Notes on the Adirondack Blowdown of July 15th, 1995

Scientific Background, Observations, and Policy Issues

BY JERRY JENKINS

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WILDLIFE CONSERVATION SOCIETY

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COVER PHOTO
Liza Graham/Area in Adirondack Park affected by 1995 blowdown

This summary report and position paper was prepared for the Wildlife Conservation Society by Jerry Jenkins, White Creek Field School, White Creek, New York 12057, (518) 686-7208.

Foreword

The Adirondack Blowdown of 1995 was a natural event at an exceptional scale. Just before dawn on the morning of July 15th, the sky exploded with thousands of lightning flashes at a rate of more than one per second. This dazzling display was the prelude to a broad wave of thunderstorms that crashed into the northwestern slope of New York's Adirondack mountains. The system proved to be a rare derecho, or straight-line storm of highly concentrated windbursts, at times surpassing 100 miles per hour. Less than an hour later, the sunrise would reveal that as many as half of all the trees in a forested area of nearly 100,000 acres were blown down, most with their crowns pointing to the southeast.

Flying over the area with Jerry Jenkins, the author of this document, I was deeply humbled by this reminder of Nature's raw power. I had witnessed the effects of tornadoes in the Midwest and volcanoes in central Africa, but these paled in comparison with the scale of this storm. Perhaps because my 14 year-old son had been camping in the area when the storm hit, I was also struck by the fact that we normally judge such natural events in human terms of structures destroyed and lives lost; some of which sadly happened in the Adirondacks, too. But the devastation was nothing like it would have been had the storm struck in an area of even moderate human settlement. Instead, the Blowdown of '95 unleashed its greatest force in the midst of one of the world's largest forest reserves.

The Adirondack Park covers more than six million acres, or 10,000 miles², of mountainous terrain in northeastern New York State. In the Oswegatchie River basin, where the storm's fury was concentrat4 mixed northern forest communities predominate over a landscape dotted with extensive wetlands and cut by a dense network of waterways. The region is further characterized by the unique mix of land ownership and land use patterns that is typical of the Adirondacks: publicly-held old-growth and functional old-growth forests, juxtaposed with active commercial forestry lands in private hands. The result is an exceptional opportunity to understand the effects of large-scale natural disturbance at an ecosystem scale, as well as the implications of such disturbance for future forest management under different land use practices.

The Wildlife Conservation Society supports more than 260 projects in 53 countries around the world. These projects combine field research to understand complex problems with active conservation efforts to protect key ecosystems and wildlife populations. The most difficult of these projects focus on last-ditch efforts to maintain small relict habitats and populations. Where possible, it is far more efficient to work at the scale of larger ecosystems. Advantages include not only the presence of intact natural communities, but more flexible options to combine preservation with systems of sustainable use, in which management is guided by regular monitoring. Such sites also represent the last "living laboratories" where natural ecological processes, including disturbance, can be studied effectively. For all of these reasons, WCS supports work at dozens of large-scale forest sites around the world, from the Congo Basin to Papua New Guinea and from the Amazon to the Adirondacks.

Notes on the Adirondack Blowdown of July 15th, 1995 contains a wealth of information about the origins, impacts, and implications of a major natural event in an ecosystem of global importance, all presented in an extremely accessible style by long-time Adirondack researcher Jerry Jenkins. The Wildlife Conservation Society is proud to have supported this effort and we hope that it proves helpful to all those interested in better understanding, managing, and protecting our natural forest heritage.

Bill Weber
Director, North America Program

WCS Working Paper Series

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NOTES ON THE ADIRONDACK BLOWDOWN OF JULY 15TH, 1995: SCIENTIFIC BACKGROUND, OBSERVATIONS, AND POLICY ISSUES

A summary report and position paper, prepared for the Wildlife Conservation Society by:

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Contents

Figures

Boxes

1. Introduction

On July 15, 1995 a severe windstorm crossed the Adirondacks. It originated north of Lake Huron, crossed Lake Ontario about 4:30 a.m. traveling east-southeast, did heavy damage to the western Adirondacks between 5 and 5:30 a.m., and passed over Lake George and out of the Adirondacks at about 7:30 a.m. It had heavy rains, much thunder and lightning, and intense, gusty, northwest winds that probably exceeded 100 mph.

Structurally the storm was a narrow, elongate, rapidly moving line of thunderstorm cells. Such storms are called ***derechos*** (literally direct or straight-line storms) by meteorologists. They differ from local storms by being longer-lived and having many convective cells in a line. Typically they are also faster moving and much more violent. They are well known in the Midwest, where they are often associated with widespread crop damage and often outbreaks of medium-intensity tornadoes. They are much less well known in the northeast, and it is possible that the July 15th storm is the most violent eastern derecho on record.

The storm did relatively little damage to structures, but blew down many trees. The New York State Department of Environmental Conservation's (DEC) current estimate is that some 38,000 acres suffered severe damage (60% or more of the trees blown down) and another 109,000 acres suffered moderate damage (30-60% of the trees blown down.) This would make the July 15th storm the second most damaging windstorm on record for New York. The first would be the windstorm of November 25, 1950, which is estimated to have caused moderate or severe damage on ca. 400,000 acres.

The blowdown had a variety of effects. It caused five fatalities, blocked (and in fact obliterated) a number of trails, and stranded roughly 90 hikers and canoeists, requiring the largest rescue operation in the DEC's history. It limited public access to wilderness and recreation and imposed large clean-up costs on towns. And, perhaps most important, it created landscape scale-changes in forest structure which will, in coming years, have continuing effects on forest ecology, forest economics, and public safety.

The effects of the blowdown, and the possible public responses to them, have created much discussion. The discussion has centered on four issues: the steps to be taken to re-open areas in which public access has been blocked, the danger of fire on both public and private lands, the extent to which salvage should be permitted on private lands, and the desirability and legality of salvage on public lands.

The issues of re-establishing, access to public lands and salvaging timber on private lands are important, but not particularly contentious. Essentially they are permitting issues. Almost everyone agrees that access should re-established and salvage permitted on private lands; the issues deal with how and to what extent these things are to be done.

The fire and public salvage issues, on the other hand, are highly contentious, and there is much disagreement on what, if anything, should be done.

