMAGED STANDS

TREE QUALITY AND VIGOUR • DECISION CRITERIA
SILVICULTURAL PRESCRIPTIONS • EVALUATION METHOD

Québec
MANAGEMENT OF ICE STORM DAMAGED STANDS

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Cover page photo
Severely damaged sugarbush on a rich site, near Kingsey Falls (1998). After two growth seasons, maple tree restoration is slow but encouraging. (Photos: Lina Breton)

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INTRODUCTION

The ice storm that swept over southern Québec from January 5 to 9, 1998, damaged approximately 1.8 million hectares of forests, mostly (92%) privately owned. The level of damage varied, but in some stands it was such that restoration and salvage work are now needed. Aerial surveys suggested that an estimated 567,737 hectares of forests (32% of the total) had been severely damaged. Young forests, which literally collapsed under the weight of the ice, accounted for 73,601 hectares, or 4% of the damaged area (7). Damage was light to moderate in the remaining stands (64% of the area), and the trees will recover naturally in the coming years. A forest survey carried out in the spring of 1998 showed that severely damaged trees accounted for nearly 40% of all standing timber (around 55 m³/ha) in Montérégie, 25% in the Eastern Townships and 19% in the Ottawa Valley (19).

The main concern at this point is salvaging the wood going to waste. However, given the extent of the damage and the large volume of timber at risk, it would be preferable to spread salvage operations over a period of time, to avoid overproduction of timber and saturation of certain markets (19). Possible time frames vary according to species and type of products and we thus have some leeway. For example, it is possible to wait one year, three years or even five years before salvaging timber, depending on whether it will be used for veneering, sawing or pulp or as fuel (5).

It is also important to restore to production any severely damaged stands containing pre-commercial trees or trees with a lower market value. If no action is taken, such stands will have very little chance of recovery, since there are not enough remaining crop trees per hectare to guarantee optimal production of quality timber.

The stability of certain stands, especially tolerant hardwood stands, is also threatened by the severity of the damage. When the forest canopy is reduced, the amount of light penetrating to ground level increases, possibly compromising the survival of young maple trees, especially seedlings², and promoting the growth of undesirable species such as beech, fir, aspen and raspberry. Increased light and heat also heighten the risk of trunk sunscald as well as soil and rootlets drying. It may lead to productivity losses.

Adventitious sprouts and buds may form on the lower part of the crown of damaged hardwoods, which would result in the downgrading of logs earmarked for veneering. In addition, broken main branches allow discoloration and decay fungi to penetrate the tree. The nectria canker, Neonectria galligena (Braz.), Ross. and Sam., can also propagate through small cracks in the bark on the branches and trunks of icefallen yellow birch trees, eventually reducing the quality of the timber (5).

If the stands are to recover, the root systems of the trees must be protected, especially during salvage operations. Before logging begins, the condition of the stand³ and the trees slated for priority salvaging must be assessed as accurately as possible. A survey method

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¹ The figures in brackets refer to the bibliography.
² Current year seedlings, especially sugar maple and yellow birch ones, are the most vulnerable, because they are rooted in the surface layer. To become established and survive, they need a plentiful supply of water and shade.
³ A stand condition assessment establishes tree vigour, which often depends on disturbances prior or subsequent to the ice storm. Tree vigour must be taken into account when selecting the trees to be salvaged in priority, especially if the goal is timber production.
for damaged stands is proposed in this document. By assessing the damage, it is possible to estimate the volume of timber to be harvested for each intended use, and to select the best management method. Such estimates are especially valuable when it comes to marketing the timber, since it may be difficult if not impossible to sell lower quality wood in the short term.

This document conveys important information for the management of ice-damaged stands. The first section contains a glossary that defines the terms as they are used in this document. Subsequent sections explain the basic notions required to assess tree vigour, timber quality and survival chances, and present management guidelines in the form of summary tables as well as simple and practical decision-making keys. The keys have been designed to help forest advisors selecting the best treatment for each stand. The text contains a number of photographs illustrating the most common problems and the long-term impacts observed in sugar-bushes in the Lanaudière region after the 1983 ice storm.

Sugarbush severely damaged by the 1998 ice storm. Maple advance-growth is poor, and the stand has been invaded by hay-scented ferns. If logging is not planned carefully, the ecological stability of the stand will be at risk.
Broken bole

Tree that is broken below the crown or whose bark has been torn off, even if the upper part is still alive (see Appendix 2, Figure 2.4).

Broken leader pruning

Pruning of the leader or the highest or second-highest internode of a crown-damaged conifer. This treatment is performed in plantations to preserve the quality of lumber to be harvested in the future (see sections 2.3.5.4 and 2.4.2).

Applications: This type of pruning, performed with shears, promotes the growth of a lateral branch to replace the lost terminal leader, thus correcting any significant curvature in trees to be preserved as crop trees in the plantation.

Recommendations: This treatment is carried out only on young pre-merchantable trees more than 1.5 m high that will eventually make up the stand.

Coppicing

Operation that consists in cutting back to approximately 5 cm from the ground young leaning or icefallen hardwood trees with a diameter at stump height (dsh) of < 15 cm, either before budbreak or after the leaves have fallen.

Applications: This operation promotes the formation of new stump sprouts. After a year, three sprouts should be selected as close to the ground as possible. The most vigorous stump sprout will finally be kept to become the crop tree (see section 2.4.1).

Recommendations: This treatment is appropriate for hardwood trees, including red maples, oaks, ashes, walnuts and basswoods, which naturally produce stump sprouts after cutting. Good results are not always achieved with yellow birch and sugar maple trees that are more than 10 cm in diameter.

Crop hardwood tree

Straight or slightly leaning tree with a dbh of between 10 cm and 24 cm, that contains at least one defect-free log and will be ready to be harvested in the next logging cycle.

Defective hardwood

A tree with a dbh of ≤ 24 cm, containing no defect-free logs and consequently destined for pulp, heating or pallet production (see section 1, Table 2).

Defective softwood

(a) Mature conifer with heart rot that still contains one saw log and that has to be salvaged quickly due to the high risk of windthrow.

(b) Uprooted, leaning or icefallen conifer containing at least one merchantable log.

(c) Merchantable conifer other than a white or red pine that has been broken at a height where the diameter is > 6 cm and that has to be salvaged due to the high risk of decay. Large crown-damaged or delimbed white and red pines are much less...
likely to deteriorate (see Appendix 4), and should be preserved as seed trees in natural stands or as quality softwoods in plantations. However, they should be harvested in priority during the next thinning cycle.

Icefallen tree
Tree leaning at an angle of more than 70° from the vertical position (see Appendix 2, Figure 2.3).

Improvement cutting
Removal of less desirable or ice-fallen trees in a stand that is past the sapling stage, to improve its composition and quality.

Large seedlings
A hardwood or conifer that is 3 or 4 years old, with an average height of between 40 cm and 60 cm, cultivated in a nursery for use in reforestation.

Recommendations: Large seedlings are used for reforestation of high-quality forest sites and abandoned farm lands where herbaceous competition is strong, as well as to fill in stands that were damaged or destroyed by the ice storm (see sections 2.3.5.4 and 2.4.2).

Leaning tree
Tree bent at an angle of between 30° and 70° (see Appendix 2, Figure 2.2). If the angle is greater than 40°, the tree has no chance of returning to a vertical position, especially if epicormic sprouts have formed on the trunk.

Lopping and scattering
This operation involves reducing the fallen branches to chips which are spread over the ground as evenly as possible. It is beneficial for the residual stand, since it improves soil quality and stimulates the growth of microflora and microfauna (see section 2.4.1).

Mini-strip cutting
This type of harvest is carried out on abandoned farm lands and in young stands damaged or destroyed by the ice storm, prior to reforestation with commercial hardwoods.

Recommendations: Strips 4 m wide and 8 m apart are clear-cut in an east-west direction. Hardwood or white pine seedlings are then planted along the northern side of the strips, where they obtain maximum sunlight and have a better chance of dominating the competing vegetation.

Sugarbush severely damaged by the 1998 ice storm, where the wood at risk should be partially salvaged. Tree recovery should be monitored. In this case, logging should be spread over a period of time, and the fate of the stand should not be decided too quickly.
Partial salvage cutting

Operation in which only dead and very weak trees are harvested in moderately damaged, average density stands and in severely damaged dense stands (priorities 1, 2, 3, 4 and 5 from Table 5).

Applications: The residual stand faces an uncertain future, and should have a basal area of at least 12 m$^2$/hectare. This threshold may be extended to 16 m$^2$/hectare for certain types of stand (see sections 2.3.1, 2.3.2 and 2.3.3).

Recommendations: If the number of trees to be salvaged in priority is such that the stand basal area would fall below the minimum recommended threshold, salvage operations should be limited to the most severely damaged sectors only. Salvaging of dead trees should also be spread over a longer period, and, in the short term, only hauling trails should be cleared, opening up access to the whole stand. This helps limit machinery movements and potential injury to the lower part of the bole and the roots of residual trees. Salvage operations should also be spread over a longer period if the markets become saturated (9). If the trees have survived this long, it is possible to wait for a few more years in order to make an informed decision regarding the management of severely damaged stands, whose recovery depends on the age and vigour of the trees and on the quality of the site.

Quality hardwood

A tree containing at least one defect-free log (see section 1, Table 2). A quality tree has the following features (1):

- dbh of $\geq$ 24 cm
- total length of $\geq$ 1.8 m
- volume reduction due to defects, estimated on the next-to-last quality face, of 60% or less
- Length of the defect-free next-to-last quality face $\geq$ 60 cm.

Quality softwood

(a) Healthy conifer or conifer with no obvious signs of decay, containing at least one saw log.

(b) Conifer broken at a height where the bole diameter was less than 6 cm and that is less likely to deteriorate as a result of decay.

(c) Young softwood grown in a plantation, straight or bent over to an angle of less than 30°, broken under the leader or the highest or second-highest internode, but that nevertheless has a good chance of recovering and maintaining its quality for lumber production (see section 2.3.5.4).

Residual crown

The portion of the crown that survived the 1998 ice storm. It is estimated visually, based on the number of twigs and adventitious branches that have grown since the storm (see Appendix 1).

Sanitation cutting

Treatment that consists in cutting down dead, dying and severely damaged trees in order to prevent infestations of secondary insects, discoloration and decay fungi, and other diseases such as nectria canker (Neonectria galligena (Bres.) Ross. and Sam.).

Applications: This type of treatment should be carried out in moderately damaged stands where trees likely to deteriorate before the next logging cycle account for no more than 30% of the stand basal area. The volume of timber to be harvested is generally low ($\leq$ 20 m$^3$/hectare).

Recommendations: Whenever possible, $\leq$ 20% of the initial stand basal area should be harvested, following the priority order shown in Table 5 (section 2.2).
and in accordance with the appropriate minimum density threshold for the type of stand involved (20 m$^2$/hectare or 22 m$^2$/hectare, see section 3.4).

**Severe bole wound**

A wound is said to be severe if the sapwood is exposed over more than 25% of the tree’s circumference (more than one exposed face). If the sapwood is exposed over 50% of the circumference, this counts as two severe bole wounds (or two exposed faces), etc. Where branches have been broken off 30 cm or less from the bole, the diameter of the stub is calculated as a percentage of the bole’s circumference, at the point of attachment (see Appendix 3).

**Severely damaged stand**

Woodlot all or part of which was severely damaged by the ice storm and which contains wood at risk. A tolerant hardwood stand is severely damaged if the weak hardwood basal area (BA) is $\leq 30\%$ (see sections 2.3.1, 2.3.2 and 2.3.3). In the case of transition stands, 30% of the BA must be composed of weak aspens (see section 2.3.5.1) and, in the case of softwood stands, a similar percentage must be composed of defective trees (crown-damaged trees) (see section 2.3.5.3). Lastly, in mixed stands, 30% or more of the BA should be composed of aspens or other weak hardwoods and of crown-damaged or defective softwoods (see section 2.3.4).

Recommendations: Woodlot owners whose trees were severely damaged may obtain technical assistance (timber marking and logging) for the salvage of commercially valuable wood at risk and restoration of their woodlots.

**Shelterwood cutting**

This involves, in the first instance, harvesting between 30% and 50% of the total volume of timber from a given site in order to encourage the growth of a new stand of equal or superior quality.

Applications: This type of cutting is suitable where portions of stands have been destroyed or severely damaged and are not regenerating properly. It should be applied only in sugarbushes, other tolerant hardwood stands (see sections 2.3.1 and 2.3.3), and conifer stands in which significant portions of the canopy have been destroyed (see section 2.3.5.3).

Recommendations: This treatment can be applied evenly to the whole of the damaged area, or to patches in evenly-structured stands where severe damage is limited to certain well-defined areas.

**Soil amendment**

Spreading of fertilizers, ash, lime or sludge on the ground, to help dying trees.

Recommendations: This type of intervention is not recommended in the first three years, first because it is not necessary (see section 2.4.1), and second because an amendment carried...
out without a chemical analysis of the soil and leaves may actually be harmful to the trees and to the stand as a whole (15).

**Straight tree**

Tree that is vertical or leaning at an angle of less than 30° (see Appendix 2, Figure 2.1).

**Total salvage cutting with advance-growth protection**

This operation consists in harvesting merchantable timber while providing the best possible protection for young trees of desirable species in stands destroyed by the ice storm. The trees left standing should be evenly spaced and sufficiently plentiful for the site to be restored to production quickly.

