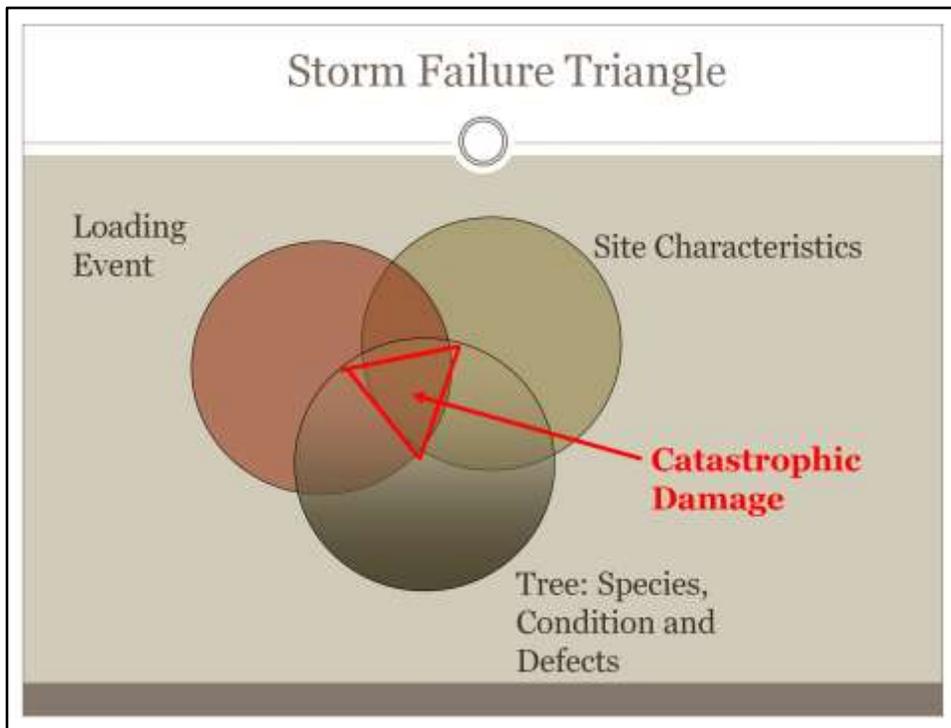


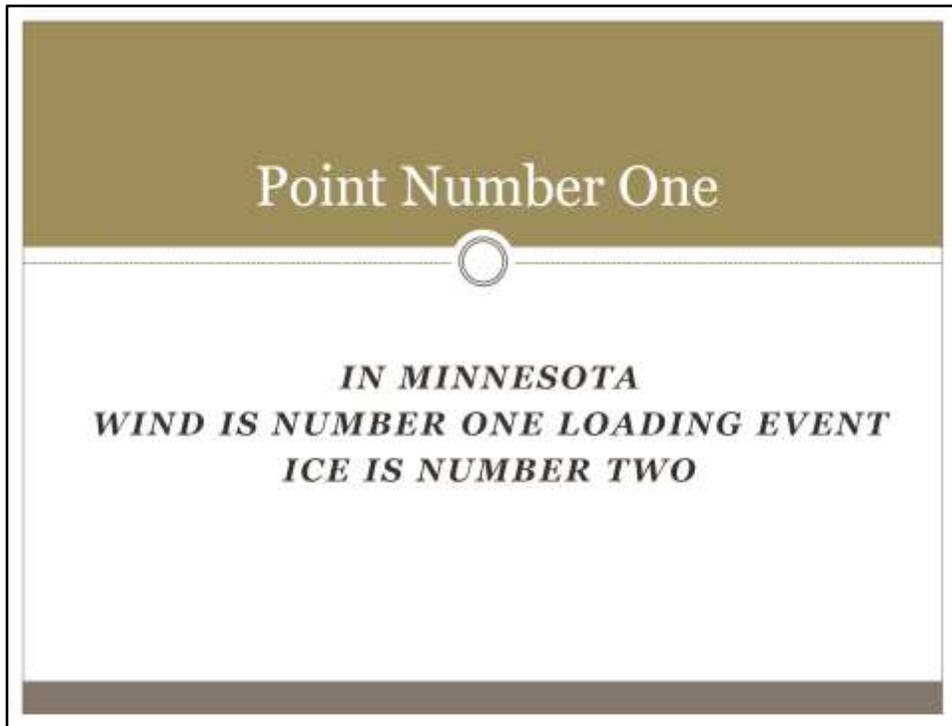
Minimizing Storm Damage to Trees



BUILDING STORM- RESILIENT TREES AND URBAN FORESTS



When trees fail during loading events, it's more than just one factor. The severity of the loading event plays a major role, as do the site characteristics. For instance, if the loading event is a straight-line windstorm and the planting site is a 3 foot wide boulevard, the chances of complete failure are much greater than a thunderstorm affecting a tree growing in a park. Likewise, the condition of the tree impacts the chances of failure, as with trees having large columns of decay in the trunk. When these three major factors overlap – severe loading event, exposed or confined spaces and trees with several defects – the chances for catastrophic losses increase greatly.