The reasons for this derive, in part, from two historical events. The first was a period of extensive fires that occurred about 90 years ago. Roughly 850,000 acres burned in 10 years, or about 14% of the area currently within the Adirondack Park. Some individual fires included over 100,000 acres and extended for 20 miles or more. Many of these fires were in logging slash on cut-over lands. Blowdowns, at least superficially, resemble cut-over lands, and many people fear that unless the fire hazard is somehow reduced we could see a return of the great fires of 1903 or 1908.

The other historical event that informs the present debate is the 1951-1954 timber salvage on forest preserve lands, in which the state contracted for the removal of about 300,000 cords of lumber to 'clean up' after a major windstorm in November, 1950 (Box 1, p. 3). About 60,000 acres of blowdown were cleared, substantial amounts of it in virgin forest. The salvage netted the state 1.2 million dollars in revenues, in apparent violation of a provision of the constitutional provision which forbids the sale of forest preserve timber.

The two events are connected because the major justification for the 1951-1954 salvage was the perceived danger of widespread fires. Conservation Department Commissioner Perry Duryea said that timber salvage was necessary because 'a single bolt of lightning or the carelessness of a single person could touch off a holocaust.' And Attorney General Nathaniel Goldstein argued that the job of the state was to preserve the forests, and that the current emergency justified following the 'spirit rather than the letter' of the constitution. This pleased the Conservation Department, who had long advocated (and would continue to advocate) that the public lands were an economic resource and should be used commercially. But it displeased people who believed that the forest preserve was created specifically to protect the forests from commercial use, and that by conducting a salvage the Conservation Department was evading its constitutional obligations.

The constitutional obligation, which goes back to 1894 and is at the heart of the debate about salvage, says bluntly that timber on Forest Preserve lands shall not be 'sold, removed, or destroyed.' The protection it affords, which is enjoyed by no other state forest system, has made the forest preserve unique among American forests, and an ecological reserve of world significance. The forest preserve currently contains some 85% of the designated wilderness in the northeastern U.S., 40% of the designated wilderness east of the Mississippi, and more old-growth (virgin) forests than the remainder of the northeast put together. The largest proven stand of old- growth forest in the Adirondacks is in the Five Ponds Wilderness. This is the area that received the most concentrated damage in the July 15th storm, and this makes the discussion of possible salvage one of national importance for conservation and ecological research.

It would at first seem that, given the clear constitutional protection of the timber and the accepted value of the wilderness area involved, that a salvage operation is unlikely. And so it may be, but preservationists note that many of the same pressures that lead to the salvage after the 1950 storm (fear of fire, desire to make economic use of the forest preserve, desire to see roads opened in roadless areas, arguments that economic loss or emergencies justify setting aside constitutional protections) still exist, and that public discussion of the values and the issues involved is clearly required.

Box 1: The 1950 Adirondack Blowdown and the Subsequent Timber Salvage

25 November, 1950. A large cyclonic storm, the 'Big Blow', moves from south to north across the western Adirondacks. The state estimates that 400,000 acres have moderate to severe damage.

12 Dec. 1950 DEC Commissioner Perry Duryea writes Attorney General Nathaniel Goldstein, saying that there has been a staggering economic loss and that there is an unprecedented fire hazard, and asking whether some combination of Article 14 and the 'broad police powers of the State 'might not allow the removal of the dead trees which 'now constitute such a menace.'

28 Dec. 1950 The Attorney General replies that 'To observe the letter of the constitutional protection with the most extreme strictness by remaining passive in the present emergency would ignore the spirit and purpose thereof an 'd destroy rather than promote its efficacy.' He says that the DEC may legally cut logs, but will need legislative authorization to sell them, and that 'Since the salvage operation is so inseparably incidental, if not essential, to the elimination of the fire hazard, in my opinion it would be within the competence of the Legislature to grant such authority, not withstanding the prohibition contained in Article)GV.' He also says, as an ancillary justification, that in the 'grave emergency facing our nation', the trees should be salvaged so their products can be used for defense needs.

16 Jan. 1951 Governor Thomas Dewey recommends that the legislature appropriate $200,000 to begin the salvage, financing it from a revolving fund into which the proceeds from the salvage would be paid. The legislature passes such a bill, and Dewey signs it on January 3. While the bill raises obvious constitutional questions, and while conservation groups have challenged much smaller timber removals in the past, the bill is never tested in court.

June 1951 The state has now put 111 parcels of blown-down timber up for bid. The conditions are fairly stiff. the contractor will have to build any necessary roads, take out all damaged trees in the work area, lop (cut branches off) tree tops all the way to the terminal bud, and may not cut undamaged trees in the work areas. Because of the conditions and the remoteness, the contracts are not popular. On first 16 parcels the DEC gets 4 acceptable bids; on the next 47, only 21 bids; on the next 48, only 11. The most desirable contracts are in areas where there were substantial amounts of old-growth pine and spruce.

31 Dec. 1952 A total of 135 salvage contracts have been negotiated, for roughly 230,00 cords of pulpwood and 30,000,000 board feet (ca. 60,000 cords) of saw timber, covering roughly 107,000 acres. 119 projects have begun, and 206,000 cords of pulpwood and 24,000,000 board feet of timber removed, or 88% of the contracted amount. But only 37,000 of the 106,000 acres have been salvaged. This is 35% of the contracted area, and only 9% of the blowdown. That 88% of the contracted volume of timber has been taken off 35% of the contracted land area indicates either that the volume of down wood is 2.5 times higher than was estimated, or the operators are taking live trees as well as down ones.

Box 1, cont.

18 July, 1953. A fire is spotted in the Cold River Blowdown, about four miles from the Shattuck Clearing Ranger Station. This is located in a 12 mile-wide blowdown that has not been salvaged because of inaccessibility. There is a recently constructed truck road to the ranger station and a foot trail along the river. The fire appeared shortly after a severe thunderstorm, and is believed to have been caused by lightning. Men carry power pumps and hoses to the fire. A rainstorm the following afternoon slows the fire, and it is controlled, with a total of 500 men and much equipment, about 48 hours after it starts. It bums 240 acres, and is the only severe fire, though not the only fire, in a blowdown area.

31 Dec. 1953 Pulpwood prices, which crashed in late 1952, remain low, hindering salvage; many operators have abandoned contracts. Balsam fir and hardwoods have decayed sufficiently that they are unmerchantable, and only spruce is currently marketable. 159 contracts have been negotiated, out of 186 offered. 230,000 cords of pulpwood and 43,000,000 board feet of lumber have been removed from 48,000 acres. This is 99% of the contracted volume, but only 44% of the estimated area.

