As regulators increasingly scrutinize reliability of electric service, storm response and mandate reliability targets, trees emerge as a major risk to utilities. Understanding the drivers of tree liability opens the door to managing tree risk and simultaneously minimizing tree-related outages and maintenance costs.

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Vegetation Management Concepts and Principles

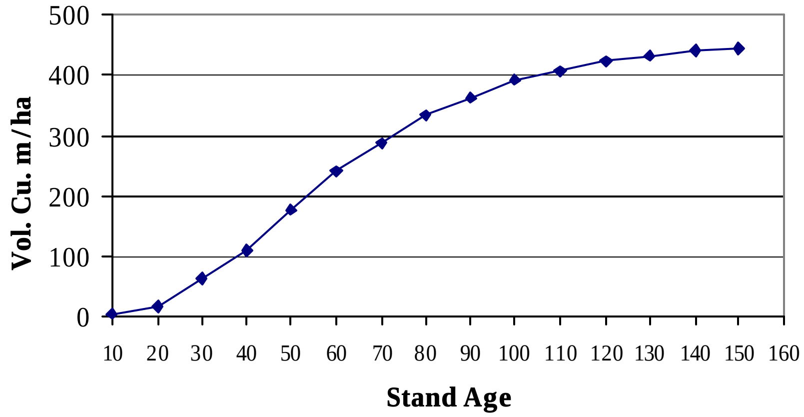
Trees that interrupt electric service can be categorized as in-growth trees and in-fall trees. The inventory of all trees that have the potential to either grow into a power line or, on failure (breakage), fall into and strike a conductor will be referred to as the utility forest. While we commonly think of forests in terms of more or less rectangular blocks the utility forest amounts to ribbons or transects of the service area. Generally, the centerline of these transects is the power line. The utility forest has the same characteristics as any forest. In most cases the tree species composition is what is native to the area and their intrinsic patterns of biomass addition (tree growth) and tree mortality apply. Both of these patterns are significant factors in power line security and both can be mathematically represented by logarithmic, exponential or sigmoid curves, as illustrated in *Exhibit 0-1* and *Exhibit 0-2.*

Biomass additions result in trees that encroach on conductors, thereby necessitating tree pruning and either mechanical or chemical (herbicide) brush clearing. Failure to mitigate this encroachment leads to deteriorating safety and reliability. *Exhibit 0-1* shows an asymptotic curve that is typical of biological populations.

Tree mortality produces decadent trees that are subject to breakage or tipping over (*Exhibit 0-2*). Tree mortality is not an event that occurs at a specific point in time. Rather, tree mortality occurs over a period of months and years. Natural tree mortality is a process of losing vigour either due to the stress of competition for light, water and nutrients or an inability to sustain the attained mass. In the early stages of senescence or decline there may be no visible defect. However, as the tree becomes increasingly decadent and subject to failure under increasingly less stress loading, symptoms of the decline become apparent. Such senescent trees must be identified as faulty and prone to failure under weather stress and must be removed prior to the occurrence of stress. *Exhibit 0-2* shows both the forest stand density over time and the population of trees of concern to utility facilities, the Decadent Trees. Because the capacity of the land-base to produce biomass is limited, the line for the evolution of decadent trees must be asymptotic. Indeed, over the eighty years of forest stand data (*Exhibit 0-2*), the line for Decadent Trees is seen to be asymptotic.

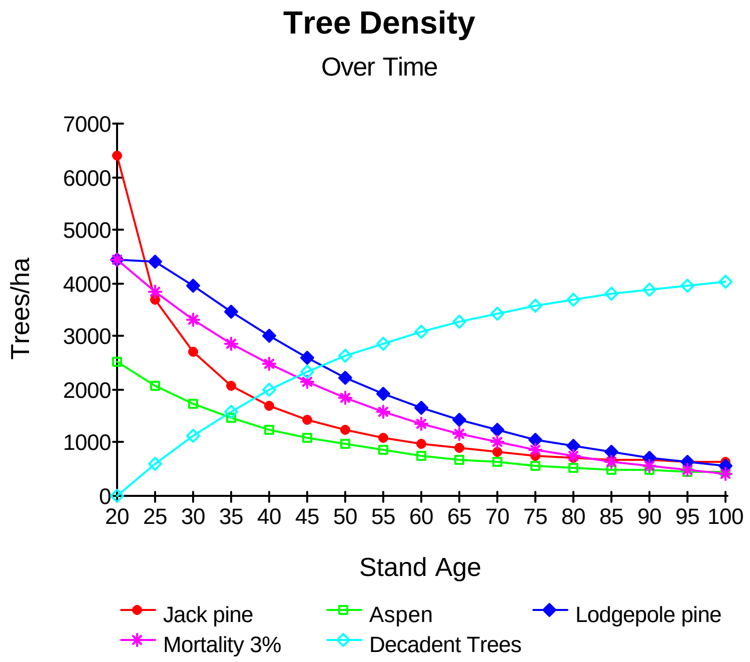
The nature of the expansion of the two sources of tree-caused interruptions, biomass addition (in-growth) and tree mortality (in-fall), is additive. This in conjunction with the

Exhibit 0-1
Forest Biomass Addition
Timber Production
Spruce on Good Site



Source: Freedman, Bill and Todd Keith, 1995. Planting Trees for Carbon Credits. Tree Canada Foundation.