**Applications:** This treatment is suitable for tolerant hardwood stands, maple stands, mixed stands and softwood stands in which advance-growth is sufficient and evenly distributed.

**Recommendations:** Care is required here, especially in young stands on good sites. Although the damage may be severe, forest advisors may suggest a partial salvage cut and then monitor the stand’s development over a number of years. Total salvage cutting should only be recommended if the trees show no signs of recovery after that period (see section 1.2, Table 4, and section 2.3.3.2).

**Trimming**

An operation that involves removing broken branches and pruning branches that pose a threat to the safety of human beings or property.

**Recommendations:** For economic reasons, systematic trimming is not recommended, except where the trees are located along roads or near constructions. Crown wounds are not exposed to moisture, and thus, do not promote decay. However, scratches on the lower part of the trunk or the roots are conducive to fungal growth.

![Sector of a young sugarbush destroyed by ice. The advance growth must be protected when salvaging the timber.](image)
infections (4) (5). Heavy equipment can also cause serious damage to the shallow roots of maple trees, especially where the ground is soaked (9) (see section 2.4.1).

**Two-step total salvage cutting**

This operation involves, in the first instance, harvesting at least 50% of the wood at risk (dead or dying trees, residual crown $\leq 10\%$, and uprooted or icefallen trees), and then waiting at least five years before the final cutting.

**Applications:** This type of salvage cutting should be applied only in hardwood stands with a high percentage of severely damaged or dead red maple trees, where trees that have retained more than 20% of their branches account for less than $16 \text{ m}^2$/hectare (see section 2.3.2).

**Recommendations:** The two-step total salvage cutting allows the wood at risk to be sold over a period of time, thus preventing market saturation, especially for low quality timber. The rest of the stand is harvested once the market capacity has been confirmed. Dead trees can always be sold for heating purposes, even if their bark has become detached.

**Unsalvageable hardwood**

(a) Young, severely leaning or icefallen tree of pre-commercial size.

(b) Weak, pulp-quality hardwood that cannot be salvaged profitably.

**Unsalvageable softwood**

(a) Mature softwood with heart rot, containing no saw logs or pulp logs.

(b) Young uprooted, leaning or icefallen pre-merchantable conifer, grown in a plantation.

(c) Young conifer broken under the second-highest internode or at a height of $\leq 2.5 \text{ m}$ (see section 2.3.5.4).

**Viable tree**

Ice-damaged tree whose short-term survival is not threatened (see section 1.2, Table 4).

**Vigorous aspen**

An aspen that has retained $\geq 60\%$ of its crown. The threshold is high because decay can cause the timber to deteriorate quickly, especially where the bole has been severely damaged (see section 1, Table 2 and Appendix 4).

**Vigorous hardwood**

A tree other than an aspen that has retained $\geq 20\%$ of its crown and whose bole is either straight or leaning slightly, with no more than one significant wound. Such trees are likely to survive and produce lumber in the next logging cycle (see Appendices 1 and 3, and Figures 2.1 and 2.2 in Appendix 2).

**Weak aspen**

(a) Aspen that has retained less than 60% of its crown or with at least two significant bole wounds, unhealed cracks, cankers, heart rot fungi or root rot fungi.

(b) Uprooted tree, severely leaning tree, icefallen tree or a tree broken below the crown that is likely to die in the short term. Growth and quality will decline considerably in the coming years.

---

4 The normal interval between thinning may have to be extended from 15 to 20 years, to ensure that the volume harvested does not exceed the periodic increment. For the sugar maple, the current annual increment in terms of basal area varies from 1.7% to 2.6% (10).
Weak hardwood

(a) Tree other than an aspen that has retained less than 20% of its crown or with at least two severe bole wounds, unhealed cracks, cankers, heart rot fungi or root rot fungi.

(b) Uprooted tree, icefallen tree or a tree broken below the crown that is likely to die in the short term, or a dying tree that has retained less than 20% of its crown. A weak hardwood will grow very slowly in the coming years, and may even die before the next cutting cycle. It will provide poor quality timber if harvesting is delayed.

Wood at risk

Wood from merchantable hardwoods and softwoods that were killed or weakened by the ice storm. In salvage logging, the dead and dying trees should be harvested first, but decisions regarding the fate of the trees that have survived but face an uncertain future should be postponed. Robust crop trees and quality trees should be protected (see Tables 4 and 5).
1.1 STEM CLASSIFICATION

The method used to classify hardwood and softwood trees damaged by the ice storm is derived from the method currently used for selection cutting in hardwood stands (11), based on tree vigour and quality (Table 1). As we know, the ice storm inflicted significant crown damage and, in some cases, caused severe wounds to tree boles, thus reducing both vigour and quality.

A tree’s ability to recover from its wounds depends not only on the severity of the damage, but also on its pre-storm vigour. The classification shown in Table 2 allows for adjustment of current vigour and quality according to the damage suffered as a result of the ice storm. It can therefore be used to classify trees when surveying a damaged stand or selecting trees which should be harvested first.

### TABLE 1  STEM CLASSIFICATION BY VIGOUR AND QUALITY

<table>
<thead>
<tr>
<th>VIGOROUS HARDWOOD</th>
<th>WEAK HARDWOOD</th>
<th>SOFTWOOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>Defective</td>
<td>Quality</td>
</tr>
<tr>
<td>CLASSES</td>
<td>I</td>
<td>II</td>
</tr>
</tbody>
</table>

Grade I yellow birch downgraded following the 1998 ice storm (category III s) and to be salvaged in priority.

Grade I sugar maple to be preserved as crop tree despite severe damage suffered in 1998.
### Table 2: Loss of Vigour and Quality in Ice-Damaged Trees

<table>
<thead>
<tr>
<th>Description of Damage</th>
<th>Vigour Before Ice Storm</th>
<th>Vigour After Ice Storm</th>
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<tbody>
<tr>
<td><strong>Crown:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residual crown</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Abundance of twigs</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bole:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deformation</td>
<td>Straight or leaning</td>
<td>Straight or leaning</td>
</tr>
<tr>
<td></td>
<td>Icefallen or uprooted</td>
<td>Broken under the crown</td>
</tr>
<tr>
<td>Wounds % of circumference</td>
<td>None</td>
<td>≤ 25% (one face)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 25% (2 faces or more)</td>
</tr>
<tr>
<td>Broken top diam. ≥ 6 cm (softwood)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
</tr>
</tbody>
</table>

#### Description of Damage

- **Vigour Before Ice Storm:**
  - Quality hardwood I
  - Quality aspen I
  - Defective hardwood II
  - Quality hardwood III
  - Defective hardwood IV
  - Quality softwood V
  - Quality V pine
  - Defective softwood VI

- **Vigour After Ice Storm:**
  - Quality hardwood I
  - Quality aspen I
  - Defective hardwood II
  - Quality hardwood III
  - Defective hardwood IV
  - Quality softwood V
  - Quality V pine
  - Defective softwood VI

#### Notes:

- Birch, aspen and softwood trees for priority salvaging. The vigour of straight class V red and white pine trees that have retained ≥ 20% of their crown is not reduced since their quality for lumber production is not at risk.
- In the case of severely leaning or icefallen trees, the updated vigour classes are the same regardless of the percentage of residual crown.
A grid is also used to classify standing hardwoods by lumber production potential. The on-site procedure used to establish tree vigour and stand potential is summarized in Figure 1, which combines the notions presented in Tables 1 and 2 as well as in Appendices 1, 2 and 3. Forest advisors should also consult the guide entitled Classification des tiges d’essences feuillues - normes techniques (1). The proposed system can be used to classify stems according to their quality (A, B, C or D), and to calculate gross timber volume depending on whether the logs are intended for veneering, sawing or pulping.

**FIGURE 1** KEY FOR CLASSIFYING HARDWOOD STEMS BY VIGOUR AND QUALITY

---

5 It should be remembered that logs measuring 24 cm at the small end qualify for veneering, and those measuring about 35 cm at the small end are generally of the best quality. Good cross-cutting can eliminate certain defects to allow the logs to meet standards. Yellow birch, white birch, trembling aspen, sugar maple, black cherry, white ash and American basswood are the main species sought by the industry.
1.2 SEVERITY OF DAMAGE AND RISK OF TREE MORTALITY

The staff at the Ministère des Ressources naturelles has created a network for monitoring the development of sugarbushes damaged by the January 1998 ice storm. The network is composed of 67 circular plots measuring 0.04 hectares each, distributed throughout the affected regions and representative of the different levels of damage. They were selected to:

- establish the relationship between damage measurements obtained on the ground and those obtained from aerial surveys;
- measure the effects of the ice storm on the growth and vigour of trees, saplings and seedlings;
- estimate the anticipated short and medium term tree mortality rate;
- establish the ecological characteristics favourable to the recovery of sugarbushes and other tolerant hardwood stands;
- validate proposed silvicultural treatments to promote woodlot recovery.

A preliminary analysis of data obtained from the network was used to establish four sugarbush mortality scenarios. The hypothesis is that a tree’s resistance to an ice storm can be expressed as a percentage of the critical residual crown (%CRC) or the threshold below which the tree is unable to recover properly. In other words, the percentage of residual crown provides a visible indicator of vitality, where the critical value varies according to conditions in the tree’s environment.

For example, a young maple tree growing on a rich and nutritious site will probably recover even if it had a residual crown of only 20% in 1998. On the other hand, an old maple tree growing in shallow, dry soil would be likely to die even if it retained 40% of its crown. The four scenarios are illustrated in the form of mathematical models in Figure 2. Each polynomial curve represents the anticipated mortality rate according to our hypothesis, where the tree has ≤ 40, ≤ 30, ≤ 20 and ≤ 10% of critical residual crown (%CRC).

The curves show the relationship between the percentage of maple trees likely to die (M%) and the average percentage of canopy lost in the stand (%Cl= 100% - % of residual canopy).

Two years after the ice storm, it is clear that the severely damaged maple trees are in a stable although critical condition. The mortality scenarios based on the ≤ 40% and ≤ 30% critical residual crown thresholds are applicable mainly to stands on sites that are less suitable for sugar maples, such as steep slopes and mountain tops. On such sites the harmful effects of the ice storm will be felt in the medium and longer terms. However, the mortality simulations based on the ≤ 20% and ≤ 10% critical residual crown thresholds paint a realistic picture of the anticipated short-term effects in well-situated sugarbushes. Indeed, the actual mortality rates recorded in 1999 are not significantly different from those produced by the ≤ 10% CRC model (Figure 2).
Table 3, constructed from the results of Figure 2, establishes a relationship between the anticipated mortality rate and the level of damage suffered by a stand. Generally speaking, significant salvage work will be required in heavily damaged tolerant hardwood stands (61% to 80% of crown loss), where 45% to 57% of the trees are likely to deteriorate or die in the coming years. In severely damaged sugarbushes where the trees lost ≥80% of their branches, between 77% and 94% of the trees are actually at risk. In moderately damaged stands, however, only 22% to 28% of the trees have deteriorated, and the figure drops to ≤10% in lightly damaged stands.

In addition, it should be remembered that the damage suffered by 64% of the forests affected by the 1998 ice storm varied from “slight” to “moderate” (6). As we will see later (section 2.3), salvage of wood at risk is not profitable in slightly or moderately damaged stands, especially when they contain a high percentage of pulpwood, and forest advisors should inform producers of this fact before any work is undertaken.

In light of the data currently available, it is still difficult to determine how trees that were severely damaged in January 1998 will react in the next few years.
Crown-damaged trees, especially sugar maples, are recovering slowly, and will need many years to rebuild completely. The data that will be collected in the next five years will be used to validate the preliminary results shown in Table 3. However, visual vitality indicators can be used in the short term to distinguish dead and dying trees from trees that have a chance of surviving in the longer term. Forest advisors responsible for assessing damage and selecting trees for salvage can base their calculations on the Table 4 data, especially when marking trees for priority harvesting.