The report of the Joint Legislative Committee on Natural Resources notes possible cutting of live trees, but thinks the amount unimportant, and blames any timber theft on individual workers: "the violations (in all cases investigated attributable to greedy wood-choppers) in view of the magnitude of the entire program have been infinitesimal." Clarence Petty, who as a forest ranger investigated many of the violations, remembers otherwise, and says they were anything but infinitesimal, and that some companies, in view of the difficulty of salvaging the dead timber, were taking as much live timber as they could get away with.'

31 Oct. 1954 The spruce is now too decayed for most mills, and the salvage essentially over. An told, 169 contracts were sold out of 194 offered. 106 contracts are judged complete, 16 still active, and the remaining 47 terminated or never started. 58,000 acres have been salvaged. This is 50% of the land contracted for, 32% of the land offered for sale, and 13% of the land blown down. 242,000 cords of pulpwood was salvaged, essentially all softwood. 40,000,000 board feet of lumber (ca. 80,000 cords) were salvaged, 77% of it softwood.

The salvage nets the state $ 1.1 million from its contracts, plus an estimated $166,000 of value from 1,800,000 board feet of lumber that it salvages for its own purposes. The geographic details of the salvage are sketchy, but there is known to have been salvage in the Blue Mt. Lake, Whitney park, Raquette Lake, Inlet, Litchfield Park, Beaver River, Stillwater, Cold River, Martin Brook and Speculator Tracts.

I have written this paper to try to contribute to that discussion. I have been doing field biology in the Adirondacks since the middle 1980's, and became interested in the blowdown and the related issues of policy and conservation while planning a trip to blowdown area in August 1995. It seemed to me that the issues involved -- forest and fire ecology, Article XIV case law, practical considerations about timber salvage and forest economics -- were factually and scientifically complex, and that there might be some use for a document that reviewed the scientific background and the facts, and explained how they related to possible policy options. Bill Weber, the director of the North American Program of the Wildlife Conservation Society (WCS), and I were at that time discussing the direction that a WCS research initiative in the western Adirondacks might take. He was interested in the idea of a short project reviewing the blowdown, and arranged for WCS to fund the field research and writing involved.

In researching and preparing this paper I had four goals:

> To gather information about the storm and blowdown, and to give a factual picture of what happened.
>
> To summarize scientific observations on similar blowdowns, and to make clear what we know and what we don't know about the effects of the blowdown on forest ecology.

To summarize some of the policy options for dealing with problems created by the blowdown, and comment on the advantage and disadvantages of the options.

To explain that the blowdown represents an opportunity to advance our understanding of forest ecology and conservation biology, and to urge readers to consider taking advantage of that opportunity.

Readers may want to note that while I have approached the factual and scientific questions in this report as objectively as I could, I have worked for many years in conservation biology, and have strong personal feelings about the value of protecting unmanaged ecosystems. This bias will be apparent in some of my evaluations of the policy options available, and in my willingness, as an ecologist and naturalist, to regard the blowdown as a gift rather than a disaster.

This study parallels an ecological evaluation of the blowdown that has been made by the DEC, and which will appear about the time that this does. The two studies are related in scope but independent and somewhat different in organization. The DEC's study was a group effort and as such was able to draw on the expertise of an impressive group of people from different fields. But it was somewhat of a disjointed effort: the working groups (meteorology, mapping, fire, wildlife, vegetation) did not meet with one another or exchange maps or data, and in some cases never visited the blowdown; and the final report was never discussed or edited by the working groups that contributed to it.

This report, on the other hand, is a one-person effort, with the strengths and weakness that that entails. Its strengths, I would like to think, arise from my having been able to gather data and ideas from many different people, and to combine them with what I had learned from three weeks of field studies in the blowdown. Its weaknesses, I think, are that a single researcher can never be expert in all the different scientific fields involved in an event of this type, and can never know enough about the factual background of the policy issues involved. In areas where my interpretation differs from that in the DEC Storm Assessment, readers should be aware that while I may have been in a better position to evaluate contradictory theories and information, the state had access to much more expertise and data than I had, and had collaborators whose scientific and historical knowledge exceeds mine.

I hope that, because of our different approaches and strengths, this report and the DEC report will be seen as complimentary, and both serve to inform scientific and public discussions of the blowdown. And I also hope, even more, that these discussions take place. The blowdown is an unusual event of great complexity, in a landscape of enormous public importance; it, and any decisions that follow from it, deserve the best science, and the most careful discussion, that we can provide.

2. Methods, Sources, Units

This paper was conceived by the author and supported by the Wildlife Conservation Society as part of its Northern Adirondacks Program. It involved about three weeks of field work and six weeks of research and writing. It draws on documents, conversations with many people concerned with the blowdown, air-photos and Landsat images assembled by the DEC, three survey and photographic flights by the author in the summer of 1995, and three weeks of fieldwork in the blowdown area by the author and his students in August and October 1995.
For readability for a general audience I have used English units (feet, miles, acres) throughout.

3. Acknowledgements

Many people supplied information and ideas. My particular thanks to Liza Graham and Bill Weber of the Wildlife Conservation Society; Ray Curran, John Banta, Karen Roy and Judy Ross of the Adirondack Park Agency; John Cannon and Jeff Waldstreicher of the National Weather Service; Curt Schwartz, Joe Kennedy, and Dave Smith of the DEC; Ken Super of Wagner Woodlands; Peter Bauer of the Residents Committee for the Adirondacks and Dave Gibson of the Association for the Protection of the Adirondacks;

John Flynn of Champion International; Charley Canham of the Institute for Ecosystem Studies, Sarah Cooper-Ellis and David Foster of the Harvard Forest, Chris Petersen of the University of Georgia, Curt Stager and Michael Wilson of Paul Smiths College, and Kerry Woods of Bennington College; and finally and especially to two remarkable scholars-at-large, whose work has supplied both the factual and conceptual foundations for many of the ideas presented here, Barbara McMartin and Charley Cogbill.