A load is anything that places a weight, bending or movement strain on a tree canopy, trunk or root system. In Minnesota, wind storms are the most common loading events, common across the entire state. Ice ranks second, but is most common on the north shore and southwest Minnesota.

Wind Loading Events

- Thunderstorms – 25-80 mph
- <http://www.youtube.com/watch?v=ssCFZ4oKP8g>
- Sustained winds – 40 mph or less
- Gusts – 60 mph or less
- Straight-line winds – 55+ mph
- Tornadoes – 40+ mph

Just about any wind-loading event has the potential of becoming severe, whether a thunderstorm or a tornado. Damage to trees starts roughly at 25 mph. However, at that wind speed, only trees or tree parts with defects commonly suffer damage.



Sustained winds are more common in the early summer, and even though they are considered sustained winds, they tend to gust and die – kind of a regular pulse of wind load. When winds gust, trees snap back after a strong wind quickly slows down and then gusts again. The action of snapping-back often is the most common reason for tree failures.

Ice Loading Events

- Glazing...adds weight
- 1/4-1/2 " ...breaks small branches
- 1/2-1" ...breaks large branches



Depending on the thickness of ice accumulation, the end result may be a minimal amount of small branch breakage to severe bending of certain tree species (birch) to major branch and leader loss on larger trees such as silver maple.



Depending on how long these trees remain bent from the weight of ice, they may return to their normal vertical position or remain permanently bent.



On other, larger, less flexible trees or trees with weak branch attachments or trees weakened by decay, the damage can be severe to destructive. Add a little wind to a heavy ice load and severe damage such as this scene from Worthington, MN in 2013 becomes common.

Point Number Two

***FEW TREES SURVIVE IN THE
DIRECT PATHS OF TORNADOES
AND STRAIGHT-LINE WINDS***

About the only trees that survive in the paths of tornadoes are small trees with little wind resistance...or lucky trees. Tornadoes can't be predicted at planting time and there's nothing that can be done to prepare trees for most severe tornadoes.

Straight-line Winds of 1998



Straight-line winds and especially those with forceful downbursts can be just as destructive as any tornado. Tornadoes and straight-line winds tend to cut a relatively narrow swath, destroying most trees in their paths while trees a couple of streets away are hardly damaged.

Saint Peter Tornado 1998



Severe tornadoes, those that are wide and lengthy, cause the most unavoidable damage. Note in this picture, though, that some small trees and a couple of lucky trees did in fact survive.

Minneapolis Tornado 2009



Note the unbridled path of destruction from this tornado and then the relatively minor damage to trees as the edges of the funnel's path. In the path, very little is undamaged, whether house or tree.

Point Number Three

***YOUR GUT FEELING IS
PROBABLY WRONG...
BIGGER ISN'T BETTER***

The bigger the trees are, the more wind resistance they offer, the harder they fall and break.

Predictable - Intuitive



Common knowledge would attest to the belief that little cars are more likely to be blown all over the road in a wind storm.