![Severely damaged maple trees that survived the 1983 ice storm have produced epicormic sprouts and adventitious branches, especially at the base of the crown. When marking, these indicators of vitality can be used to distinguish between trees to be harvested and those to be left standing.](photo: Bruno Boulet, MRN)

### TABLE 3 MORTALITY RATE OF MAPLE TREES BY LEVEL OF DAMAGE IN 1998

<table>
<thead>
<tr>
<th>SEVERITY OF DAMAGE</th>
<th>MORTALITY RATE OF MAPLE TREES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CRITICAL RESIDUAL CROWN</td>
</tr>
<tr>
<td></td>
<td>≤ 40%</td>
</tr>
<tr>
<td>CATEGORY</td>
<td>QUALITY OF SITE</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td>SLIGHT</td>
<td>≤ 20%</td>
</tr>
<tr>
<td>LIGHT</td>
<td>21% - 40%</td>
</tr>
<tr>
<td>MODERATE</td>
<td>41% - 60%</td>
</tr>
<tr>
<td>HEAVY</td>
<td>61% - 80%</td>
</tr>
<tr>
<td>SEVERE</td>
<td>&gt; 80%</td>
</tr>
</tbody>
</table>

1 Most likely mortality rate in sugarbushes in the short (2 years)** and medium (5 years)* terms, and probably in other tolerant hardwood stands too.
### Table 4: Visible Indicators of Vitality and Probable Recovery in Ice-Damaged Trees

<table>
<thead>
<tr>
<th></th>
<th>Dead Trees</th>
<th>Weak Trees</th>
<th>Living Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td></td>
<td>Less than 20% of residual crown (&lt; 60% for aspen)</td>
<td>All trees that are not dead or weak are considered to be vigorous or quality trees</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dying Trees</td>
<td>Viable Trees</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Uprooted or icefallen trees</td>
<td>- Slightly leaning trees (angle of 30° to 40°)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Severely leaning trees (&gt; 40°)</td>
<td>- Trees wounded on one face of the bole</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Trees wounded on two faces of the bole and considered vulnerable to decay, including red maples and beech</td>
<td>- Sugar maples less than 40 years old, growing on good sites</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Trees broken below the crown</td>
<td>- Species known to be resistant to crown loss, such as the basswood, ash, oak, black cherry, etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Trees damaged by canker and decay fungus</td>
<td>- Mature white and red pine trees with severe crown loss</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Softwoods with crown damage at a level where the diameter is &gt; 6 cm</td>
<td>- Dying trees that have lost part of their bark</td>
</tr>
<tr>
<td><strong>Visible vitality:</strong></td>
<td>No crown</td>
<td>No recovery in the crown</td>
<td>Presence of adventitious sprouts and epicormic twigs in the crown or on the bole</td>
</tr>
<tr>
<td><strong>Healing of taps:</strong></td>
<td>Nil</td>
<td>Very slow (&gt; 8 years)</td>
<td>Slow (5 to 8 years)</td>
</tr>
<tr>
<td><strong>Companion species:</strong></td>
<td>No stump sprouts</td>
<td>Sometimes numerous stump sprouts</td>
<td>Presence of stump sprouts</td>
</tr>
<tr>
<td><strong>Probability of recovery:</strong></td>
<td>Nil</td>
<td>Weak</td>
<td>Variable depending on the quality of the site</td>
</tr>
<tr>
<td><strong>Root rot:</strong></td>
<td>High risk</td>
<td>High risk</td>
<td>Moderate to low risk</td>
</tr>
<tr>
<td><strong>Timber downgrading:</strong></td>
<td>High risk</td>
<td>Moderate to low risk</td>
<td>No risk</td>
</tr>
<tr>
<td><strong>Life expectancy:</strong></td>
<td>None</td>
<td>&lt; 5 years</td>
<td>&gt; 5 years</td>
</tr>
<tr>
<td><strong>Wood at risk:</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Variable depending on the quality of the site</td>
</tr>
<tr>
<td><strong>Timber to be harvested in priority:</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Salvage period:</strong></td>
<td>Short-term</td>
<td>Variable</td>
<td>Long-term</td>
</tr>
<tr>
<td></td>
<td>Medium-term (maple sugar production)</td>
<td>Variable</td>
<td></td>
</tr>
</tbody>
</table>
they serve as a pretext for converting stands with timber or maple potential into agricultural land, even if they are low in density and poor in quality, or contain less valuable species such as grey birch or red maple from stump sprouts. The Act to protect agricultural land and agricultural activities\(^6\) contains certain provisions concerning sugarbushes. The Commission de protection du territoire agricole has been required, since 1978, to preserve sugarbushes in order to maintain maple production activities for the benefit of future generations. In particular, the Act states that “No person may, except with the authorization of the Commission, use a sugarbush situated in a designated agricultural region for any other purpose, nor fell maple trees there, except for the purpose of selection or thinning within the framework of forest management” (1978, c. 10, s. 27).

Producers, assisted by forest advisors, must do all they can to restore damaged stands, to preserve biological diversity, and to ensure adequate regeneration of stands in which salvage work is required.

The silvicultural work proposed in this document has been adopted to avoid compromising stand health. Excessive thinning of the canopy can reduce the vigour of residual trees and affect maple sap production, causing tree quality to decline and altering the stand’s natural development. A more plentiful supply of light may promote the growth of intolerant species that will compete with sugar maple seedlings and other high-value hardwoods. The quality trees will also be vulnerable to sunscald, the ratio crown/bole may become

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greater or they may be attacked by the sugar-maple borer, Glycobius speciosus (Say), and bole or root rot fungi including Cerrena unicolor (Bull.:Fr) Murr. and Armillaria ostoyæ (Romag.) Herink (6) (9). If the residual density falls below a certain critical threshold, the trees are weakened and both stand stability and soil quality are compromised (11). It is therefore important to comply with the recommended density thresholds for each stand. The density thresholds, expressed as the basal area of trees with a dbh of \( \geq 9.1 \) cm, are the best indicators at our disposal for estimating probable stand recovery (see the summary tables in section 2.3).

There are fewer restrictions on salvage and management work in high-density stands that have suffered only moderate damage. However, there is much less flexibility in severely damaged stands with a low initial density, since only dead trees can be salvaged over short rotations (from 3 to 5 years). Excessive logging may well cause more harm to the stand than the ice storm. Indeed, it is often best to leave the poor quality trees standing, since they will help restore the stand. If they are cut indiscriminately, tree vigour may be reduced, stand structure may be altered, and stand survival may actually be threatened, especially for sugarbushes.

### 2.2 Salvage Priorities

The process of salvaging ice-damaged trees must be planned very carefully, in particular to avoid wasting the resource and placing additional stress on the surviving trees, thus compromising maple sap or lumber production in sugarbushes and other stands. Salvage priority is established according to the risk of downgrading the various species, the amount of debris hindering access to the forest, the quality and value of the trees to be salvaged, and marketing considerations.

In general, it is best to salvage sawing logs (priority 7) before icefallen or severely leaning pulp quality trees (priority 8). However, on some sites this priority order will need to be reversed, so that machinery can circulate freely in the forest. Even so, before salvaging weak trees for pulpwood (priorities 6, 7 and 10 in Table 5), foresters should always ensure that the wood can...
be sold on markets that might well become saturated, at least temporarily, in the coming years. Otherwise, the resource may be wasted. Table 5, which presents a priority order for salvage operations, can be used as a guide during marking.

It is important to remember that the order proposed in the table will vary depending on the production objectives and the situation of the woodlot owner. Forest advisors should remember, among other things, that maple producers may decide to sacrifice a certain amount of maple lumber in order to preserve as many taps as possible. Such a choice is perfectly justified from a maple production standpoint (see section 2.3.3.1). Marking will therefore differ from one sugarbush to the next, depending on the type of production required. However, post-salvage stand density must always be sufficient to preserve vigour and allow for regeneration by desirable species.

Dead yellow birch and white birch trees lose their value quickly, because the sapwood changes colour when humidity levels drop (4). They should therefore be salvaged first, and processed immediately. Sugar maples and companion species, however, maintain their value for a much longer period, and salvage operations can wait at least a year. In the case of weak hardwoods that have retained 20% or less of their crowns, saw quality trees with significant wounds to the bole or base of the crown should be salvaged first, before they are attacked by discoloration fungi. It should be remembered that only fungal sap-stain is a threat in the short term, and that heartwood defects (brown-stain or decay) are not due to the 1998 ice storm. In addition, the large number of branches developing at the base of severely damaged yellow birch crowns will eventually be detrimental to veneer quality.

Generally speaking, trees that were weakened can be left standing as long as their cambium is still alive and humidity levels remain high. They should be ranked for salvage based on their species, age, residual crown and wounds. Young trees are more vigorous and resistant than older trees, and companion species such as white ash, red oak, butternut, bitternut hickory, black cherry and American basswood have a better chance of survival than the sugar maple, even if they are severely damaged.

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Generally speaking, trees that were weakened can be left standing as long as their cambium is still alive and humidity levels remain high. They should be ranked for salvage based on their species, age, residual crown and wounds. Young trees are more vigorous and resistant than older trees, and companion species such as white ash, red oak, butternut, bitternut hickory, black cherry and American basswood have a better chance of survival than the sugar maple, even if they are severely damaged. Indeed, it should be remembered that the species most vulnerable to ice damage are also those that are best able to rebuild their crowns. However, the aspens and birches are more susceptible to sap-stain and decay fungi than the other hardwoods. Weak aspens are also undesirable as seed trees, especially in...
sugarbushes, and they should therefore be harvested first. Crown-damaged conifers including fir, spruce, larch, jack pine, hemlock and cedar, are much more susceptible to attacks by the pine sawyer and decay fungi than large white pine and red pine trees (see Appendix 4). These latter, even when they have lost some of their branches or part of their crowns, continue to be good seed trees and should be preserved in damaged natural forests. Ice damage should therefore not be used as an excuse to cut down pine trees that have not reached maturity, except in very severely damaged plantations where surviving trees are insufficient in number and thus susceptible to windthrow (see section 2.3.5.4).

Icefallen or severely leaning trees are likely to die or deteriorate in the medium term, even if their crowns are intact. Young birch trees are especially vulnerable. However, trees of other species will survive in good condition for several years, because their crowns are generally not in contact with the ground and they create shade, preventing the ground from drying out and protecting the seedlings from sunscald. Since they are rarely large enough for lumber production, they can be salvaged later as pulpwood or fuelwood.

### 2.3 SILVICULTURAL WORK IN DAMAGED STANDS

The summary tables and logic diagrams in this section show the different silvicultural treatments and variants for hardwood, mixed and softwood merchantable (even-aged plantations and natural stands) or non-merchantable (uneven-aged stands) stands, and for young pre-merchantable stands. In merchantable stands, specific density thresholds should be applied, so as:

- to preserve the vigour and quality of the residual trees;
- to ensure the stand’s ecological stability;
- to avoid leaching of certain chemical elements from the soil;
- to reduce the risk of windthrow;
- to stimulate regeneration of desired species, thus promoting the restoration of production to the site;
- to ensure sustainable development.

#### TABLE 5  SALVAGE PRIORITY ORDER IN ICE-DAMAGED STANDS

1. Dead saw quality yellow or white birch trees, whether standing or uprooted.
2. Dead saw quality trees of other species, whether standing or uprooted.
3. Dead pulp quality trees, whether standing or uprooted.
4. Weak saw quality yellow or white birch trees.
5. Weak saw quality aspens.
6. Weak pulp quality aspens.
7. Weak saw quality trees of other species.
8. Living pulp quality icefallen or severely leaning trees (see Appendix 2).
10. Weak pulp quality hardwoods other than yellow birch trees.
DID YOU KNOW?

In sugarbushes, salvage work should ideally be carried out in the winter, to protect advance growth and tree roots. Heavy machinery should not circulate in the forest during the fall rainy season or in early spring, to avoid rutting. Advance-growth should also be protected by spacing out machinery tracks (see also sections 2.3.2 and 2.3.4 for red maple and mixed stands).

For example, Figure 3 shows the best type of harvesting for certain tolerant hardwood stands, depending on the basal area to be preserved. These recommendations are explained in detail in sections 2.3.1, 2.3.2 and 2.3.3. Section 2.3.4 examines mixed stands, and section 2.3.5 examines transition hardwood stands, pre-merchantable stands, plantations and conifer forests.

FIGURE 3 HARVESTING METHODS RECOMMENDED BY BASAL AREA TO BE PRESERVED IN TOLERANT HARDWOOD STANDS

<table>
<thead>
<tr>
<th>TYPE OF STAND</th>
<th>BASAL AREA TO BE PRESERVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOLERANT HARDWOODS</td>
<td>12 m²/ha</td>
</tr>
<tr>
<td>MANAGED FOR LUMBER PRODUCTION</td>
<td>Shelterwood cutting or total salvage cutting with protection of advance-growth</td>
</tr>
<tr>
<td>RED MAPLES</td>
<td>Two-step total salvage cutting</td>
</tr>
<tr>
<td>MAPLE STANDS MANAGED FOR SAP PRODUCTION</td>
<td>Shelterwood cutting or total salvage cutting with protection of advance-growth</td>
</tr>
</tbody>
</table>
2.3.1 Tolerant hardwood stands (other than red maple)

Instructions concerning the best silvicultural treatments for each type of tolerant hardwood stand are summarized in the following pages, in the form of easy-to-consult synoptic tables. Figure 4, for example, indicates the best harvesting methods according to the basal area to be preserved in tolerant hardwood stands (other than red maple) managed for lumber production. Sanitation cutting is recommended in lightly or moderately damaged stands, and shelterwood cutting or total salvage cutting with protection of advance-growth is recommended in stands destroyed by the ice storm. The future of stands in which the basal area of living trees varies from 14 m²/ha to 20 m²/ha is uncertain; some of the dead or dying trees should be salvaged first, and the development of the surviving trees should then be monitored for a period of five years before making a final decision. The recommendations in Figure 4 also apply to other types of hardwood stands, although the basal area requirements for living trees differ (see Figure 3 and sections 2.3.2 and 2.3.3).

FIGURE 4 DECISION KEY FOR MANAGING MERCHANTABLE TOLERANT HARDWOOD STANDS

Sanitation cutting
Leave more than 20 m²/ha

Basal area to be preserved
> 20 m²/ha

< 14 m²/ha

Partial salvage
Initially, salvage only the dead and weaker trees, then monitor the situation for 5 years.

Shelterwood cutting or total salvage cutting with protection of advance-growth

from 14 m²/ha to 20 m²/ha

7 The recommended basal area thresholds are more conservative than those proposed by American authors who believe that hardwoods not damaged by ice can self-prune properly after partial cutting when the residual density varies from 16 m²/ha to 18 m²/ha.