Others supplied help, time and skills. I thank my field colleagues in the blowdown, Fionna Hawley, Liza Graham and Michael Papaik; our co-teachers in the blowdown Peter Bauer, Michael Wilson, and Kerry Woods; the students and teaching assistants in the 1995 Adirondacks course in the Bard College Graduate School of Environmental Studies: Mary Bums, Vince Clephas, Eleanor Hoffman, Gigi Giacomanni, Alex Morton, Michael Papaik, Sarah Poppenhouse, Daphne Ross, Kathy Scullion, Michelle Vasques, and Linda Vaeth; and the safest pilot in the north, George (Fivestring) Wilson.

4. Maps

This section contains 12 maps showing aspects of the storm, the resulting damage, and the relation of the current blowdown to the 1950 blowdown and the 1903 fires. All were drawn or redrawn for this report. One is an adaptation of a published map by the New York Department of Environmental Conservation. Eight are generalizations of recent air photos, weather radar, and satellite imagery. And three are combinations of recent imagery with historical maps. Brief captions are given with each map, and more detailed information here.

Map 1 is adapted from a highly generalized map circulated by the DEC immediately after the storm. It was based on air reconnaissance but not on satellite imagery or surveys. It outlines the general area affected accurately, but misses the distinctive linear character of the damage and suggests incorrectly that the damage was far more homogenous than it actually was.

Map 2 was prepared from satellite imagery and air photos, both taken in August, 1995. The hatched polygons are areas of moderate damage taken from air photos. The black bands, taken from a Landsat 'change image' prepared at St. Lawrence University, are probably the tracks of individual elements of the storm that caused intense damage. 71be damage within the bands is not as continuous as shown, but the bands are a faithful representation of the amazingly sharp edges of the intense damage swaths shown in the satellite image.

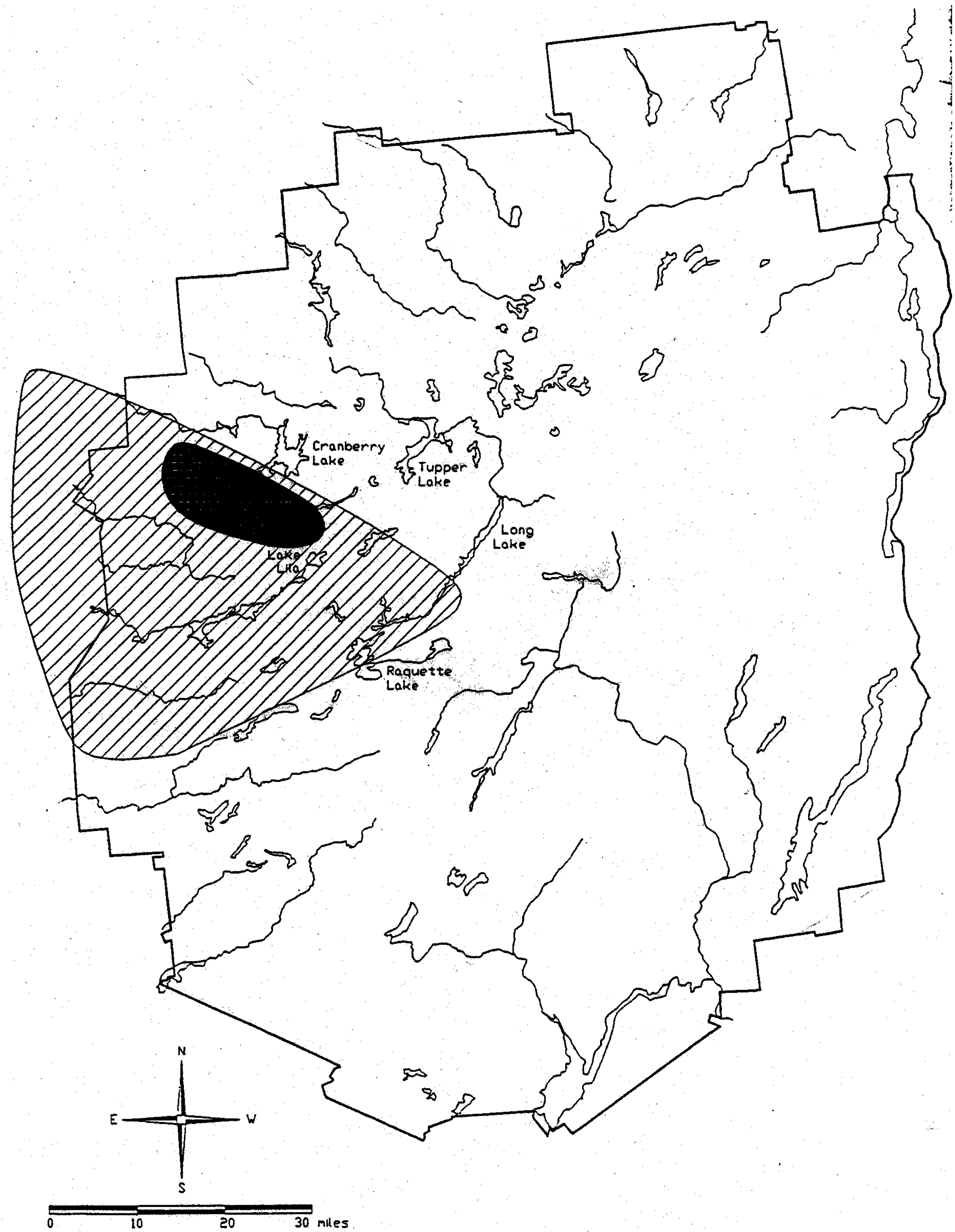
Map 3 is an enlargement of Map 2, superimposed over a map of State Forest Preserve lands.

Maps 4 and 5, and 5a are the author's interpretation of the areas of medium and concentrated damage in the Wolf Mt. and Five Ponds USGS quadrangle maps. They are based on high-altitude air photos taken by the DEC and low-altitude air photos taken by the author. They were drawn by comparing the photos to topographic maps, and show the damage as more uniform and precisely bounded than it actually is.

Map 6 superimposes the generalized damage pattern of Map 2 on a digitized version of a map of the 1950 blowdown prepared from air photos and field reports by the DEC. Small patches of blowdown that couldn't be shown at this scale are represented by circles. Map 12 is similar, but superimposes the damage pattern on the 1916 Schmidt map of the 1903 and the 1908 fires.

Map 7 is compares the blowdown visible on air photos to the Landsat change image for the area immediately around the Five Ponds. The change image is a false color image made by comparing 1994 and 1995 images pixel by pixel. No single color corresponds exactly to the observed blowdown. In this case I am comparing the areas shown in orange or light red (the colors which seemed to correspond best to the air photos) to the areas of clear blowdown on the air photos.