Predictable – Factual*

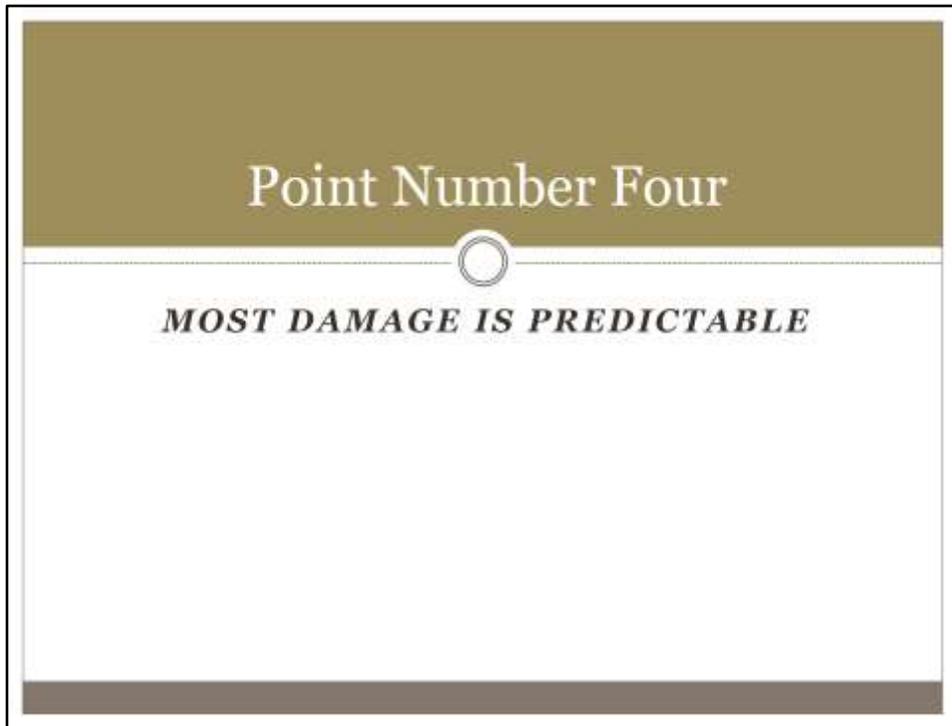


*University of Maryland – wind tunnel research 1990

The reality is that the larger the car (or tree) and the more wind resistance it offers, the more likely it will be the victim while the little car drives around it.



Note in this picture of destruction in North Minneapolis how the lone, undamaged tree is a flowering crabapple (circled).



Even though most damage is predictable, either from catastrophic and powerful loading events or tree weaknesses, don't take this as a message that it's all preventable.

Most Common Damage: Total Failure (54%)*



*University of Minnesota 1995-2005

First of all, based on 11+ years of storm damage research conducted at the University of Minnesota's Department of Forest Resources, the most common damage to urban trees from loading events is total failure. This can be trunks broken off at or below the ground line, true wind-throws or buried trunks breaking at compression points from stem girdling roots several inches below ground.

Second Most Common: Canopy Damage (30%)*



*University of Minnesota 1995-2005

The second-most common type of tree failure includes those that damage the canopy, the area of a tree that begins with the first, main, structural branch and upward.

Third Most Common: Trunk Failure (16%)*



*University of Minnesota 1995-2005

Finally, the third-most common failure is failure at the trunk line, the area below the first main structural branch and the ground line.

Point Number Five

***THERE ARE ONLY A FEW
COMMON CAUSES FOR DAMAGE
OR FAILURE***

Other than the loading events and the confines of the siting of trees, common, pre-existing causes of damage are relatively few. This actually makes it easier to minimize the frequency of storm damage by managing the condition of the trees.

Common Causes for Total Failures

1. ***STEM GIRDLING ROOTS***
2. ***DISPROPORTIONATE SITING***
3. ***ROOT DAMAGE/LOSS***
4. ***ROOT DECAY***

The (ranked) most common, pre-existing conditions that lead to total failures of urban trees in loading events.

1. Stem Girdling Roots



Photo: Eric Berg

Presence of buried stems with stem girdling roots (SGR) is the number one reason why urban trees fail in wind-loading events. As in this photo, they usually break at a point below the compression point of the SGR.

1. Stem Girdling Roots



Photos: 1997



26% of all boulevard
tree failures*

*University of Minnesota 1995-2005

For trees that fail in boulevards, the presence of SGRs accounted for about 1 in 4 tree failures. This damage goes beyond personal losses. Since these are boulevard trees, publicly-owned trees, everyone in this community that pays taxes pays for these losses and subsequent replacement.

Stem Girdling Roots (SGR)



Unfortunately, most SGRs go undetected due to the fact that they're buried below ground, doing their damage to buried tree trunks. Most of the time, surveys and investigations have found that decay is present at the compression point and at the point of failure of the tree trunk.

2. Disproportionate Siting



There really is nothing wrong with these spruces except that they are dense and provide significant resistance to wind-loading events and that they have been planted too close to infrastructure that has severely retarded their normal root plate expansion.

2. Disproportionate Siting



2013

Little boulevards like this can safely support little plants...like weeds, not trees. Note how the roots of this hackberry turned and ran parallel with the sidewalk when the roots met the pavement, rather than growing under the sidewalk like most people think they do.

2. Disproportionate Siting



2013

And despite the fact that this was a generous median strip – 12 feet wide – the density of the trees (little-leaf linden) and the wind-tunnel that this parking area affords was too much for its limited stability.