Sugarbush heavily damaged in 1998 where total salvage cutting with advance-growth protection is required.
<table>
<thead>
<tr>
<th>SEVERITY OF DAMAGE</th>
<th>DESCRIPTION</th>
<th>RECOMMENDED SILVICULTURAL TREATMENTS</th>
</tr>
</thead>
</table>
| SLIGHT            | • ≥ 80% of crown intact  
                    • Not enough trees for salvage to justify harvesting | No intervention required  
                    • Review marking if selection cutting or thinning is planned |
| LIGHT OR MODERATE | • Medium to high density stands where the trees have retained 40% to 80% of their crowns  
                    • Not enough trees for salvage to make harvesting profitable (less than 20 m³/ha) (see Table 3)  
                    • Living trees ≥ 20 m³/ha  
                    • Enough vigourous or quality trees (200-400/ha) based on the site’s quality | Sanitation cutting  
                    • Leave ≥ 20 m³/ha  
                    • Salvage < 20% of the initial basal area  
                    • These stands should retain their timber production potential  
                    • The maple production potential of young stands will remain at an acceptable level if ≥ 150 taps per hectare can be installed (see section 2.3.3.1)³. |
| HEAVY             | • Medium to high density stands where the trees have retained 40% or less of their crowns  
                    • Dead or weak trees represent ≥ 30% of the initial basal area  
                    • Dead or weak trees generally represent > 20 m³/ha, except in low density stands  
                    • Living trees represent between 14 m³ and 20 m³/ha | Partial salvage cutting⁹  
                    • Salvage only dead trees and weaker saw-timber quality trees  
                    • These stands face an uncertain future, depending on the quality of the site, the vigour of the trees, their age, and so on  
                    • Take follow-up action after 3 years to check the amount of advance-growth and the condition of the residual trees |
| SEVERE            | • Stands in which extensive salvage work is required  
                    • Stands where the trees have retained less than 20% of their crowns  
                    • Living trees represent less than 14 m³/ha, except in young stands  
                    • The surviving trees will produce poor quality timber, and the stand must be regenerated | Total salvage cutting with protection of advance-growth  
                    • Shelterwood cutting⁹  
                    • Recover deteriorating saw-timber quality trees first  
                    • Assess advance-growth density  
                    • Wait at least 5 years before salvaging the residual stand  
                    • Consult section 2.3.3.2 to select the best restoration method  
                    • Protect soil and advance-growth during logging operations |

³ If young hardwoods such as the yellow birch have been downed or are severely leaning, they should be returned to an upright position and then staked or supported (especially if they are growing in bare patches created by the removal of older trees), otherwise they will die. Saplings leaning at an angle of less than 45° should recover on their own in the coming years. Young beech trees, especially those grown from root suckers, should be cut to leave more room for other companion species (see section 2.3.5.2).

⁹ Partial salvage, total salvage or shelterwood cutting may be carried out in patches of heterogeneous stands where very severe damage is limited.
2.3.2 Red maple stands

The silvicultural treatments recommended for red maple stands are also suitable for transition stands containing varying numbers of intolerant hardwoods such as aspens or white birch, and for stands containing a significant percentage of fir and yellow birch.

<table>
<thead>
<tr>
<th>SEVERITY OF DAMAGE</th>
<th>DESCRIPTION</th>
<th>RECOMMENDED SILVICULTURAL TREATMENTS</th>
</tr>
</thead>
</table>
| SLIGHT, LIGHT OR MODERATE | • Medium to high density stands where the trees have retained 40% or less of their crowns  
• Dead or weak trees represent ≤ 30% of the basal area  
• Not enough trees (less than 20 m²/ha) for salvage to make harvesting profitable | Partial salvage cutting  
• Leave ≥ 16 m²/ha  
• Recover only dead trees and weaker saw-timber quality trees  
• These stands should retain their production capacity if the site is of good quality\(^{10}\)  
• Take follow-up action after 3 years to check the condition of the residual trees |
| HEAVY | • Medium to high density stands where the trees have retained 20% to 40% of their crowns  
• Dead or weak trees represent ≥ 30% of the basal area  
• Dead or weak trees generally represent ≥ 20 m²/ha, except in low density stands  
• Trees that have retained more than 20% of their crowns represent more than 16 m²/ha  
• There are enough vigorous or quality trees (200-400 trees/ha) based on the quality of the site | Two-step total salvage cutting\(^{11}\)  
• Salvage deteriorating saw-timber quality trees first  
• Wait at least 5 years before salvaging the residual volume, which will be used mainly for pulp and fuel purposes  
• Protect soil and advance-growth during salvage operations  
• Regeneration will come partly from stump sprouts |
| SEvere | • Stand is severely damaged and very extensive salvage work is required  
• Stands where the trees have retained > 20% of their crowns represent < 16 m²/ha  
• It is unlikely that the stand will produce quality trees upon maturity, and it needs to be regenerated  
• Red maple trees are very susceptible to decay and will deteriorate, unless they are under 25 years old | Sanitation cutting, if necessary  
• Review marking if selection cutting is planned |

\(^{10}\) If young red maples have been downed or are severely leaning, they should be cut back, especially if they are growing in bare patches created by the removal of older trees, otherwise they will die. Saplings leaning at an angle of less than 45° should recover on their own over time (see also section 2.3.5.2).

\(^{11}\) Partial salvage, total salvage or shelterwood cutting may be carried out in patches of heterogeneous stands where very severe damage is limited.
### 2.3.3 Maple stands managed for sap production

<table>
<thead>
<tr>
<th>SEVERITY OF DAMAGE</th>
<th>DESCRIPTION</th>
<th>RECOMMENDED SILVICULTURAL TREATMENTS</th>
</tr>
</thead>
</table>
| **SLIGHT**         | - ≥ 80% of residual crown  
|                    | - Not enough trees for salvage to justify harvesting | No intervention required  
|                    | - See the management method that will produce optimal yields in these stands (section 2.3.3.1) |
| **LIGHT OR MODERATE** | - Medium to high density stands where the trees have retained 40% to 80% of their crowns  
|                     | - Not enough trees have been destroyed or are threatened to make harvesting profitable in the short term (see Table 3)  
|                     | - Living trees represent ≥ 22 m²/ha | Sanitation cutting  
|                     | - Leave ≥ 22 m²/ha  
|                     | - Salvage < 20% of the initial basal area |  
|                     | - These stands should retain their sap production potential  
|                     | - See the management method that will produce optimal yields in these stands (sections 2.3.3.1 and 2.4.1) |
| **HEAVY**          | - Medium to high density stands where the trees have generally retained between 20% and 40% of their crowns  
|                    | - Dead or weak trees represent ≥ 30% of the basal area  
|                    | - There are some trees for salvage, but the quality and quantity of lumber varies by age and condition  
|                    | - Living trees represent between 12 m²/ha and 22 m²/ha | Partial salvage cutting  
|                    | - Salvage only dead trees¹²  
|                    | - The future profitability of sap production depends on the quality of the site, the vigour of the trees and the density of the residual stand (see section 2.4.1)  
|                    | - Review the stand’s sap production potential in 3 years’ time (see sections 2.3.3.1 and 2.4.1) |
| **SEVERE**         | - Stands in which extensive salvage work is required  
|                    | - Stands where the trees have retained less than 20% of their crowns  
|                    | - Living trees represent less than 12 m²/ha, except in young stands  
|                    | - The surviving trees will produce poor quality timber, and little sap. | Shelterwood cutting¹³  
|                    | - It is unlikely that such a stand will be profitable in the short term  
|                    | - Assess advance-growth density  
|                    | - Consult section 2.3.3.2 to select the best restoration method  
|                    | - See also section 2.4.1 on tapping methods |

¹² If young sugar maples have been downed or are severely leaning, they should be returned to an upright position and then staked or supported (especially if they are growing in bare patches created by the removal of older trees), otherwise they will die. Sugar maple saplings leaning at an angle of less than 45° should recover on their own in the coming years. Young beech trees, especially those grown from root suckers, should be cut to leave more room for other companion species (see section 2.3.5.2).

¹³ Partial salvage, total salvage or shelterwood cutting may be carried out in patches of heterogeneous stands where very severe damage is limited.
2.3.3.1 Sugarbush management method

To understand the recommended method of restoring damaged sugarbushes, it is useful to have a basic grasp of the management methods generally used in healthy stands. In both cases, there are two main goals, namely to optimize maple sap production and to obtain an acceptable return on the money invested. To achieve this, it is necessary:

1. before intervening, to ensure that the basal area is at least 24 m²/ha, otherwise thinning is not possible;
2. to preserve at least **180 taps/ha when thinning**. However, young sugarbushes are considered to have potential if they allow for at least 150 taps/ha;
3. if there are signs of dieback, if light-tolerant species are present or if there is a shortage of young maple saplings, to preserve a minimum basal area of 20 m²/ha when thinning;
4. to carry out thinning every 10 or 15 years, and to remove ≤ 20% of the basal area, including trees that are accidentally wounded or cut down on the hauling trails;
5. to preserve 10% to 15% of co-dominant companion species, ensuring that they are evenly distributed throughout the sugarbush;
6. to maintain a balanced uneven-aged structure throughout the sugarbush, thus promoting renewal (11) (14);
7. to improve the stand’s productivity by gradually eliminating weak, defective and poorer quality trees, to leave more room for previously crowded crop trees (11);
8. when marking, to pay special attention to:
   - undesirable species;
   - weak or defective trees, i.e. trees in vigour classes 3 and 4 (see Tables 1 and 2).

**DID YOU KNOW?**

The companion species to be retained are mostly tolerant to shade, and include the eastern hemlock, white spruce, ironwood, red oak, American basswood and white ash. Trees of certain semi-tolerant or intolerant species should also be preserved, including the white pine, yellow birch, bitternut hickory, butternut, American elm, hackberry, green ash, bur oak, white oak and black cherry. The climax and semi-climax species described grow naturally in stands that have reached the last successional stages. They do not threaten the stability of sugarbushes (see also Appendix 4).

Sugarbush destroyed by the 1983 ice storm in the Lanaudière region now replaced by the vigourous young hardwoods that were protected during salvage cutting.
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DID YOU KNOW?

In a sugarbush, undesirable species include the balsam fir and transition species such as the trembling aspen and white birch, which threaten the stability of the stand. Beech propagation should also be limited, and this species should not account for more than 20% of the basal area (15).

Maple producers should follow marking rules established according to their priority goals14, by marking, in order:

1. **Undesirable species**, such as balsam fir trees15, which are cut down to ensure the sustainability of the sugarbush and prevent it from deteriorating or evolving into another type of stand in the longer term (15 years)16.

2. **Weak, defective or diseased trees**, which are cut down to eliminate specimens with canker or advanced decay, and especially those whose branches are likely to be broken off by the wind, to guarantee the safety of human beings and property, and to prevent the spread of diseases such as eutypella canker, *Eutypella parasitica* David. & Lorenz.

3. **Invasive companion species** such as the beech, which are partially harvested in order to release young quality maples growing close-by in overcrowded conditions. However, beech trees should not be eliminated systematically, since this would open up the stand too much, stimulating a suckering response and thus threatening the stability of the sugarbush.

4. **Overmature maples**, which are cut down in order to eliminate trees that grow too slowly and yield only small quantities of sap, so as to maintain maple production levels in the longer term. The selection process benefits nearby vigorous and quality trees with good radial growth.

5. Lastly, if the above goals are achieved, **old, still vigorous trees are then marked** to maintain or restore a balanced uneven-aged structure in the sugarbush, thus promoting renewal.

It is important to remember that it is difficult if not impossible to achieve all these goals in a single thinning operation, since it is necessary to harvest ≤ 20% of the initial basal area and preserve a residual density of ≥ 20 m²/ha. Sugarbush improvement is a long-term process that must be carried out in successive steps. Extensive thinning may well modify the structure of the stand, provoke windthrow, expose the trees to insects and diseases such as dieback, and kill young sugar maples. The selection of the trees to be harvested will vary from one sugarbush to the next, according to the structure, composition and density of the stand and the health of the individual trees. Harvesting of overmature or diseased trees considered surplus to requirements in the various diameter categories promotes the growth of crop trees and thus creates openings conducive to regeneration. By making well-calculated, balanced treatments, maple producers can gradually restore their sugarbushes and achieve optimal, sustainable yields.

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14 These rules obviously apply only if the sugarbush was not heavily damaged by the ice storm. Otherwise, the priority order shown in Table 5 should be applied.

15 Eliminating balsam fir trees also reduces the risk of squirrel damage to tubing.

16 Normal life span of tubing used for collecting sap.
2.3.3.2 Restoration of sugarbushes destroyed by the ice storm

Heavily damaged sugarbushes with a basal area of less than 12 m²/ha of surviving trees are likely to disappear completely or deteriorate to such an extent that they are not worth preserving. Stands such as these are considered to have been destroyed. In such cases, silvicultural treatments should be aimed at renewing the stand in the immediate future, or at least avoiding further deterioration of the site.

Total salvage cutting with advance-growth protection is the best method for sugarbushes in which sugar maple and high-value hardwood saplings are present in sufficient numbers and evenly distributed throughout the ice-damaged area. However, this approach is not appropriate and should be avoided if there are not enough sugar maple saplings. In this latter case, shelterwood cutting is recommended.

Total salvage cutting with advance-growth protection is designed to promote the establishment of a new stand equal or superior in quality to the damaged one. The canopy is partially opened to stimulate the growth of maple seedlings and saplings and the establishment of high-value hardwoods such as the American basswood, yellow birch, American ash, red oak and the hickories, which need a plentiful supply of light to become established and grow quickly in the early stages (see Appendix 4).