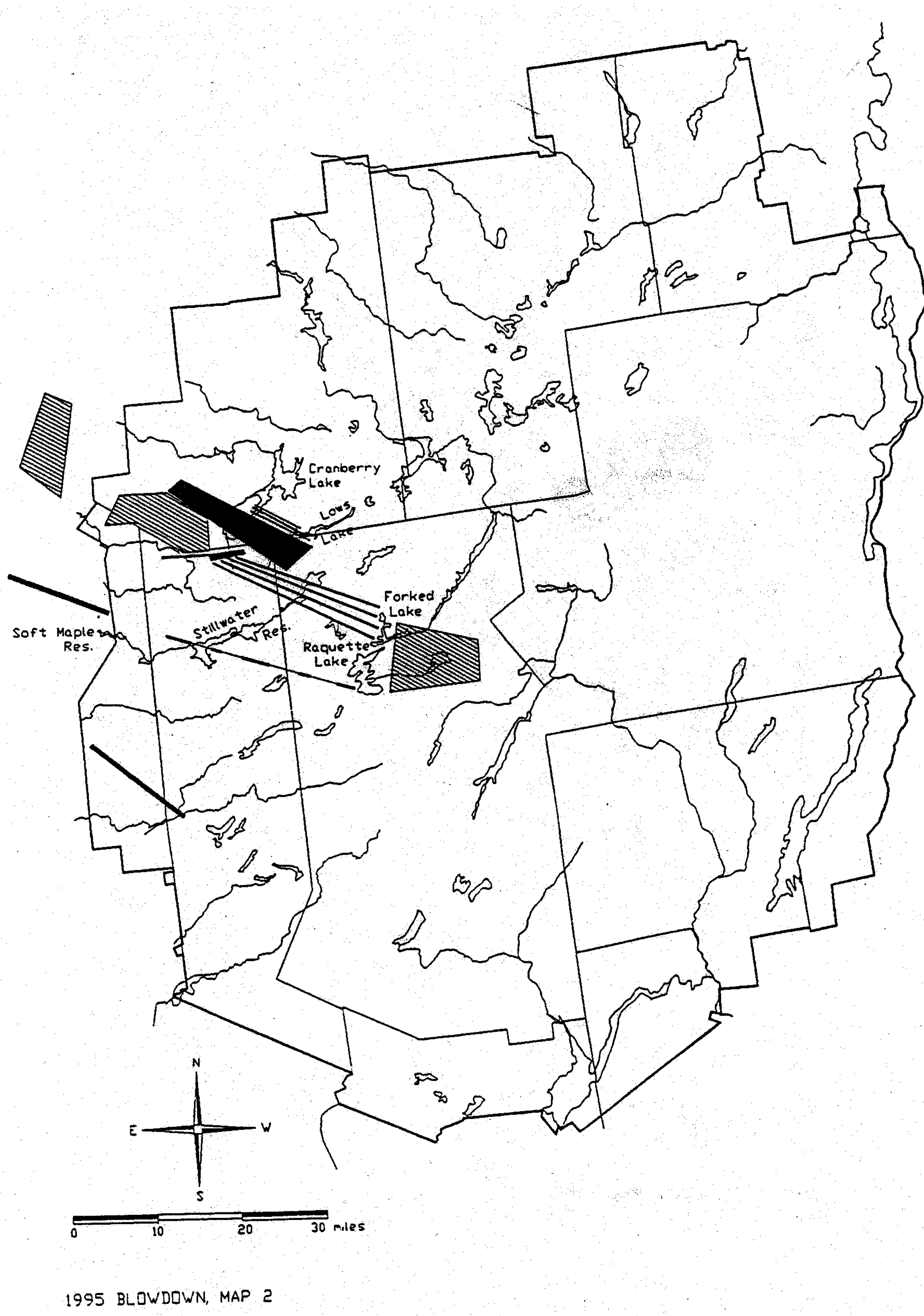
Maps 8-10 are digitized from archived doppler radar images of the storm taken by the National Weather Service radar at Beme, N.Y. Shading shows radar reflectivities in Maps 8 and 10, and the velocities relative to the radar in Map 9. 1 The outline of the most intense damage area from
Map 2 is superimposed.
Map 11, illustrating problems in mapping blowdowns, shows two published versions of the 1950 blowdown in the Cold River area.