2. Disproportionate Siting



Photos; Mary Montagne 2007

It's about physics. Seventy foot tall trees in narrow boulevards are more likely to fail than the same tree a few feet away in a landscape with normal root plate development.

2. Disproportionate Siting



Photos: Ben Johnson 2013

Another example. The larger the tree, the more likely it will fail in these tight footprints.

3. Root Damage or Loss



Fresh sidewalk repair
2005
Tree failure 2007



New curb and street installation

Root severance is the third-most common pre-existing condition for failures...when they can be documented. Anything that removes part of a tree's root plate makes it less stable. If the rooting space is already confined, the effects are even greater. The red arrow to the left is pointing at fresh sidewalk repairs made less than 12 months before the storm hit this community. The red arrow to the right is pointing out the new street surface and curbing in this area. Whenever this type of construction is done, root loss almost always occurs.

3. Root Damage or Loss



When sidewalk sections are repaired such as the two sections replaced in this photo, it's usually because trunk flares or roots have damaged the previous sidewalk. In this case, roots are ALWAYS cut prior to repair of the damaged sections.

4. Root Decay



Photo: Terry Straub 2013

Finally, root decay. Decay can start as wounding of roots or of trunks that has resulted in the decay moving into the trunk flare or root system. Regardless, the tree's strength has been compromised. This is very difficult to detect. Even if surface roots are visible, they may not show signs of decay even though they are decayed. Roots tend to compartmentalize better than branches or trunks, that is to contain decay in a certain area of the wood. However, most root decay begins at the underside of the root, moving upward so it can be difficult to detect.

Common Causes for Canopy Damage

1. ***INCLUDED BARK IN BRANCH ATTACHMENTS***
2. ***CODOMINANT LEADERS***
3. ***DECAY***
4. ***THE FAILURE TRIFECTA***

The failure trifecta is actually the most common reason that large branches fail: a combination of included bark, codominant leaders and decay. For small to mid-sized trees, included bark in branch attachments and codominant leaders are the most common reasons. A lot of the canopy damage records collected over the years includes damage due to ice storms, as opposed to total failures which are exclusively wind loading victims.

1. Included Bark Branch Attachments



First of all, look at the trees in the background. No damage. This was a thunderstorm. This ash had a branch attachment that was weak and heavy. Note the included bark attachment, bark included in the union of the branch to the trunk. The wood-to-wood union was compromised because the bark was taking up space.

1. Included Bark Branch Attachments



Photo: B Kirkpatrick

These weak attachments can occur all through the tree's canopy, not just lower branches. This branch was about 25 feet above ground.

Weak Branch Attachment: External View



Photo: Antoine Tireau

This is what a weak attachment, one with included bark looks like on the outside of the branch.

Weak Branch Attachment: Internal View



Photo: Antoine Tireau

To the inside, it's evident that there is not a normal branch wood-to-trunk wood connection. As the branch and trunk get larger and push against each other, the union develops a crack and is more likely to split out in a loading event.

Weak Branch Attachment: Internal View

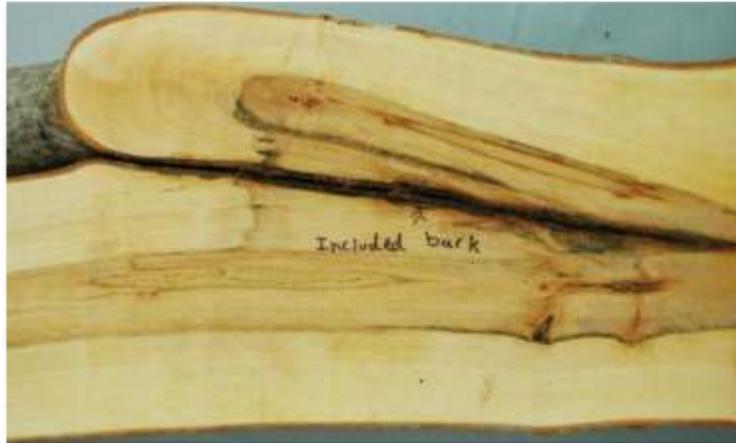


Photo: Antoine Tireau

As the cracking worsens, decay often enters the picture, further weakening the attachment.