Harvesting methods are more or less the same in all tolerant hardwood stands. They depend on the abundance and type of advance-growth, which in turn indicates the stand’s level of stability. The methods will differ according to whether the goal is:

- to restore a sugarbush that was destroyed and is not regenerating well;
- to restore a sugarbush that was destroyed but is recovering;
- to restore a sugarbush that was destroyed and has regenerated in species other than the sugar maple.

**Sugarbushes destroyed by the ice storm and not regenerating well**

Regeneration is said to be insufficient if there are fewer than 5,000 viable sugar maple seedlings per hectare in a sugarbush. A sugar maple seedling is viable if it is ≥ 0.5 m high. Smaller seedlings that are suddenly exposed to the sun are likely to die in the coming years due to drought or attacks by the pitted ambrosia beetle, Corthylus punctatissimus Zimm. They should therefore be ignored in the regeneration survey, as should seedlings and saplings of undesirable species, such as balsam fir American beech or red maple. In addition, transition species such as the aspens should not be counted, since they also threaten the stand’s succession and normal development.

Maple stands that do not contain enough sugar maple saplings may not renew adequately, especially if they are dense and still growing and if they are used as browsing areas for cattle. A similar problem may also be encountered in cleared stands used for sap production.

Initially, partial salvage cutting should be carried out to harvest the deteriorating lumber, beginning with the quality trees in accordance with the priority order proposed in Table 5 (see section 2.2). Partial opening of the canopy will stimulate the regeneration of desirable species while ensuring that maple seedlings receive minimum competition from intolerant species and proper protection from drought and sunscald.

Ideally, a total of 50 seed trees per hectare should be left, including companion species. Forest advisors may sometimes suggest a lower figure, especially in stands growing on shallow soil cover on sites
exposed to the wind, since adult trees are likely to fall, die back or deteriorate to such an extent that they will no longer be worth salvaging in the final harvest.

The stability of stands growing on shallow or poorly drained soil is at risk in the short term. If regeneration is insufficient after three years – a situation that is likely to occur on the sites least favourable to the sugar maple – it should be filled in with other high-value hardwoods and white pine trees (10 and 21). The final cut will take place no earlier than five years after the initial treatment, when the new growth has had time to become established. Measures must be taken to protect the future stand during harvesting.

Sugarbushes destroyed by the ice storm and in the process of growing back

Stands containing enough sugar maple saplings, i.e. at least 5,000 viable ones per hectare, including 400 evenly-distributed crop trees, have a good chance of recovery. In stands under reconstruction, new growth will often have become established following dieback, logging or other disturbances prior to the ice storm. The normal succession and stability of such stands is not at risk, and one-step total salvage cuts can therefore be carried out provided the advance-growth is protected. To protect young maple trees, it is best to carry out salvage operations at the beginning of winter, cutting trees at an angle of 20° to 30° from the hauling trails, which should be between 20 m and 30 m apart. If possible, the branches should be removed on the logging site prior to hauling.

Destruction of the forest canopy by the ice will stimulate the growth of young trees in the coming years. Crop trees must therefore be released as soon as they are identified, i.e. when they exceed the regenerating storey, or in approximately 10 years’ time. Screening for young vigorous maple trees is usually carried out during the summer, and the final choice of crop trees is made the following spring based on the sap sugar content, measured using a
refractometer (15). Crop trees should be between 3.5 m and 5.0 m apart, with a clear area of 75 cm around the crown. This allows for between 400 and 800 trees per hectare. Crop trees are selected from saplings with a larger-than-average diameter and height, since the others have little chance of becoming dominant in the new stand (22) (see section 2.3.5.2).

Sugarbushes destroyed by the ice storm and regenerating with species other than the sugar maple

Destroyed stands that are regenerating well, but in species other than the sugar maple, pose the most problems. The time needed for them to resume maple sap production will vary according to the quality of the site. New growth on rapidly drained sites at the top of slopes and poorly drained sites in depressions is usually composed of American beech, red maple and intolerant hardwoods. Dry sites are often invaded by raspberry plants, including Rubus idaeus L., while subhydrous sites attract ferns such as Matteuccia struthiopteris (L.) Tod. Sugar maple trees that survive on these sites will very probably decline and die in the next few years (see section 1.2, Figure 2 and Table 3). Such stands do not have sufficient potential for sap production, and the timber should be salvaged.

A one-step total salvage cut can be carried out, but it is best to leave between 10 and 20 seed trees per hectare, preferably companion species, even if they are eventually lost to windthrow. This measure is suitable only for sugarbushes in which the maple trees have been, or are being replaced by other species. On dry sites with shallow soil cover, stands should be restocked with red oak and white pine seedlings, and on wet sites, with bur oak and yellow birch.

DID YOU KNOW?

Winter logging can limit the spread of intolerant hardwoods while protecting maple and other high-value hardwood seedlings. However, if the goal is to maintain or increase the number of yellow birch trees in a stand, it is best to begin logging in the fall, disturbing the soil sufficiently to create a proper seedbed for the birch seedlings, whose rootlets cannot penetrate a thick litter.
2.3.4 Mixed stands

In mixed stands, hardwood trees such as the yellow birch and trembling aspen have generally suffered more severe damage than the conifers. Balsam fir trees, spruce trees, jack pines, larches, hemlocks and cedars (FSPLHC) that have been uprooted or have suffered crown damage at a diameter in excess of 6 cm must be salvaged within three years, to avoid deterioration by red heart rot. The same applies to weak hardwoods with severe bole wounds that have retained 20% or less of their crowns (or less than 60% in the case of weak aspens) (see section 1.1, Table 2). The damage can first be assessed summarily, and then, if necessary, the mixed stand can be surveyed and a salvage plan drawn up. Partial salvage cutting is justified if the weak hardwoods, aspens and softwoods (FSPLHC) account for ≥ 30% of the stand basal area. For management purposes, mixed stands should be subdivided into two categories:

1. those containing tolerant or semi-tolerant hardwoods;
2. those containing intolerant hardwoods.

**Mixed stands with tolerant or semi-tolerant hardwoods, such as the yellow birch, sugar maple and red maple:**

- salvage the weak or defective trees, leaving at least 10 vigorous hardwoods per hectare (yellow birch or sugar maple) selected from the dominant or codominant storeys, to serve as seed trees.

**Mixed stands with intolerant hardwoods, such as the trembling aspen and white birch:**

1. if advance-growth of desirable species is insufficient, carry out a partial salvage cut, preserving only the softwoods and commercial hardwoods whose quality is not at risk;
2. if advance-growth of desirable species is sufficient and well-established in the stand, carry out a partial salvage cut to eliminate the weak or defective trees, beginning with intolerant species. No more than 40% of the basal area should be harvested, to prevent windthrow.

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17 Red and white pine trees, which often grow alongside hardwoods, are not included in the FSPLHC group. Pine trees that have lost their crowns or some of their branches do not need to be salvaged urgently, because their boles are not likely to deteriorate in the medium term.

18 Although it is difficult to predict how mixed stands with tolerant hardwoods will regenerate, there is some concern that radical opening may trigger an invasion of raspberries, intolerant hardwoods and softwoods, including balsam fir. Forest managers should therefore promote the establishment of yellow birch, at the expense of softwood and intolerant hardwood species. To do this, the litter should be turned over in small patches during hauling. However, care is needed to avoid scalping the ground and wounding the seed trees during logging. Contrary to prior instructions concerning sugarbushes (see section 2.3.1), trees in mixed stands should be salvaged after they shed their leaves but before the ground freezes.

19 A defective softwood whose crown has been broken off at a diameter of 6 cm or more should be salvaged before the timber deteriorates (3 years). A weak hardwood that has retained 20% or less of its crown must be salvaged in priority, especially if it is a sawing quality or veneering quality yellow birch (see section 1.2, Table 2).
2.3.5 Other types of stands

2.3.5.1 Trembling aspen stands

In poplar stands destroyed by the ice storm, the timber can be salvaged in a single operation. Total salvage cutting is the best solution if weak aspens make up ≥ 50% of the basal area. Growing poplar stands usually regenerate naturally, thanks to root suckering. Older destroyed stands may be taken over by balsam firs and red maples previously established in the undergrowth. If there are not enough softwoods, the site should be restocked with large seedlings, and release cutting should be carried out among the young crop trees.

In poplar stands that were less severely damaged, we recommend salvaging some of the trees with less than 60% of residual crown, if they account for 30% of the basal area. Damaged aspens are particularly vulnerable to white trunk rot caused by Phellinus tremulæ Bond. & Bor., white pocket rot caused by Inonotus rheades (Pers.) Bond. & Sing., and hypoxylon canker, Entoleuca mammata (Wahl.) J.H. Rogers & Ju.

Transition stands containing tolerant hardwoods or softwoods should be managed in accordance with the methods described in sections 2.3.1, 2.3.2, 2.3.3 and 2.3.4, so as to respect the natural succession order. However, it should be remembered that cutting will stimulate root suckering in aspens, and is likely to hinder the development of maple and tolerant hardwood saplings. Cutting should therefore take place in midsummer, to reduce root suckering and, if necessary, to release the crop trees.

2.3.5.2 Pre-merchantable hardwood plantations and stands

The ice storm also affected some young hardwood stands, causing severely leaning and icefallen trees to become so tangled that they have no chance of recovery. In such cases, losses are not measured in terms of volume, since the trees have not yet reached commercial size and are therefore not valuable enough to justify harvesting. Forest areas such as these are likely to remain unproductive if nothing is done to repair them. As we saw earlier, total salvage cutting allows young aspen stands to recover by promoting root suckering. However, it is more difficult to restore young transition stands by increasing the percentage of high-value hardwoods in order to obtain ≥ 800 crop trees per hectare. Stands that are sufficiently dense (≥ 5,000 trees/ha), i.e. those containing at least 250 crop trees per hectare, should be restored first. The decision key shown in Figure 5 can be used to establish the best method of restoring young hardwood stands. The key is both simple and practical, and takes into account constraints and costs as well as anticipated benefits.
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2.3.5.3 Softwood stands

- **Sanitation cutting**
  
  This method is suitable for use in lightly damaged stands where defective softwoods account for less than 30% of the basal area. The risk of wounding the trees is high if low intensity thinning is carried out, since the forestry workers have less space to move their machinery around. Sanitation cutting may therefore be unprofitable and even costly if care is not taken to protect crop trees when cutting and hauling salvaged trees.

- **Total salvage cut with advance-growth protection**
  
  Total salvage cut with advance-growth protection can be carried out in softwood stands where fallen trees or trees broken at a diameter of ≥ 6 cm account for more than 50% of the basal area, and where advance-growth is sufficient and evenly distributed. This treatment is not recommended in poorly regenerated stands, since intolerant species, such as the white birch, striped maple, mountain maple, beaked hazelnut, wild raspberry and fireweed compete strongly with softwood saplings.

Instead, we recommend partial salvage cutting, which resembles shelterwood cutting and is respectful of the renewal and succession dynamics of stands following natural disturbances.

- **Shelterwood cutting**
  
  In damaged, poorly regenerated softwood stands, shelterwood cutting promotes natural reseeding. It is less costly than reforestation with large seedlings. Defective and diseased trees and those with severe crown damage that are likely to die or fall over while the young seedlings are becoming established should first be cut. Partial opening of the canopy stimulates the germination of desired species while providing softwood saplings with adequate protection from drought and reducing competition from intolerant species.

It is preferable to harvest during the winter if there is a chance that rich, open sites will be invaded by the mountain maple, or if fir advance-growth is to be protected. However, if the goal is to obtain a suitable seedbed for spruce and white pine trees, cutting should take place in the fall and the litter should be carefully turned over.

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**DID YOU KNOW?**

The young saplings selected to become crop trees and subsequently released are not necessarily those that will grow most after thinning. It may happen that a selected tree reacts badly to release cutting and dies or is replaced by a more vigorous neighbouring tree that does not meet quality standards. As a precaution, we suggest releasing at least 800 young trees per hectare, or around one tree every 3.5 m, to obtain normally stocked stands with the best possible distribution coefficient.

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Pre-merchantable hardwood stand destroyed by the 1998 ice storm.

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20 The aim should be to obtain more than 1,500 saplings, 15-cm high or more per hectare and a distribution coefficient of ≥ 60%, i.e. one sapling every 4 m², in 60% of cases.
FIGURE 5 DECISION KEY FOR MANAGING YOUNG ICE-DAMAGED HARDWOOD STANDS

- **Average height of dominant trees**
  - < 10 cm
  - ≥ 4 m
  - ≥ 4 m

- **Stand density:**
  - ≥ 5,000 trees/ha
  - Top quality crop trees ≥ 250 / ha

- **Average dbh of stand**
  - 10 cm < dbh < 24 cm
  - ≥ 24 cm
  - < 4 m
  - < 10 cm
  - ≥ 10 cm

- **Round no. of top quality crop trees per hectare**
  - ≥ 250 stems
  - < 250 stems

- **Decisions**
  - Release the crop trees and, if necessary, fill in the gaps
  - Release, straighten or cut back crop trees as required, and fill in, if necessary
  - Prepare the site for reforestation
  - Total salvage cutting with advance-growth protection
  - Prepare the site for reforestation

- **Actions**
  - Reassess the stand’s condition in 5 years
  - Clear cut without salvage
  - Fill in gaps with white pine and fast growing species (hybrid poplar or larch)
  - Mini-strip cutting without salvage
  - Total salvage cutting

- **Conditions**
  - High risk of browsing by white-tailed deer
  - Profitable harvesting of wood at risk
  - Desired advance-growth density: ≥ 5,000 trees/ha
  - Prevent harvesting of wood at risk

- **Outcomes**
  - Yes
  - No
In white pine and white spruce stands, better results are obtained when partial cutting and scarification coincide with a good seed year. Shelterwood cutting must be adapted to the type of stand. The method proposed here allows the specific features of the following stands to be taken into account:

- balsam fir and spruce stands,
- white pine forests,
- other conifer stands.