Exhibit 0-2
Stand Density
Fire Origin Species



Source: Adapted from Johnstone, W.D. 1976 & Plonski's Yield Tables

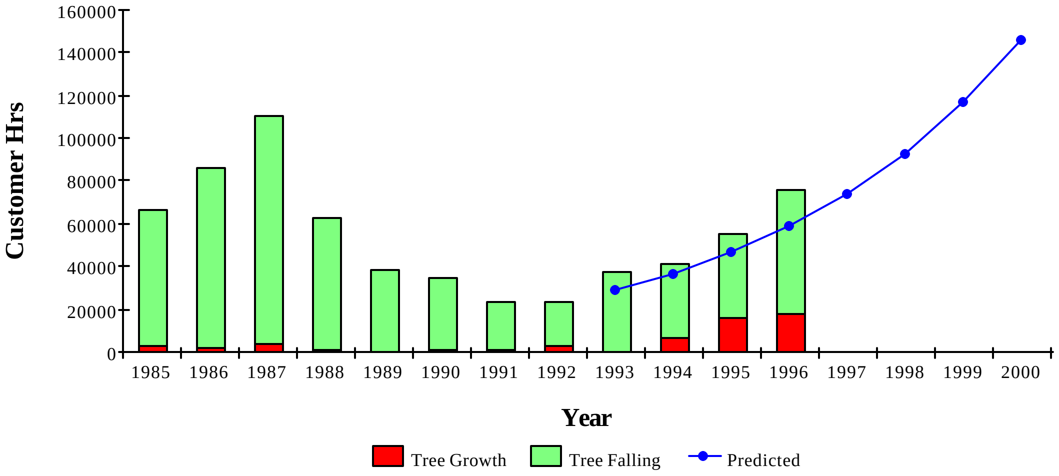
Note: To the graph showing the remaining live, viable trees over time, a line showing the cumulative dead or dying trees, labelled Decadent Trees, has been added. It is these decadent or emerging hazard trees that are of interest to utilities because they hold the greatest potential to disrupt electrical service. From 40% to > 80% of trees in the 20 year-old stand die over the next 80 years.

process of tree mortality leads to insight into the consequences of failure to manage trees in proximity to power lines.

From a utility perspective, trees represent a liability in both the legal and financial sense. The fact that utility forest expansion follows an exponential or logarithmic function is significant. It means that the tree liability, if not managed, will grow exponentially.

Trees cause service interruptions by growing into energized conductors and establishing either a phase-to-phase or phase-to-ground fault. Trees also disrupt service when they or their branches fail, striking the line and causing phase-to-phase faults or phase-to-ground faults or breaking the continuity of the circuit. Because the two factors that are responsible for service interruptions, tree growth (biomass addition *Exhibit 0-1*) and tree mortality (*Exhibit 0-2*), change by exponential or logarithmic function, the progression of tree-related outages is, necessarily, also exponential (*Exhibit 0-3*). Failure to manage the tree liability leads to both exponentially expanding future costs and tree-related outages. Conversely, it is possible to simultaneously minimize vegetation management costs and tree-related outages (*Exhibit 0-4*).

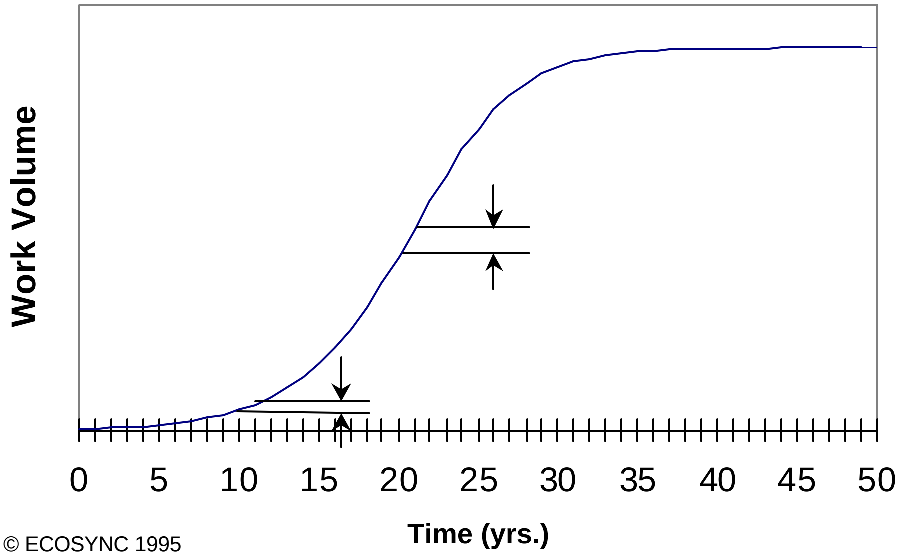
Exhibit 0-3
Tree-caused Distribution Outage Statistics