2. Codominant Leaders



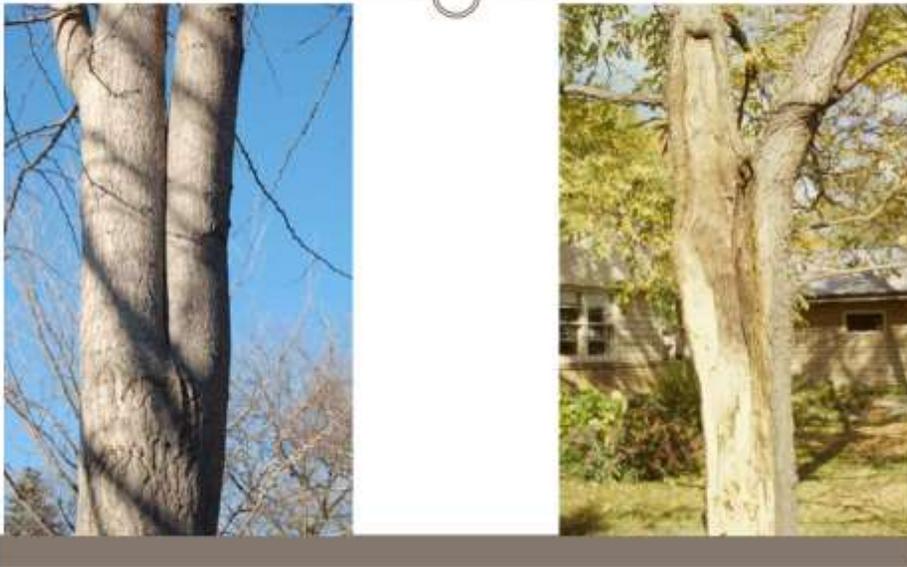
Codominant leaders, aka multiple leaders, are the second reason for branch failures in the canopy. The more vertical a branch grows, the more likely it will be heavy and the more likely it will have a weak attachment to the other leaders.

2. Codominant Leaders



Even historically strong trees such as this bur oak can develop codominant leaders. And even if the attachments are strong, they're not strong enough for tons of wood, moving violently in wind storms or weighted down mightily by ice. When they fail, they cause a lot of damage to the rest of the tree. This tree is beyond saving.

2. Codominant Leaders



Any tree can develop codominant leaders, such as this ginkgo to the left and Kentucky coffeetree to the right. Keep a close eye out for these problems when the trees are young and easy to care for.

Codominant Leaders: External View



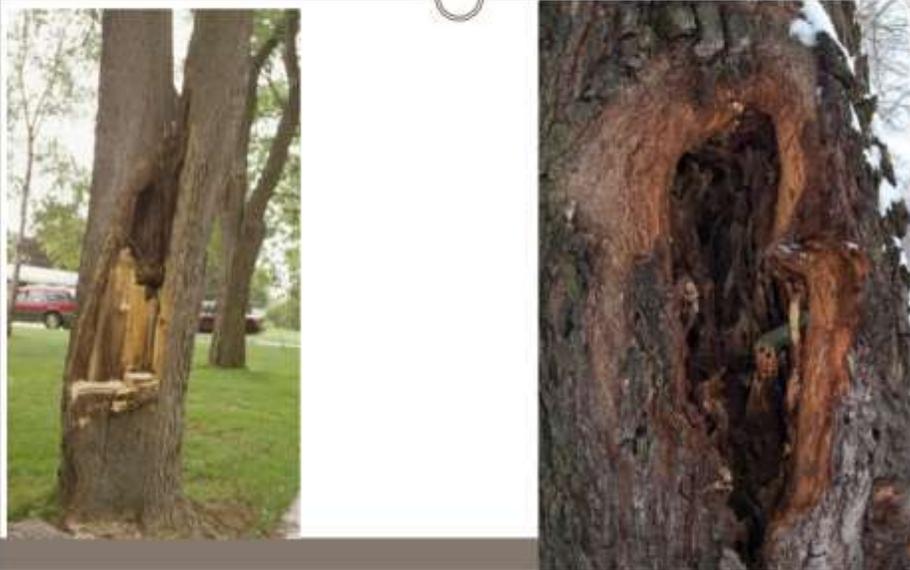
An external view of two trees with codominant leaders and included bark in their attachments.

Codominant Leaders: Internal View



The same trees, with an internal view. Note that there is no wood-wood attachment between the leaders.

3. Decay



Decay is the most common overall condition associated with failures, especially with codominant leaders and included bark. Decay weakens and makes bad situations worse. Often, it is difficult to detect decay in branch attachments with included bark, but it pays to be suspicious.