**Balsam fir and spruce stands**

In these stands, shelterwood cutting opens the canopy sufficiently to allow the young conifers to grow freely. It is entirely suitable for rich balsam fir stands where the dense cover slows down the growth of young softwoods, or prevents them from becoming established.

When shelterwood cutting is carried out in an ice-damaged balsam fir stand, downed trees and trees broken at a diameter equal or superior to 6 cm should be salvaged first. Indeed, we suggest that all defective trees should be salvaged, up to a ratio of 50% of the stand basal area, to stimulate desired regeneration while preventing windthrow. We recommend harvesting mature trees with butt rot first, together with any intermediate and co-dominant trees that were more severely damaged by the ice. In such cases, shelterwood cutting has the same effect as average-to-high intensity thinning from below. Care is needed during salvage operations to avoid damaging the residual trees which, as we said earlier, are highly susceptible to decay. Lastly, final salvage cutting should be postponed until the advance-growth is well-established (around five years), and the young trees should be carefully protected.

**DID YOU KNOW?**

Because of deer pressure on hardwood advance-growth, large seedlings or fast growing species such as the hybrid poplar must be planted, so that short-term growth is sufficient to protect the terminal buds. With regard to young high-value hardwoods such as oaks and ashes, which may also be browsed in the early years of growth, we suggest cutting them back in order to stimulate stump sprouts, which can grow to a height of nearly 2.0 m in a single year. 

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We recommend cutting a maximum of 30% to 40% of the initial basal area of stands growing on wet sites or shallow soil and those in which pre-commercial thinning has not yet been carried out. These stands are particularly vulnerable to windthrow. Large rotten balsam fir trees are often carriers of fungi, and may be swollen and cracked at the stump, infested by black carpenter ants or attacked by woodpeckers.
White pine stands

White pine regenerates badly in most stands that have suffered only slight damage. Indeed, saplings may be practically non-existent in dense pine forests growing on mesic sites, covered with a thick litter. Shelterwood cutting has a similar effect to a moderately intense fire, creating openings that promote pine regeneration and stand renewal. This treatment is appropriate for softwood stands with a white pine basal area of $\geq 30\%$, in those with $> 12 \text{ m}^2/\text{ha}$ of pine or white spruce, and in mixed stands where the percentage of pine trees is to be maintained or increased.

Ice damage can have the same effect as site preparation carried out to promote natural seeding of even-aged pine stands. It opens up the forest canopy, mainly by removing the crowns of co-dominant and middle storey trees.

Heavy cutting would favour competing species such as balsam fir, red maple, trembling aspen and beaked hazelnut, to the detriment of the white pine which, as we said earlier, grows slowly at the sapling stage. However, if only the dead, dying and weakened trees are salvaged, the litter is sufficiently disturbed during hauling to expose the underlying mineral layer and create an adequate seedbed for pine seeds. The light and heat penetrating through the small gaps created by the salvage work will stimulate advance-growth and suppressed pine trees, which must be protected during harvesting and hauling of the wood at risk. Large white or red pine trees should be preserved as seed trees, even if their crowns have been broken off at a level where the diameter is greater than 6 cm. They will continue to grow, and are not likely to deteriorate if there are no serious wounds in the lower part of the bole.

Other softwood stands

Raspberry and mountain maple are a real menace in dense, poorly regenerated cedar bushes and hemlock forests destroyed by ice. The prognosis is poor for these stands, which nevertheless regenerate fairly well when lightly or moderately damaged, because such damage favours cedar and hemlock saplings over competing species. In addition, cedar seeds germinate well on mineral soil or decomposing wood, while hemlock is able to become established in any type of humus, and even in a thick litter of leaves or needles.

Shelterwood cutting can therefore be carried out in cedar bushes and hemlock forests that have been damaged but not destroyed by ice, especially if they are to be maintained as winter shelters for white-tailed deer. The cutting method recommended for balsam fir forests can be applied here.
2.3.5.4 Conifer plantations

The best type of treatment for a plantation depends on the height of the trees and the potential market for the timber. Plantations can be divided into three categories:

- young plantations less than 1.5 m high,
- pre-merchantable plantations more than 1.5 m high, and
- merchantable plantations.

Plantations less than 1.5 m high

Most young plantations were protected by the snow, and ice damage was limited to bent or broken leader growth. Given the high cost involved and the expected results, broken leader pruning is not recommended. Most of the damaged trees should recover their apical dominance naturally in the coming years, and their future is not at risk.

Pre-merchantable plantations more than 1.5 m high

During the 1998 ice storm, pine and larch plantations suffered more damage than spruce plantations. Heavily damaged plantations with trees measuring between 1.5 m and 4 m are the most problematical, since they are not yet commercially valuable and the wood at risk cannot be salvaged. Jack pine and spruce plantations still offer some potential for the future, if they have \( \geq 800 \) quality trees per hectare distributed evenly over the site. Below these thresholds, total cutting or partial conversion cutting should be carried out. In the latter case, the most heavily damaged sectors made unproductive by the ice storm should first be identified.

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DID YOU KNOW?

On the richest sites, intensive cultivation can produce 300 m\(^3\) per hectare of hybrid larch in less than thirty years, and nearly 10 m\(^3\) per hectare of hybrid poplar per year after twenty years.

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Forest producers face a dilemma here, especially if the trees at risk cannot be sold for pulp. Should they convert a heavily damaged plantation immediately, to obtain maximum production in 50 or 60 years, or should they wait 10 to 20 years to salvage around 50% of the volume they would have got without the ice storm? Each case should be analyzed on its own merits, and the final decision is up to the forest producer. There is no miracle solution to a disaster like the 1998 ice storm. The role of the forest advisor is simply to explain the various options to woodlot owners, and leave them to make the best decision in the circumstances.
Partial conversion cutting is appropriate when the damage is severe but concentrated in patches. If the patches account for more than 12.5 m² in spruce plantations (or more than 28.5 m² in pine forests), restocking is preferable, provided intolerant species are avoided. In older plantations, saplings planted in patches measuring less than 50 m² have little chance of catching up with the dominant trees, and are more likely to be browsed by hares.

Broken leader pruning may also be useful in heavily damaged softwood plantations, but should be applied only to the trees that will make up the new stand, i.e. 800 spruce or jack pine per hectare, or 350 white or red pine per hectare. There is a risk that forks or multiple heads will develop on trees that have lost the highest part of their crowns. In the case of the spruce this is corrected naturally, but it can be a problem in pine trees. In addition, softwoods whose boles have broken at a diameter of more than 6 cm are likely to deteriorate due to discoloration and decay, usually caused by the red heart rot, Stereum sanguinolentum (Alb. et Schw.) Fr. and the red ring rot, Phellinus pini (Thore: Fr.) A. Ames (4). Red pine trees are less susceptible to decay, even if a crook forms on the bole and persists for several years. When such trees reach maturity, in 35 to 40 years, their value to the sawing industry will probably not be compromised.

Merchantable plantations

Merchantable plantations containing ≥ 800 quality trees per hectare (≥ 500 trees if the plantation has already been thinned), 40% of which are dominant or co-dominant, still offer good potential. Although several such plantations were salvaged in the spring of 1998, others are threatened by windthrow. It is therefore important to salvage only the wood at risk, and to leave as many trees per hectare as possible. The risks of windthrow are particularly high in:

- plantations over 30 years old;
- dense plantations, especially those growing on rich sites;
- plantations in which pre-commercial thinning has not been carried out;
- plantations in which severely damaged trees were salvaged in the spring of 1998 and less than 800 trees per hectare were left standing;
- plantations in which the dominant and co-dominant trees are bent or leaning.

**DID YOU KNOW?**

Crown-damaged trees have a slower upward growth rate than neighbouring undamaged trees. They will therefore form a sub-storey in the final crop, and will not produce much timber. Even so, it is not worth systematically pruning all broken trees, because many will die before reaching maturity.
Red pine plantations in which partial salvage cutting has been carried out should be restocked so as to increase the new stand’s resistance to any future ice storms. Natural stands containing several storeys (multistoried stands) were damaged less than plantations in which all the trees were the same height (single storied stands). To introduce a multistoried structure in such plantations, a mixture of red pine, white pine, white spruce and even larch or hybrid poplar should be planted. A certain number of high-value hardwoods (300 saplings per hectare), such as red oak or white ash, which are particularly well-suited to rich sites, can also be planted.

2.4 OPERATIONS RELATED TO THE SALVAGE OF DAMAGED TREES

The following information has been provided to help forest advisors answer the main questions raised by forest producers concerning suitable and unsuitable operations in sugarbushes and plantations and the salvage of wood at risk. The description of each treatment includes an assessment of its relevance, the associated constraints and its anticipated impact on the stand.

Hardwood stands destroyed by ice storm in the Lanaudière region in 1983 contain large residual trees that have become nesting sites and sources of food for many species of mammals and birds, including the pileated woodpecker, Dryocopus pileatus.
### 2.4.1 Hardwood stands

<table>
<thead>
<tr>
<th>INTERVENTION</th>
<th>RELEVANCE / CONSTRAINTS</th>
<th>ANTICIPATED EFFECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil amendments (lime-ashes-fertilizer)</td>
<td>To be avoided in the short term, because the root systems of the trees are intact – To be reassessed in the next few years in stands whose succession or stability is threatened.</td>
<td>Variable results in sugarbushes affected by dieback – No conclusive results with regard to maple production (23).</td>
</tr>
<tr>
<td>Trimming of sugarbushes</td>
<td>Specialized task, too expensive – Limited manpower – Justified to ensure the safety of people and property – Quality of work is not guaranteed.</td>
<td>Often stimulates the formation of suckers that are not viable in the longer term – Does not guarantee tree survival – No impact on the progression of decay, which is negligible in sugar maples &lt; 40 years old and red maples &lt; 25 years of age (16) (17).</td>
</tr>
<tr>
<td>Salvage of broken branches</td>
<td>Especially useful in clearing access roads and tubing – Low yield: the volume of wood harvested is generally ≤ 20 m³/ha.</td>
<td>Windrowing delays decomposition of timber by fungi that do not attack living trees (4).</td>
</tr>
<tr>
<td>Loping and scattering</td>
<td>Profitable if the branches are triturated in the first year – After a year, saprophytic fungi will already have invaded the dead wood – Expensive operation.</td>
<td>Quick recycling of debris by white rot fungi (saprophytic fungi).</td>
</tr>
<tr>
<td>Control or elimination of advance-growth</td>
<td>To be avoided in the short term – Release only the tubing and trees with ≥ 50% of their crowns remaining, which can be tapped without threatening their health.</td>
<td>Regeneration protects against bole sunscald, summer drying of roots, soil degradation and sapling dieback (9).</td>
</tr>
<tr>
<td>Interplanting of sugar maples in sugarbushes</td>
<td>Useful if there are less than 5,000 saplings over 0.5 m high per hectare – Do not plant smaller seedlings, because they may not survive.</td>
<td>Increases the percentage of trees from desirable species.</td>
</tr>
<tr>
<td>Planting of high-value hardwoods in tolerant hardwood stands</td>
<td>Useful in heavily damaged forests and transition forests with dieback growing in rich soil – Requires no site preparation – If browsing is likely to be a problem, hybrid poplars or high-value hardwoods, such as oaks or ashes, should be planted, since they grow quickly after coppicing.</td>
<td>The butternut, shagbark hickory and bur oak give good yields on waterside sites and lowlands – the black cherry, red oak, white ash and bitternut hickory give good yields on well-drained sites (20) – The white pine manages well on sandy soils.</td>
</tr>
<tr>
<td>Activity</td>
<td>Description</td>
<td>Notes</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Release of crop trees</td>
<td>Allows production to be restored immediately in severely damaged patches.</td>
<td>May help improve stand quality.</td>
</tr>
<tr>
<td>Staking of leaning trees</td>
<td>Low yield: under 20 trees per day – Increased risk of wounds on trees used as anchor points.</td>
<td>Production is restored immediately.</td>
</tr>
<tr>
<td>Coppicing of young icefallen or severely leaning hardwoods</td>
<td>Appropriate for young hardwoods under 10 years of age – Effective if done in early spring – Ashes and oaks react well to this treatment, especially on good sites.</td>
<td>Coppicing triggers rapid growth in well-established damaged trees, and allows production to be restored on the site, to the detriment of undesirable species.</td>
</tr>
<tr>
<td>Conservation of large snags in damaged woodlots (3 or 4 snags per hectare)</td>
<td>Preserves shelter for wildlife and provides choice nesting sites (birds of prey) – Involves some risk to humans, especially in sugarbushes used for sap production (see Appendix 4).</td>
<td>May help control the small mammals that attack young trees and tubing – The polypores that grow on the snags are not a major source of infection for living trees (3).</td>
</tr>
<tr>
<td>Tapping of maples after the ice storm&lt;sup&gt;23&lt;/sup&gt;</td>
<td>Trees with less than 50% of their original crowns will not provide much sap – Increased risk of stain and decay, because the taps will take more than 5 years to heal.</td>
<td>The growth, sap flow and healing of the trees will be slower in the next few years – Sap stain and decay may compromise long-term maple yields (15).</td>
</tr>
<tr>
<td>Reconstruction of the sap transportation system</td>
<td>The operation’s profitability is not guaranteed if maple trees that have preserved ≥ 50% of their crowns provide less than 150 taps/ha – Before tapping severely damaged maples, producers should consider their own short-term financial interests and the impact of the operation on long-term tree health.&lt;sup&gt;23&lt;/sup&gt;</td>
<td>The use of the site for maple production should be reviewed in severely damaged sectors where tree survival is compromised.</td>
</tr>
</tbody>
</table>

<sup>23</sup>Maple producers should consult regional advisors of the ministère de l’Agriculture des Pêcheries et de l’Alimentation on this subject.