1995 BLOWDOWN, MAP 1

GENERAL AREAS OF MODERATE AND SEVERE DAMAGE

Adapted from DEC maps
JCJ, 1995

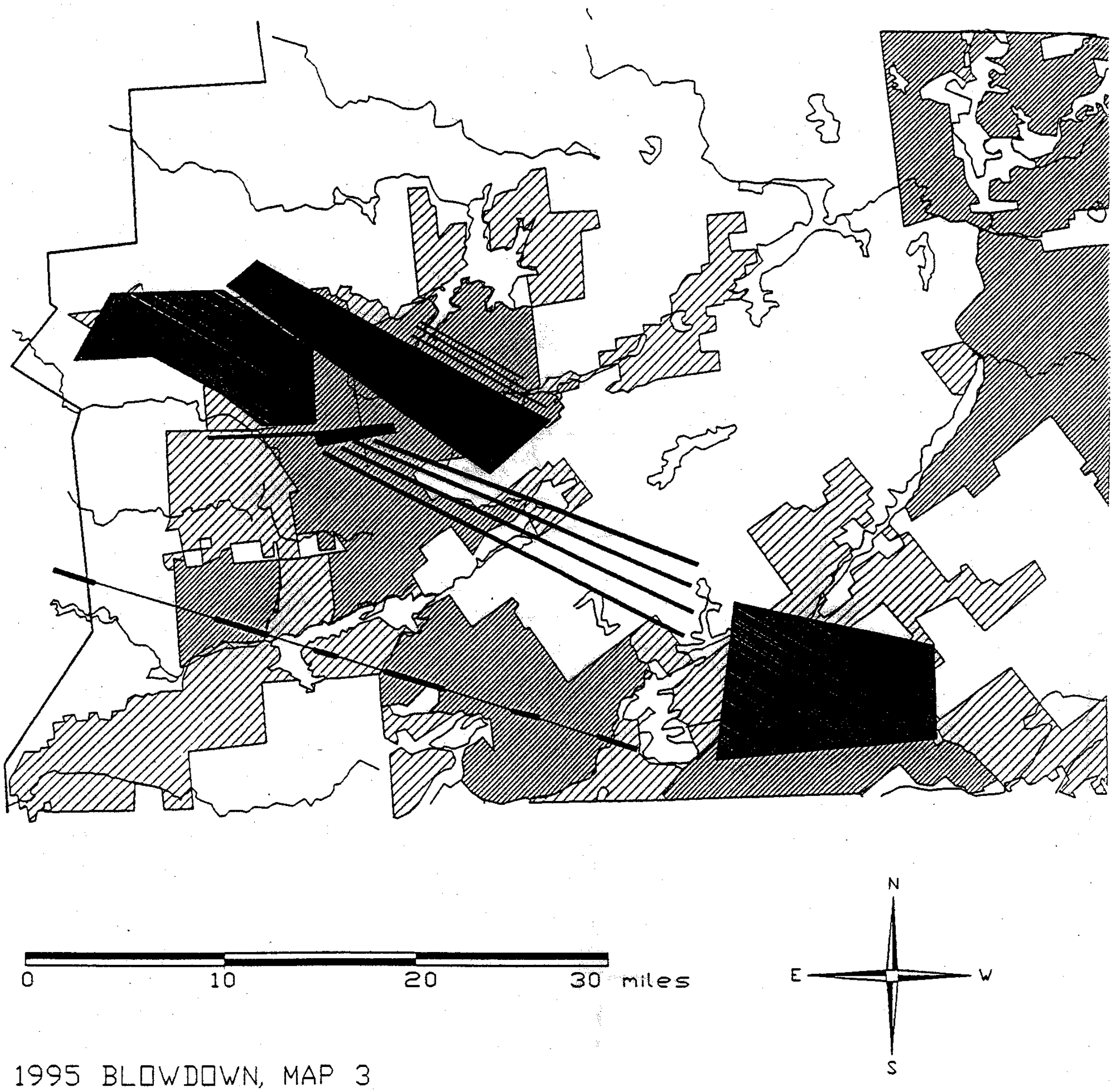


1995 BLOWDOWN, MAP 2

SWATHS OF CONCENTRATED DAMAGE

Heavy bands are generalized damage swaths taken from a Landsat change image prepared at St. Lawrence University; hatched bands are additional areas of damage generalized from DEC airphoto analysis.