3. Decay



Photo: Terry Straub 2013

Decay is often found in extensive columns in tree trunks and main branches. Trees that are weak compartmentalizes have difficulty containing decay and tend to develop these extensive columns of weaknesses.

4. Failure Trifecta

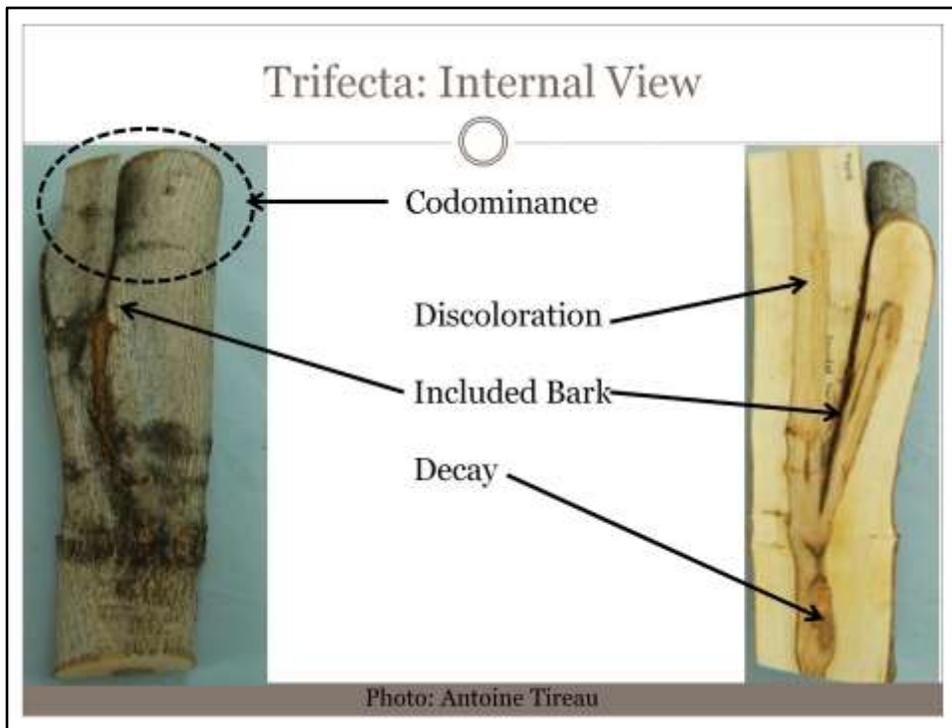


Although decay can be difficult to detect from the outside, a tree care professional should be suspicious when a tree has included bark and is codominant. Decay almost always accompanies these weakness, especially on larger, more decay-prone trees. Both of these trees are throwing strong hints at the person evaluating them: the tree to the left has an opening down in the trunk and the tree to the right is “fluxing” at the union. Both are indicators that there is decay to some degree.