Windrowing delays wood decomposition and saprophytic fungi, such as the common split gill, *Schizophyllum commune* Fr.
2.4.2 Softwood plantations

<table>
<thead>
<tr>
<th>INTERVENTION</th>
<th>RELEVANCE / CONSTRAINTS</th>
<th>ANTICIPATED EFFECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restocking</td>
<td>Useful in plantations under 8 years of age, especially in patches of more than 12.5 m² for spruce and more than 28.5 m² for pine — <strong>In older plantations, restocking is useful in patches of more than 50 m²</strong>, even though there is a high risk of browsing.</td>
<td>Restocking guarantees optimal production.</td>
</tr>
<tr>
<td>Pruning of the broken leader and / or straightening of a side branch</td>
<td><strong>Useless for trees under 1.5 m high</strong> and for larger trees where only the leader has been broken. Necessary for trees between 1.5 m and 4 m high that have broken below the second-highest internode — Low risk of decay on red pines (see Appendix 4). — Straightening of a side branch might be suitable.</td>
<td>Straightening will occur naturally in the short term, and damage is inconsequential in the medium term. Eliminates multiple leaders and maintains apical dominance — High risk of decay in softwoods (FSPLHC) if the bole is broken at a level where the diameter exceeds 6 cm.</td>
</tr>
<tr>
<td>Straightening of trees and guying</td>
<td>Appropriate for young trees leaning at an angle of ≥ 30° — Expensive if the trees treated are more than 3 m high — <strong>Useless if there are more than 800 spruce or jack pine trees per hectare or more than 350 red or white pine trees per hectare.</strong></td>
<td>Provides better long-term yields — Enhances the quality of the butt log.</td>
</tr>
</tbody>
</table>

In plantations 8 years of age or older, restocking is useful if trees have been destroyed on sufficiently large patches. Otherwise, the young trees have little chance of survival.
3.1 MULTIPLE-STAGE SURVEY

Surveying of damaged stands has several goals:

- to estimate the severity of the damage;
- to establish the extent of the most severely damaged forest strata;
- to obtain dendrometric data representative of the most severely damaged forest strata;
- to make the necessary silvicultural recommendations for restoring the stands;
- if necessary, to prepare the salvage plan, taking into account tree vigour and quality, the risk that the timber will deteriorate, and the type of products;
- to spread salvage operations so as to avoid saturation of certain markets;
- to assess the residual stand's chances of recovering and regenerating.

The recommended evaluation method (see Figure 6) is part of a multiple-stage sampling process aimed first at optimizing data collection so as to make informed silvicultural decisions, and second, where applicable, at salvaging wood at risk first. For example, on-site damage estimating involves assessing the severity of the damage visually, optimizing the sampling plan through the use of plots and, if necessary, defining the sectors where treatments are required.

Many requests for service from forest producers can probably be settled with a short visit to the woodlot, especially if the damage is slight to moderate. For stands that appear to be heavily damaged, however, the forest advisor should carry out a point sampling survey. If the survey confirms the severity of the damage, the advisor and producer should work together to see whether it is possible and economically profitable to salvage the wood at risk.

3.2 APPROPRIATE SAMPLE SIZE AND SURVEY PERIOD

The ideal period for the survey begins when the leaves first appear, since it is easier at this point to detect dead branches and assess the recovery rate of surviving branches, as well as visible tree vigour, and determine the tree's chances of survival. For example, a large number of new shoots on a tree that had lost most of its branches is a good indicator of vigour (see Tables 3 and 4).

The proposed sampling method is based on the forest survey process used for private forests. It involves point sampling using an angle gauge with a basal-area factor of 2 m² per hectare. The number of sample points varies according to the area of the stand or part of a stand to be surveyed (Table 6).

The sample points should be distributed at random through the forest strata so as to obtain optimal assessment of damage (8). To avoid false measurements, the sample points should be at least 50 m apart, and there should be at least 25 m between the points and the roads or stand margins.

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34 To check the reliability of a factor 2 gauge, draw two vertical lines 20 cm apart on a sheet of paper and pin it to a wall. Look at the paper through the gauge, from a distance of 7.07 metres, i.e. the furthest distance (R) for accepting a 20 cm diameter tree (D) according to the angle count method: \( R_m = 0.3535 \times D_{cm} \) (Figure 7).
FIGURE 6 STEPS IN ASSESSING DAMAGE, FORMULATING APPROPRIATE SILVICULTURAL RECOMMENDATIONS AND MONITORING THE RECOVERY OF ICE-DAMAGED STANDS

- **Damaged woodlot with an area of > 4 ha**
  - **Carry out stand reconnaissance and make a global assessment of the damage**
  - **Draft a summary evaluation report of the damage and give it to the producer**
  - **Formulate silvicultural recommendations with a view to restoring the stands and give them to the producer**
  - **Mark the trees, including those to be cut down for road construction**
  - **Inform the producer of the work to be carried out**
  - **Salvage lumber at risk first**
  - **Prepare the report on the work and give it to the producer**
  - **Monitor the stand and reassess its potential in 3 years’ time**

- **Woodlot not admissible for salvage of wood at risk**
  - **Close the file**

- **Heavily damaged stand – Basal area (BA) of trees to be salvaged > 30%**
  - **Carry out a survey in heavily damaged stands (point-sampling method)**
  - **Compile the data using a specially-designed software package**
  - **Formulate the necessary silvicultural recommendations**
  - **First check for the presence of vulnerable species to adapt harvesting accordingly**
  - **Check the markets before cutting**
  - **Determine the best cutting period and the type of equipment required**

- **Woodlot not admissible for the technical assistance program**
  - **Close the file**

- **Woodlot admissible for salvage of wood at risk**
  - **Close the file**

- **Woodlot not admissible for the technical assistance program**
  - **Prepare the report on the work and give it to the producer**
Special attention is required when accepting or rejecting neighbouring trees (see Figure 7), i.e. trees whose images are partly hidden in the angle gauge or those that intersect at the borderline distance for a given diameter (8). Less experienced observers, if they do not use a tape measure to check whether these trees should be included in the sample, may tend to accept them and hence overestimate stand density.

### TABLE 6  NUMBER OF SAMPLE POINTS TO BE ESTABLISHED BY STAND AREA

<table>
<thead>
<tr>
<th>AREA TO BE SURVEYED (HECTARES)</th>
<th>REQUIRED NUMBER OF SAMPLE POINTS</th>
<th>NUMBER OF ADDITIONAL POINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 2 ha</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>From 2,1 ha to 3 ha</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>From 3,1 ha to 4 ha</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>From 4,1 ha to 6 ha</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>From 6,1 ha to 8 ha</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>From 8,1 ha to 12 ha</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>From 12,1 ha to 16 ha</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>From 16,1 ha to 20 ha</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>≥ 20,1 ha</td>
<td>10 + 1 point every 5 additional ha</td>
<td>One point every 10 ha</td>
</tr>
</tbody>
</table>

**DID YOU KNOW?**

At least two point samples are required per hectare to represent an uneven-aged hardwood stand structure (8). However, it is better to sacrifice accuracy in order to optimize sampling in the areas to be surveyed. Care is needed to ensure that estimates are not biased.
3.3 THE VARIABLES

During the survey, all merchantable trees (dbh $\geq 9.1$ cm) in the sample point must be measured using the angle gauge, even those that are broken under the crown, uprooted, icefallen or leaning.

In addition, the saplings and seedlings to be preserved as crop trees must be identified in sectors where shelterwood cutting is required. These estimates, expressed as a number of trees per hectare, can be made visually if regeneration is very abundant or very sparse. In all other cases\(^{25}\), the seedlings and saplings must be counted in circular sample plots. The size of the plots will vary according to the development stage of the advance-growth:

- $1/100$ ha ($100$ m$^2$ or $5.64$ m in radius) for saplings with a dbh of $1.0$ cm to $9.0$ cm;
- $1/350$ ha ($28.6$ m$^2$ or $3.02$ m in radius) for tolerant hardwood seedlings with a dbh of $< 1.0$ cm and a height of $\geq 0.5$ m, and softwood seedlings $\geq 15$ cm high.

The form used to note the data obtained from the point sampling appears in Appendix 5. The forestry variables used on the form are as follows:

- species;
- diameter breast height (dbh), expressed in 2 cm intervals;
- tree vigour and quality categories (see section 2.2);
- the percentage of residual crown, taking into account the branches that have formed since the ice storm (expressed in 10% intervals);
- the position of each tree studied in the sampling point;
- the number of seedlings and saplings of desirable species, per hectare\(^{26}\);
- bole shape (see the diagrams in Appendix 2);
- the type of stand and the type of product it is intended for;
- the silvicultural treatments applied before the ice storm.

\(^{25}\) Plots must be established when it is not clear, from a visual inspection alone, that the advance-growth is sufficiently dense, i.e. in excess of 5,000 viable hardwoods or sugar maples per hectare, excluding small hardwood saplings less than $0.5$ m high and undesirable species such as balsam fir, beech, red maple and trembling aspen (see section 3.4).

\(^{26}\) This information is only useful in severely damaged sectors where shelterwood cutting is required.
CHAPTER 3

THE EVALUATION METHOD

MANAGEMENT OF ICE STORM DAMAGED STANDS

FIGURE 7 SAMPLE POINT AND SAMPLE PLOTS ESTABLISHED TO ESTIMATE CROWN COVER, STAND DENSITY AND ADVANCE-GROWTH

BITTERLICH FORMULA

\[ R_m \leq f \times D_{cm} \]

- **f**: angle gauge constant
- **D**: diameter of tree (dbh cm)
- **R**: critical distance (m) between the centre of the plot and the centre of the tree
3.4 DATA COMPILATION

The survey data can be used to obtain an overview of the damage and quantify the volume of wood at risk for each product category. Based on this information, forest advisors can recommend appropriate silvicultural treatments and, where applicable, draw up a salvage plan. Marketing considerations must always be taken into account before any intervention. In addition, as we saw earlier, it is not possible to salvage all the wood at risk in a single operation, since this hinders stand recovery. Before a salvage program is implemented, the following compilations, obtained using a specially-designed software program, should be taken into account:

- the basal area of living merchantable trees;
- the basal area of dead merchantable trees;
- the basal area of merchantable aspens that have retained 60% or less of their crowns;
- the basal area of uprooted, icefallen or severely leaning trees;
- the basal area of merchantable softwoods broken at a level where the diameter is $\geq 6$ cm, except mature red and white pines;
- the basal area of merchantable tolerant or semi-tolerant hardwoods that have retained between 10% and 20% of their crowns;
- the basal area of merchantable hardwoods that have retained $\leq 10\%$ of their crowns;
- the volumes of wood to be salvaged (veneer logs, saw logs, pulp, etc.) and the order in which harvesting should take place;
- the residual basal area and the cumulative thinning rate;
- the density of desirable softwood and hardwood advance-growth.

Table 7 provides an example of a tool that may be extremely useful when deciding on the silvicultural treatment required and the volume of wood to be harvested, based on the priorities established in Table 5. It can be drawn up after compiling the data collected in accordance with the above instructions (see Figure 6).