Source: Western Canadian utility
Note: This work and prediction for future tree-caused outages was performed in early 1997 to show the expected trend to 2000 based on funding below that required to remove the annual workload volume increment.

It is not possible to totally eliminate the tree liability because the ecological process of succession is a constant force for the re-establishment of trees from whence they were removed. The tree liability then is like a debt that can never be completely repaid. Under such circumstances, the best economy is found in maintaining the debt at the minimum level, thereby minimizing the annual accrued interest. However, irrespective of cost, minimizing the size of the tree liability or utility forest is rarely an option for utilities because there are multiple stakeholders with an interest in the trees. What can be achieved, however, is equilibrium. The tree liability can be held at a constant point by annually addressing the workload increment (*Exhibit 0-4*). To continue the debt analogy, a debt is stabilized when the annual payments equal the interest that accrues throughout the year. The interest equivalent in the utility forest is comprised of annual tree growth and mortality. Actions that parallel the reduction in the debt principal are actions that actually decrease the number of trees in the utility forest. Such actions include removal of trees and brush by cutting or through herbicide use.

Exhibit 0-4
Stabilizing Tree Workload
(Illustrative Model)



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The graph shows the work volume that must be completed in a year to hold tree work inventory, costs and reliability steady. Performing less than the annual workload-volume increment shifts the total tree work inventory to the right, thus necessitating greater annual vegetation management expenditures to arrest the expansion of tree-related service interruptions.

When the pruning cycle removes the annual growth increment and the hazard tree program removes trees as they become decadent (*Exhibit 0-4*), tree-related outages are stabilized. The residual level of tree-related outages reflects the interaction of several characteristics, including the size of the utility forest, chosen maintenance standards (such as clear width), tree-conductor clearance, and tree-species characteristics (such as mode of failure and decay). An expression of a managed tree liability, one in which the annual workload volume increment is removed, is stable tree-related outages. Reducing tree-related outages below an achieved equilibrium necessitates actions that decrease the size of the utility forest. Actions are not limited to vegetation management. For example, increasing conductor height reduces the size of the utility forest as it reduces the number of trees that are capable of striking the line.

Funding

There are three possible outcomes, which are determined by the level of investment made in vegetation management.

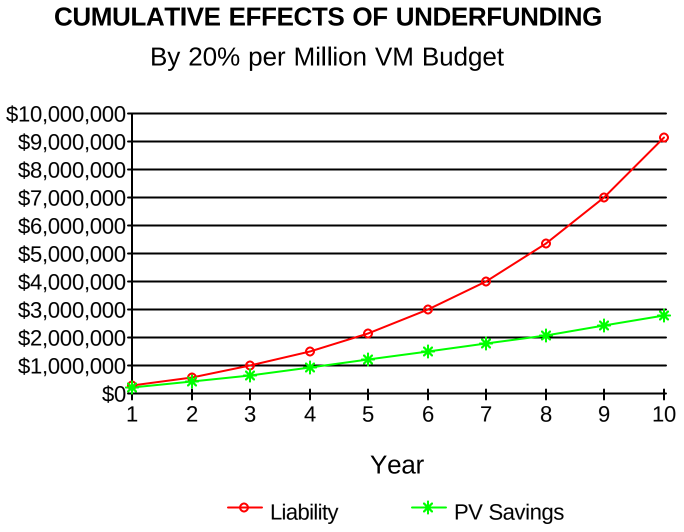
1. The annual workload volume increment is removed, thus keeping the size of the tree liability and next year's workload increment constant.
2. More than the annual workload volume increment is removed, thus decreasing the size of the tree liability and the subsequent year's workload increment.
3. Less than the annual workload volume increment is removed, thus increasing the size of the tree liability. That is because the work not done, expands exponentially, thus increasing the workload increment for the following year.

Tree-related outages are an expression of the tree liability. Hence, changes in the tree liability result in proportional changes in tree-related outages (*Exhibit 0-3, Exhibit 0-5*). Actual outage experience may deviate from the trend based on variance from mean weather conditions.