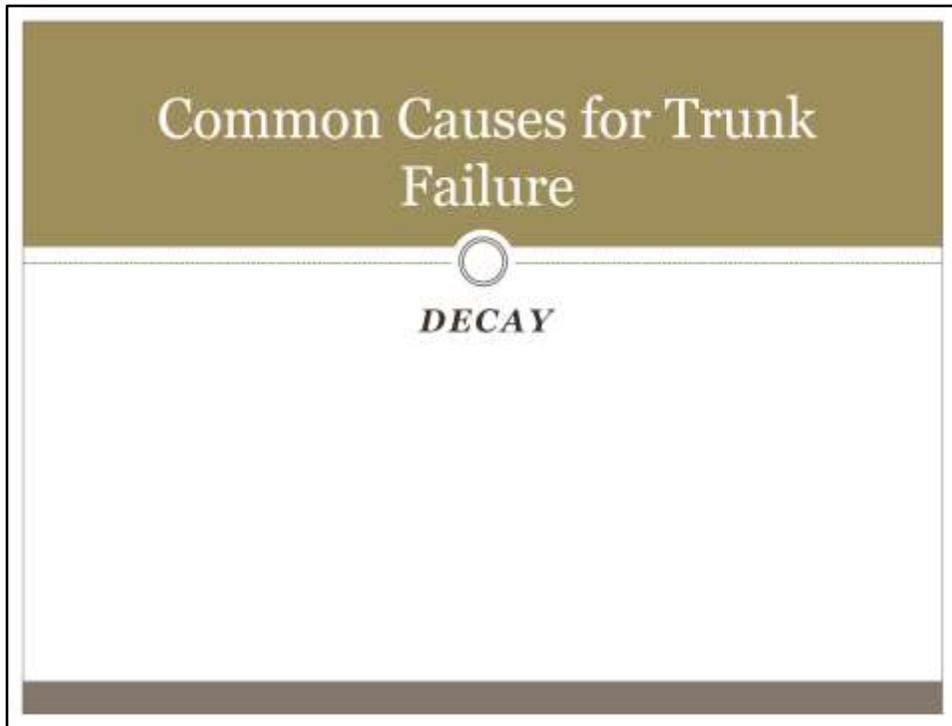
4. Failure Trifecta: Most Common Cause



When these three weaknesses meet on a larger tree, especially one prone to decay such as this hackberry, catastrophic damage result. This damage could have been prevented about 30 years ago with a couple of well-placed pruning cuts.



A seemingly harmless outside view can disguise a lot of interior defects. Learn how to recognize these indicators and get suspicious.



Trunk failures are pretty easy...they're almost always (>82% of the time) caused by decay in the trunk, a weakness in a dangerous spot.

Trunk Decay



Both of these trees had extensive decay before they failed. It also shows how even a relatively thick sapwood column can support a decay-weakened interior...to a point.

Trunk Decay



Ganoderma Wood Decay

Fruiting structures such as these that belong to one of the more common decay-causing fungi, are a definite clue that something is wrong. When *Ganoderma* produces a fruiting structure, the decay is already extensive in the trunk and perhaps the root system. Remove the tree before the next storm.



Sometimes the clue is a small hole to the exterior. It may be a squirrel hole or an old wound, like the one on the upper left. If it's a decay-prone tree like the silver maple to the left, get suspicious. The only clue on the ash to the right was that it was under a powerline and had been "topped" for several years, leaving large leaders chopped back like corn stalks.

Point Number Five

***MANY LOSSES CAN BE
MINIMIZED BY MANAGING
CAUSES OF DAMAGE***

It's not realistic to think all losses, even those predictable losses, can be prevented. But a realistic goal would be to minimize them, to a degree that the losses were no longer catastrophic or economically unacceptable.

Managing Causes of Damage

- **NO BURIED TREE TRUNKS**
- **NO BIG TREES IN SMALL TREE SPACES**
- **MINIMIZE ROOT LOSS OR REMOVE TREES**
- **NO CODOMINANTS – NO INCLUDED BARK**
- **WOUND AS LITTLE AS POSSIBLE**

There are many practices that can reduce the impact of storm losses. Here are five that more or less encompass a lot of the problems.

1. No Buried Tree Trunks



Photo: Sean Peterson

Don't bury tree trunks. If tree trunks aren't buried, the odds of SGRs causing trunks to snap off in wind storms is almost eliminated. There are instances of SGRs forming only above ground but that's a pretty unusual instance. At planting time, make sure all excess soil is removed above the first main order root and that the first main order root is level with the landscape surface. If that rule is followed, the tree trunk won't be buried.

1. No Buried Tree Trunks



Photos: Ben Johnson

Burying tree trunks can happen for a lot of reasons. Other than planting problems, excavations and regrading around trees in the landscape is probably the second-most common reason tree trunks get buried. First, don't allow soil to be stock-piled around tree trunks. It's bad for the roots, and rarely does all of the soil get removed carefully. Either there's too much soil removed during regrading and surface roots are damaged, or too much soil is left over the roots and against the tree trunk.

2. No Big Trees in Small Spaces



Boulevards need to be 8 feet wider than the projected flare of the tree trunk. Don't plant trees that have projected trunk flares of 6 feet in boulevards that are 6 feet or less in width. There will be problems. The trees will be damaged during the repair of the sidewalk or curb. The trees will more likely fail during wind storms.

2. No Trees in Small Spaces



The same rule applies above ground. If trees that are too tall for spaces under utility wires are topped back every 5-6 years, decay will set in, more dead wood will be produced, and more branches will break and fall in ice and wind storms.

2. No Trees in Small Spaces



Note the tree to the left. It's been pruned back so many times that there is extensive decay present and a lot of dead wood. It's perched in a narrow, inhospitable boulevard, so there's even more defensive die-back. The tree to the right is again just too big for the root plate space.

2. No Big Trees in Small Spaces



Great space to the left. 20 feet of planting strip will keep these trees healthy and vertical. Absolutely a waste of trees to the right. Boulevard less than 4 feet wide. These trees will fail prematurely in a wind storm...it's just a matter of time.

How About No Small Spaces Period?