**DID YOU KNOW?**

Simply increasing the number of sample points is not enough to improve the accuracy of the survey. Special attention must also be paid to the stratification of the sectors surveyed and the quality of the dendrometric data gathered. In addition, the sample points must be selected on a strictly random basis.
### TABLE 7  SALVAGE PROGRAM ESTABLISHED ACCORDING TO THE VALUE OF THE WOOD AT RISK

| Basal area and % of merchantable trees in good condition | 12.3 m$^3$/ha | 62.7% |
| Basal area and % of trees at risk | 7.3 m$^3$/ha | 37.3% |
| Merchantable basal area and % of icefallen trees/T.M.B.A. | 1.33 m$^3$/ha | 6.8% |
| Merchantable basal area and % of hardwoods other than aspens with ≤ 10% of residual crown | 2.00 m$^3$/ha | 10.2% |
| Merchantable basal area and % of hardwoods other than aspens with 10% to 20% of residual crown | 4.67 m$^3$/ha | 23.7% |
| Merchantable basal area and % of aspens with ≤ 60% of residual crown | 0.00 m$^3$/ha | 0.0% |
| Merchantable basal area and % of softwoods broken at more than 6 cm, except mature white and red pines | 0.67 m$^3$/ha | 3.4% |
| Merchantable basal area and % of hardwoods other than aspens with > 20% of residual crown | 9.67 m$^3$/ha | 49.2% |
| Total merchantable basal area (T.M.B.A.) | 19.67 m$^3$/ha |

**No. of sample points: 6**

<table>
<thead>
<tr>
<th>Category</th>
<th>Residual crown</th>
<th>Species</th>
<th>Vigour</th>
<th>Condition</th>
<th>Saw logs</th>
<th>Pulp</th>
<th>Total</th>
<th>Cumulative volume</th>
<th>B.A.</th>
<th>cumulative</th>
<th>% cumulative</th>
<th>% Residual B.A.</th>
<th>Harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>III 0%</td>
<td>Tolerant hardwoods</td>
<td>Dead</td>
<td>Quality</td>
<td>0.5</td>
<td>2.0</td>
<td>2.5</td>
<td>2.5</td>
<td>2%</td>
<td>0.3</td>
<td>0.3</td>
<td>2%</td>
<td>19.3</td>
<td>100%</td>
</tr>
<tr>
<td>IV 0%</td>
<td>Tolerant hardwoods</td>
<td>Dead</td>
<td>Defective</td>
<td>3.5</td>
<td>3.5</td>
<td>6.1</td>
<td>5%</td>
<td>0.7</td>
<td>1.0</td>
<td>5%</td>
<td>18.7</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>VI ≤ 10%</td>
<td>Tolerant hardwoods</td>
<td>Weak</td>
<td>Quality</td>
<td>1.5</td>
<td>6.1</td>
<td>7.6</td>
<td>17.8</td>
<td>14%</td>
<td>1.0</td>
<td>2.7</td>
<td>14%</td>
<td>17.0</td>
<td>80%</td>
</tr>
<tr>
<td>III ≤ 10%</td>
<td>Aspens</td>
<td>Weak</td>
<td>Quality</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>17.8</td>
<td>14%</td>
<td>0.0</td>
<td>2.7</td>
<td>14%</td>
<td>17.0</td>
<td>0%</td>
</tr>
<tr>
<td>III ≤ 20%</td>
<td>Tolerant hardwoods</td>
<td>Weak</td>
<td>Quality</td>
<td>3.6</td>
<td>14.2</td>
<td>17.9</td>
<td>35.7</td>
<td>28%</td>
<td>2.3</td>
<td>5.0</td>
<td>25%</td>
<td>14.7</td>
<td>70%</td>
</tr>
<tr>
<td>VI Broken top</td>
<td>Softwoods</td>
<td>Weak</td>
<td>Defective</td>
<td>2.1</td>
<td>3.1</td>
<td>5.2</td>
<td>40.9</td>
<td>32%</td>
<td>0.7</td>
<td>5.7</td>
<td>29%</td>
<td>14.0</td>
<td>100%</td>
</tr>
<tr>
<td>IV ≤ 10%</td>
<td>Tolerant hardwoods</td>
<td>Weak</td>
<td>Defective</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>40.9</td>
<td>32%</td>
<td>0.0</td>
<td>5.7</td>
<td>29%</td>
<td>14.0</td>
<td>0%</td>
</tr>
<tr>
<td>IV ≤ 60%</td>
<td>Aspens</td>
<td>Weak</td>
<td>Defective</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>40.9</td>
<td>32%</td>
<td>0.0</td>
<td>5.7</td>
<td>29%</td>
<td>14.0</td>
<td>0%</td>
</tr>
<tr>
<td>IV ≤ 20%</td>
<td>Tolerant hardwoods</td>
<td>Weak</td>
<td>Defective</td>
<td>13.4</td>
<td>13.4</td>
<td>54.3</td>
<td>42%</td>
<td>2.3</td>
<td>8.0</td>
<td>41%</td>
<td>11.7</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>III &gt; 20%</td>
<td>Tolerant hardwoods</td>
<td>Weak</td>
<td>Quality</td>
<td>3.2</td>
<td>12.9</td>
<td>16.2</td>
<td>70.5</td>
<td>55%</td>
<td>2.0</td>
<td>10.0</td>
<td>51%</td>
<td>9.7</td>
<td>0%</td>
</tr>
<tr>
<td>III &gt; 60%</td>
<td>Aspens</td>
<td>Weak</td>
<td>Quality</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>70.5</td>
<td>55%</td>
<td>0.0</td>
<td>10.0</td>
<td>51%</td>
<td>9.7</td>
<td>0%</td>
</tr>
<tr>
<td>IV &gt; 20%</td>
<td>Tolerant hardwoods</td>
<td>Weak</td>
<td>Defective</td>
<td>2.0</td>
<td>2.0</td>
<td>72.5</td>
<td>56%</td>
<td>0.3</td>
<td>10.3</td>
<td>53%</td>
<td>9.3</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>IV &gt; 60%</td>
<td>Aspens</td>
<td>Weak</td>
<td>Defective</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>72.5</td>
<td>56%</td>
<td>0.0</td>
<td>10.3</td>
<td>53%</td>
<td>9.3</td>
<td>0%</td>
</tr>
<tr>
<td>II &gt; 60%</td>
<td>Aspens</td>
<td>Vigorous</td>
<td>Defective</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>72.5</td>
<td>56%</td>
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<td>Defective</td>
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<td>1.7</td>
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<td>61%</td>
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<tr>
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<td>Aspens</td>
<td>Vigorous</td>
<td>Quality</td>
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<td>0.0</td>
<td>0.0</td>
<td>80.8</td>
<td>63%</td>
<td>0.0</td>
<td>12.0</td>
<td>61%</td>
<td>7.7</td>
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<td>I &gt;60% (&lt;24cm)</td>
<td>Aspens</td>
<td>Vigorous</td>
<td>Quality</td>
<td>1.9</td>
<td>1.9</td>
<td>82.7</td>
<td>64%</td>
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<td>12.3</td>
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<td>V 100%</td>
<td>Softwoods</td>
<td>Vigorous</td>
<td>Quality</td>
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<td>71%</td>
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<td>Tolerant hardwoods</td>
<td>Vigorous</td>
<td>Quality</td>
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<td>11.7</td>
<td>14.6</td>
<td>109.7</td>
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<td>81%</td>
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<td>Vigorous</td>
<td>Quality</td>
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<td>100%</td>
<td>3.7</td>
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<td>100%</td>
<td>0.0</td>
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</table>

Saw and veneer volumes to be harvested: 8.0 m$^3$/ha
Pulp volume to be harvested: 31.3 m$^3$/ha
Total volume to be harvested: 39.4 m$^3$/ha
Residual volume: 89.5 m$^3$/ha
% of volume to be harvested in priority: 31%
% of basal area of trees at risk: 37%
Admissible for assistance program: Yes

Basal area to be harvested: 5.7 m$^3$/ha
Residual basal area: 14.0 m$^3$/ha
% of basal area to be harvested: 29%

Equipment recommended for harvesting:
- Manual logging - skidder
- Desirable advance-growth: Hardwoods: 10,200 saplings / ha
- Softwoods: 2,125 saplings / ha
In the case shown in the table, 100% of the dead trees intended for lumber or pulp production (10.2 m$^3$/ha) and all the weak softwoods (5.2 m$^3$/ha) would be harvested in priority, during the first stage. As there is some leeway with regard to the residual basal area required, the forest advisor could set a harvesting rate to allow for the salvage of some weaker trees. In addition, 40% of the weak and defective hardwoods (40% of 13.4 m$^3$/ha = 5.4 m$^3$/ha), 80% of the birch, maple and other quality tolerant hardwoods with ≤ 10% of their crowns remaining (80% of 7.6 m$^3$/ha = 6.1 m$^3$/ha) and 70% of those with ≤ 20% of their crowns remaining (70% of 17.9 m$^3$/ha = 12.5 m$^3$/ha) would be harvested. This would mean removing 29% of the basal area, i.e. 5.7 m$^3$/ha or 39.3 m$^3$/ha of the standing volume, leaving any good black cherry and white ash specimens standing, since they generally recover well. It should be noted that not all the wood at risk (7.3 m$^3$/ha) is systematically harvested. After the first partial cut, the stand would have a density of nearly 14.0 m$^3$/ha or 89.5 m$^3$/ha, which is the minimum recommended density for this type of stand (see Figure 4).

If all the trees at risk were salvaged, the basal area would be reduced to 11.7 m$^3$/ha, which is unacceptable in forestry terms. It is important to leave at least some standing trees with less than 20% of residual crown, since they have a good chance of recovering in the next few years.

Warning
Marking is an important operation that should be carried out carefully and meticulously by experienced forestry technicians. It is this step that will determine the success of the operation.

In applying a salvage program as shown in Table 7, it is important to avoid wounding the trees with the machinery or harvesting unmarked trees. During marking, we propose reducing the volume of wood to be salvaged by 10% (10% of 39.4 m$^3$/ha, or approximately 4 m$^3$/ha) to compensate for the inevitable losses: trees cut down by mistake or to create hauling trails, etc. (18).
CONCLUSION

Forest producers tend to underestimate a stand’s ability to recover, even if it has been very severely damaged. There is no immediate need to cut down trees. Indeed, it is best to wait a few years, to assess their reactions and see whether new branches are formed. It will then be easier to make informed decisions. Nature will dictate the measures required (6).

Special steps must be taken to ensure worker safety in ice-damaged stands. For example, forestry workers should never be left unsupervised.

Everyone working in the stand must be aware of the safety rules to be applied during the salvage operations proposed in this document (12 and 13). First, piles of branches and uprooted or leaning trees may hinder circulation in the forest. Second, once the leaves appear it may be difficult to see lodged trees and hanging branches that are likely to fall during salvage work (13). Lastly, leaning trees are always a danger to forestry workers during logging, even after several years.

The ice storm that devastated Québec’s forests in 1998 left forest and maple sap producers in a very difficult situation.
After the disaster, the damage had to be assessed, a salvage program for wood at risk drawn up, and practical solutions proposed for the restoration of damaged stands. This document is the result of a collective effort. Those involved pooled their knowledge to answer questions concerning stand restoration and to solve the problems of marketing salvaged wood. The silvicultural treatments proposed in this document have been studied carefully, and their short and long-term impacts on tree health and the ecological integrity of stands have been assessed. The document contains all the technical information at our disposal to help alleviate the effects of the 1998 ice storm and any other natural disasters that may affect our forests in the future.

Manual removal of bent or broken trees and trees containing broken and snagged branches can be very risky for forestry workers engaged in salvage operations.
SELECTED REFERENCES


APPENDIX 1  RESIDUAL CROWN OF ICE-DAMAGED TREES

1.1

Section to be assessed

Section destroyed

Lower part of crown

Residual crown: 65%

1.2

Section destroyed

Section to be assessed

Lower part of crown

Residual crown: 25%

1.3

Section to be assessed

Section destroyed

Lower part of crown

Residual crown: 45%

1.4

Section destroyed

Section to be assessed

Lower part of crown

Residual crown: 70%
APPENDIX 2  BOLE DEFORMATIONS IN ICE-DAMAGED TREES

2.1 Straight
Code: S

2.2 Bent or leaning
Code: L

2.3 Icefallen
Code: I

2.4 Broken
Code: B
APPENDIX 3  ASSESSING THE SEVERITY OF BOLE WOUNDS ON ICE-DAMAGED TREES

Damaged circumference: $20\% + 45\% = 65\%$

Wounds on three faces
### Characteristics of Species: Heartwood Resistance to Decay, Shade Tolerance, Life Span, Growth Rate and Potential Use by Wildlife

**APPENDIX 4**

(Taken from Boulet and Sirard, under preparation)

#### Upward Growth Rate (cm/yr)
- 30-60
- < 30
- > 60

#### Life Span (years)
- > 200
- 100-200
- < 100

#### Porosity of Wood
- —
- d: diffuse
- s.r.: semi-ring porous
- r: ring porous

#### Shade Tolerance
- Highly intolerant
- Intolerant
- Semi-tolerant
- Tolerant
- Highly tolerant

#### Attraction for Wildlife (No. of species)
- > 50
- 25-50
- 5-14
- < 5

---

#### Resistance to Decay — High* or Average¬

<table>
<thead>
<tr>
<th>Species</th>
<th>Upward Growth Rate (cm/yr)</th>
<th>Life Span (years)</th>
<th>Porosity of Wood</th>
<th>Shade Tolerance</th>
<th>Attraction for Wildlife</th>
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<td>Douglas fir ¬</td>
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<td>Eastern white pine ¬</td>
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#### Resistance to Decay — Low* or Nil¬

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<th>Shade Tolerance</th>
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1. Hardwood porosity: d: diffuse; s.r.: semi-ring porous; r: ring porous.
APPENDIX 5  ICE DAMAGE SURVEY FORM

LOT: ____________________ RANGE: ____________________ MUNICIPALITY: ____________________

SECTOR: ____________________ AREA: ____________________

SURVEYOR: ____________________ DATE: ____________________

SURVEY LINE NO.: ____________________ PLOT NO.: ____________________

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<th>NOTE(S)?</th>
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</tbody>
</table>

Tree no.: □
Species: ____________________
Type of stand: ____________________
Distance: ____________________
Location (GPS file no.): ____________________

Silvicultural treatment:
Past: ____________________
Prescription: ____________________

Tapped sugarbush: □

Desirable advance-growth:
(straight sapling, unhindered growth, debris free)
Main species: ____________________

Recent harvest:
- Advance-growth: □
  - abundant: □
  - sparse: □
  - Seedlings _________ / ha
  - Saplings _________ / ha
  - Total _________ / ha

1. Bole shape:
   S: Straight
   L: Leaning
   I: Icefallen
   B: Broken under the crown

2. Note(s):
   N. o. faces wounded
   D: Dieback
   W: Windthrow
   D: Significant decay in bole

3. Silvicultural prescription:
   PS: Partial salvage
   TS: Total salvage
   TSAGP: Total salvage with advance-growth protection
   2STS: Two-step total salvage
   MSC: Mini-strip cutting
   SC: Sanitation cutting
   GSC: Shelterwood cutting

Total: ________________