JCJ. 1995

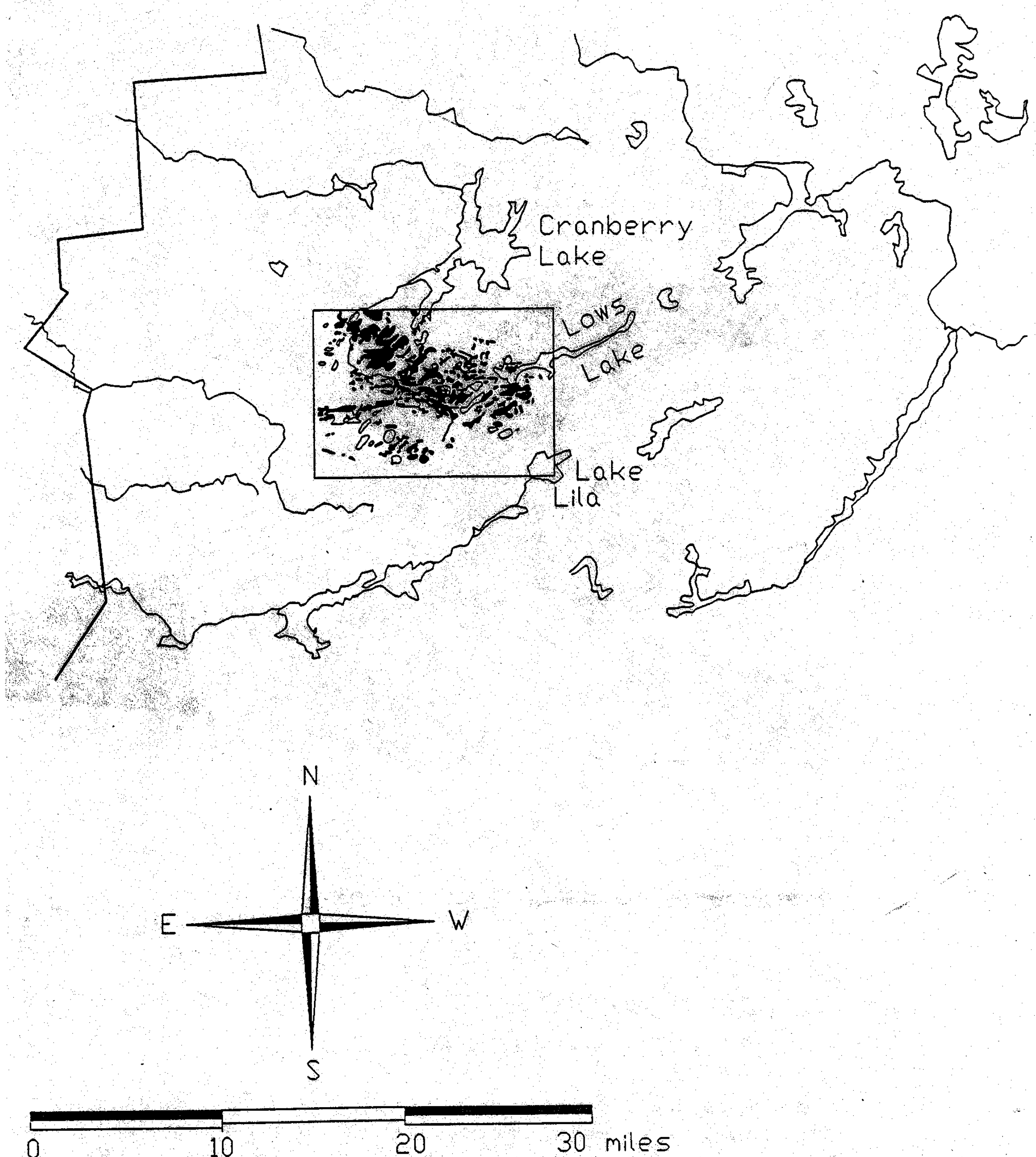


1995 BLOWDOWN, MAP 3

PUBLIC LANDS IN MAIN DAMAGE AREA

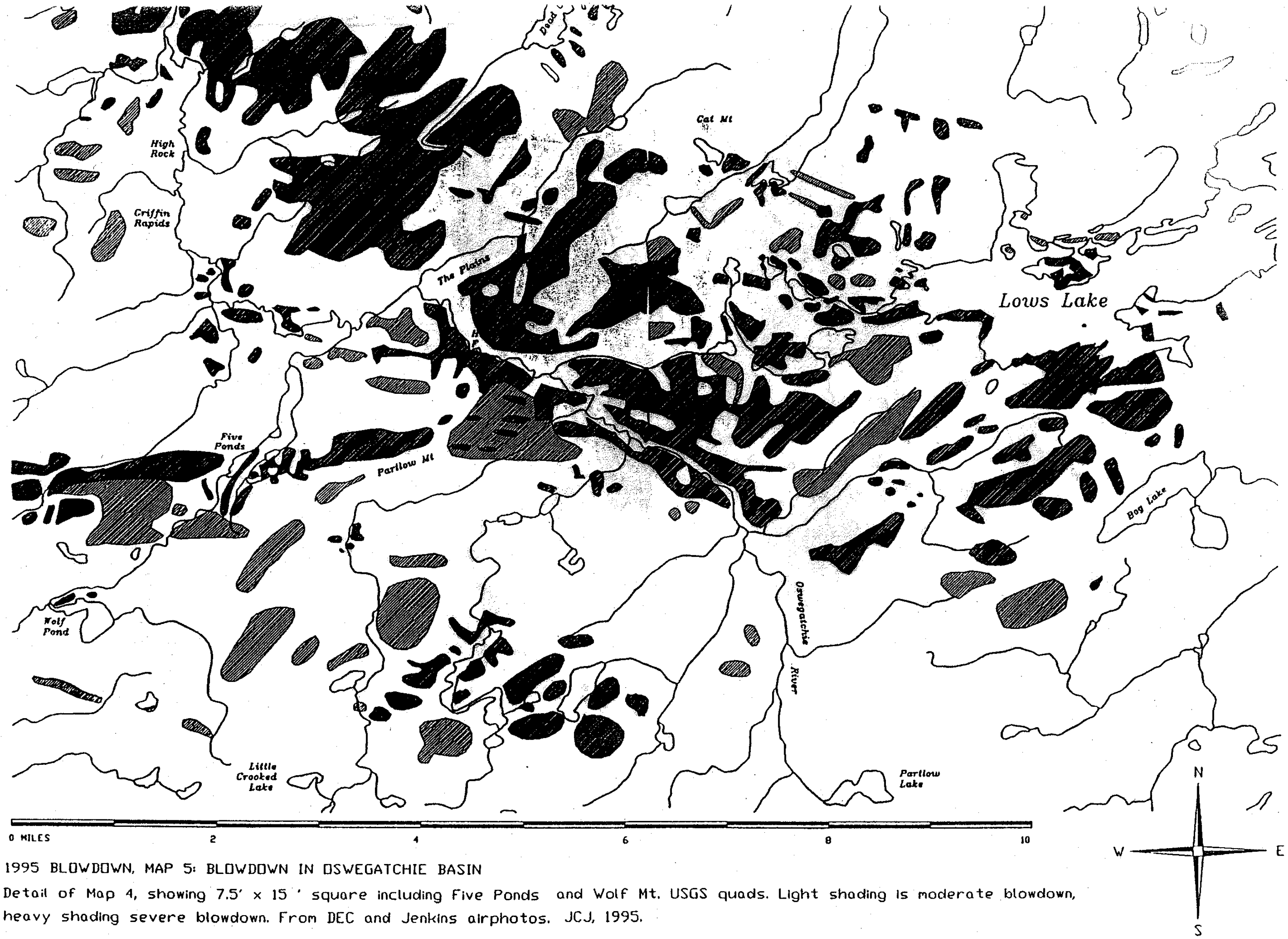
Damage swaths from Landsat change image have heavy shading, other damage areas from DEC damage map have lighter shading Wilderness areas have narrow hatching, other state lands have broader hatching; private lands not hatched.

Adapted from Landsat difference image and
1987 APA Land Use Map. JCJ, 1995



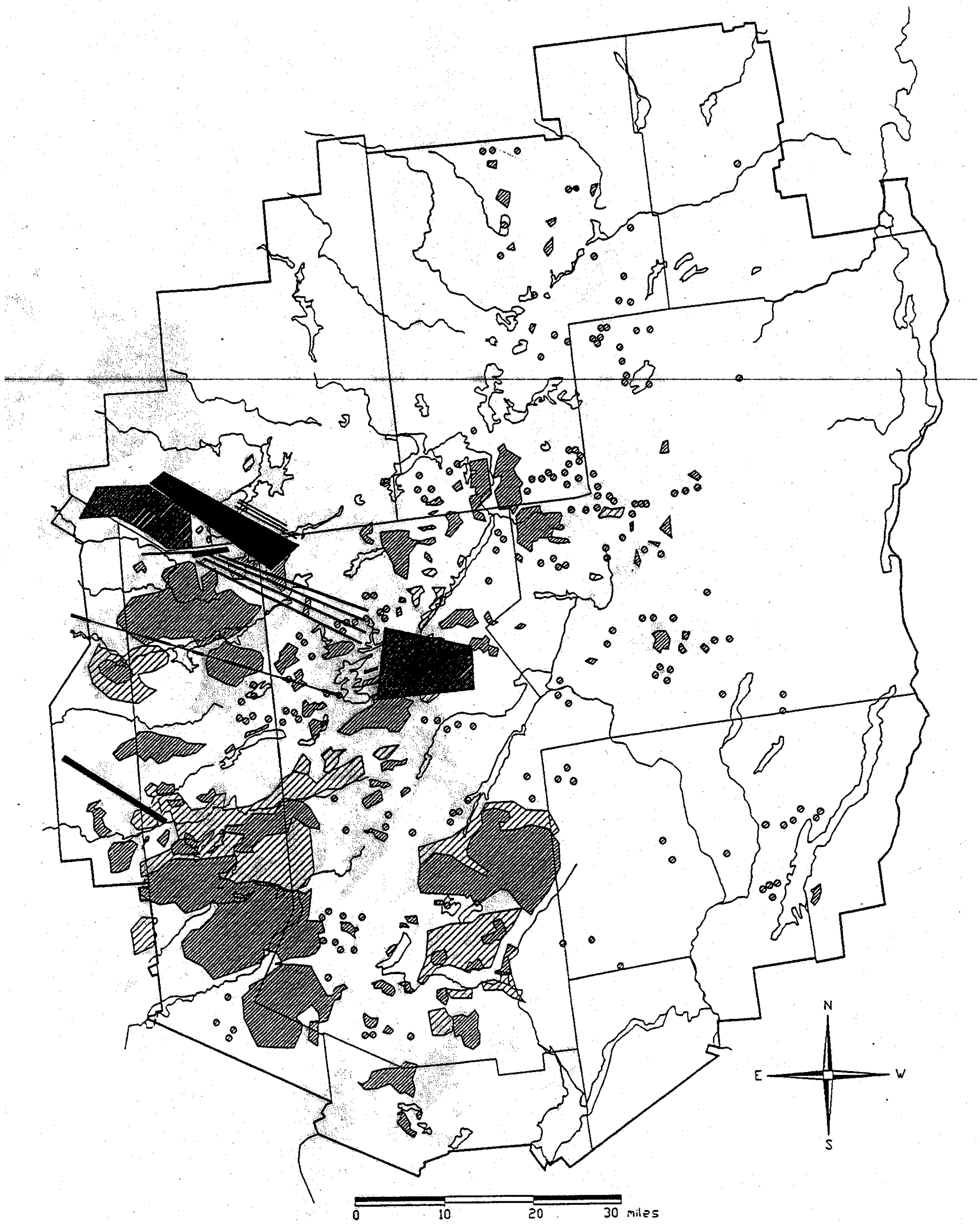
1995 BLOWDOWN, MAP 4: BLOWDOWN IN OSWEGATCHIE BASIN