One solution if the community can't provide wider boulevards is to have no boulevards. This neighborhood moved the sidewalks next to the curb and planted the trees to the front yard side of the sidewalk, which is city Right-of-Way property, still city property and still city trees.

3. Minimize Root Loss or Remove Trees



The sidewalk and soil over these ash trees has been excavated and reformed, compacted, etc. These trees should be removed now. Nothing should be replanted in these skinny boulevard spaces.

3. Minimize Root Loss or Remove Trees



Despite the cries of neighborhood to keep trees at all costs, sometimes it's just not reasonable to keep unstable trees. If root systems can't be preserved, then remove the tree during street/sidewalk construction and plant an alternative plan.

3. Minimize Root Loss or Remove Trees



Note the freshly repaired sidewalk and the horizontal oak. No good came from damaging so many tree roots and then keeping an unstable tree.

3. Minimize Root Loss or Remove Trees



Left Photo: Advanced Tree Care, Inc.

Relocating sidewalks that have come in conflict with tree roots is a good way to keep trees stable and sidewalks solid. The tree to the right was preserved with a large rooting space during development and 15 years later is still healthy and vertical.

4. No Codominants...No Included Bark



Remove codominant leaders when they are small and light. The resulting wounds are smaller and will compartmentalize faster. Within a couple of years, the trees will look like nothing was ever removed from their canopy.

5. Wound as Little as Possible



No Flush Cuts



No Large+Sloppy Cuts

No flush cuts. Flush cuts are too large and they wound the tree trunk, setting off a decay process that will shorten the tree's life. On the right photo, a good example of a property-owner waiting too long to prune the tree. The diameter of the pruning wound is 14 inches, very difficult to seal over quickly and efficiently compartmentalize the wound. Plus, whoever pruned the branch did it poorly. Note the torn bark, further wounding the tree trunk.

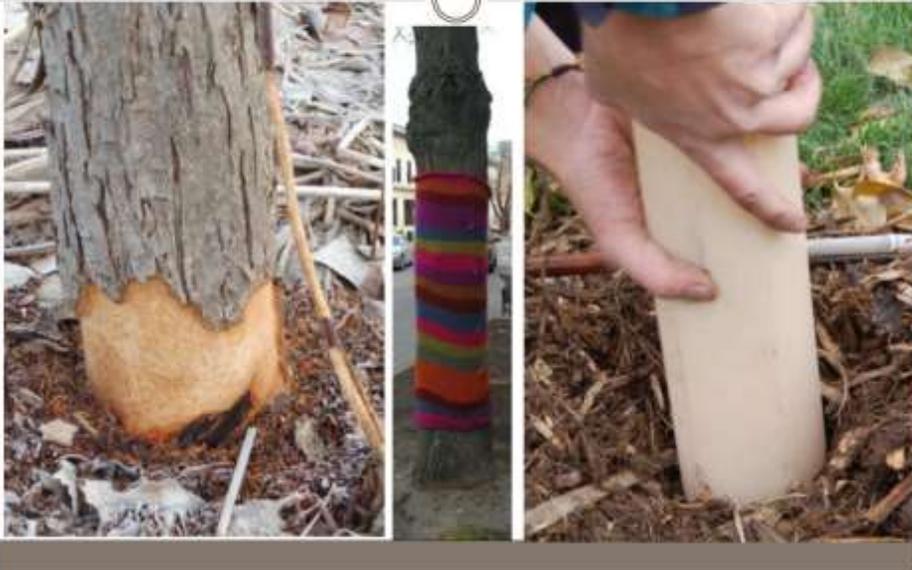
5. Wound as Little as Possible



Avoid Drought or Drought-like Conditions that Lead to Frost Cracks

Frost cracks wound trunk wood and begin the inevitable decay. Frost cracks form when it's real cold, they start at a wound on the stem and they are a major problem only on water stressed trees. So, avoid wounding tree trunks, keep the trees well-watered in droughty periods or if they've been planted in a droughty site (e.g., parking lot), and the frequency of frost cracks drops significantly.

5. Wound as Little as Possible



Prevent critter damage to trees. Hardware cloth and tree tubes will keep rabbits and voles from wounding the stems, beginning the decay process.

5. Wound as Little as Possible



Avoid Mower/Trimmer Damage

Finally, protect the tree trunks from lawnmowers and string trimmers. Trunk guards help. Getting rid of turfgrass growing near tree trunks removes the necessity of trimming the grass away. Fewer wounds, less decay, fewer frost cracks.

This presentation available at:

www.trees.umn.edu



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