When less than the annual workload volume increment is removed, the fact that tree liability increases exponentially has two major implications for future costs and reliability. First, the impact of doing less vegetation management work than the annual workload volume increment, as expressed through tree-related outages, may be relatively imperceptible for a few years. Second, the point at which the impact of under-funding is readily observed in deteriorating reliability is where the effect of annual compounding in the workload, and thereby costs, is large (*Exhibit 0-5*). The lack of a significant negative reliability response to reduced vegetation management investment (see 1992 to 1996 *Exhibit 0-3*) may provoke further funding reductions, thereby exacerbating the size of the future re-investment required to contain tree-related outages.

Recognition that the tree workload expands exponentially serves to explain some common utility experience. For many utilities, graphing customer hours lost on tree-caused interruptions over the last ten to twenty years reveals cyclical up and down trends (*Exhibit 0-3*). There are periods when trees are perceived as a problem and funding is increased. Increased funding permits a buying down of the tree liability, reducing tree risks and tree-related outages. Faced with these positive results, spending on vegetation management is reduced. While this tendency is perfectly logical, without the conceptual framework outlined, it is inevitable that funding will be reduced to the point where there is an observable response in tree-related outages. Unfortunately, by the time that tree-related outages are definitively observed to be on an increasing trend, vegetation management investment has been less than what is required to remove the annual workload volume increment for some years. At this point, the power of compounding is well under way and only a very aggressive increase in funding will arrest the trend. The rate of change in the workload liability in *Exhibit 0-5* is approximately equal to a compounding rate of 27% per year. Warmer climates with a longer growing season support higher rates of change. In other words, for distribution systems, the rate of change in the tree workload is substantially higher than the discount rate one would conceivably use to derive the present value benefit of deferred maintenance spending. Taking a short-term financial perspective, any deferred or diverted vegetation management funding that inhibits removal of the annual workload volume increment is poorly allocated unless it provides a better rate of return. The example provided in *Exhibit 0-5* shows that returning the work volume and reliability to the original levels after 10 years of under-funding by 20%, increases costs by 80% over maintenance, which annually removes the workload volume increment.

Exhibit 0-5
Impact of Under-Funding Vegetation Management Revealed Over Time



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Notes: Rate of change in liability based on western Canadian utility with a 4-month growing season.
Interest/Discount rate = 6%

It has been shown that under-funding VM has a substantial impact on future reliability and costs to return to the level of reliability enjoyed before under-funding. The increase in workload due to deferred maintenance is not linear. Hence, the impacts of a dollar deferred this year cannot be erased with an investment of a dollar next year. Further, this section has provided the conceptual context that utilities have lacked, which lack has allowed the inefficient, repetitive cycles of under-funding followed by reactive catch-up periods.

Exhibit 0-5 illustrates that failing to make the necessary investment in vegetation management will, in most circumstances, prove imprudent. While utilities are expected to justify their intended vegetation management expenditures, regulators play a role in the effectiveness of the program. Failure to understand the nature of vegetation management workload expansion or skepticism that leads to decisions limiting the ability to remove the annual workload volume increment, will impose the inefficiencies illustrated in *Exhibit 0-5*. By focusing on cost containment, the regulatory process risks supporting such inefficiency. Utilities that are pressured to minimize costs must prove the harm that will result as a consequence of failure to fund and perform proposed work. This burden of proof proves very challenging for maintenance work, where it becomes necessary to prove that an event that did not occur would have occurred but for specific actions and expenditures. By insisting on demonstrable harm, the regulatory structure supports a reactive approach to maintenance with the attendant cyclical inefficiencies.

Managing the Tree Liability for Positive Returns

Trees need to be recognized as a liability in a utility context. While this puts utilities in conflict with community perceptions of trees as assets, the conflict does not change the fact that trees hold only the capacity to impair the safe, reliable operation of the electric system, not to augment it in any way. Recognizing and quantifying the utility forest as a liability provides a measure of the potential for, or risk of, tree-conductor conflicts. Furthermore, it connects and clarifies the influence of design and operating decisions on maintenance costs and reliability risks.

Managing the tree liability necessitates an understanding of how and where tree risks arise, a quantification of the extent of tree exposure, the rate of change in the tree liability, and a commitment to funding that permits, at a minimum, the removal of the annual workload volume increment.

Appropriate investment in vegetation management is one of the best investments a utility can make. It serves to minimize tree-caused interruptions for the chosen clearance standard, thereby avoiding customer complaints, the need for regulator intervention, and in some cases performance penalties. It avoids the inefficiencies that are inherent in the cycle of allowing trees to become a major problem, getting trees under control by buying down the tree liability, and then losing the investment by failing to contain the tree liability. Investment based on the removal of the annual tree workload increment provides the conceptual approach that is needed to deliver a sustainable, least-cost vegetation management program (*Exhibit 0-4*). Simultaneously, such a program provides the lowest incidence of tree-caused service interruptions for community-accepted clearance standards, thereby benefiting ratepayers and shareholders alike.