Square is 7.5′ x 15′ and shows combined boundary of the Five Ponds and Wolf Mt. USGS Quads. Shading is moderate or severe blowdown. From 1995 air photos by DEC and J. Jenkins. JCJ, 1995.



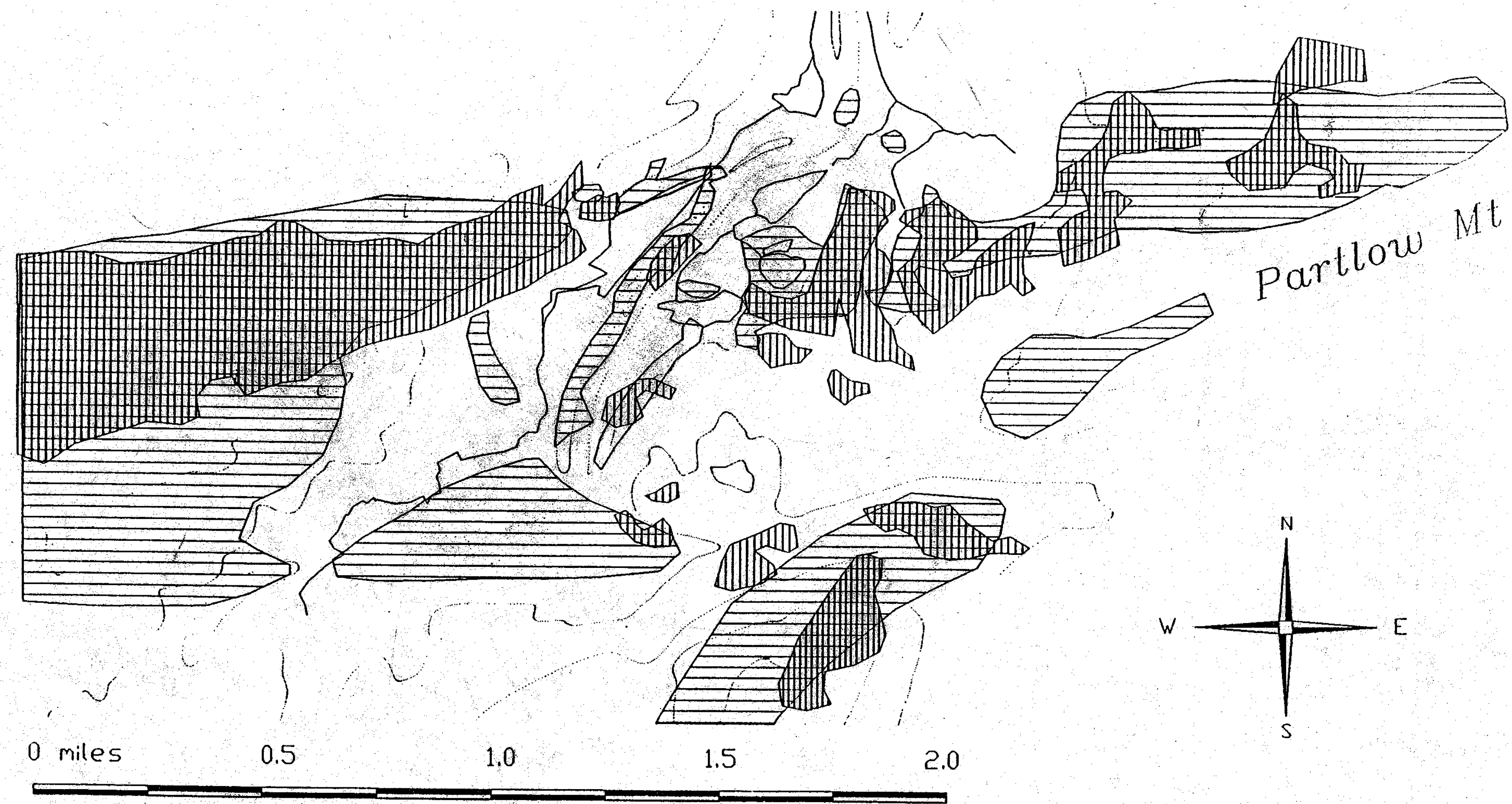
1995 BLOWDOWN, MAP 5: BLOWDOWN IN OSWEGATCHIE BASIN

Detail of Map 4, showing 7.5′ x 15 ′ square including Five Ponds and Wolf Mt. USGS quads. Light shading is moderate blowdown, heavy shading severe blowdown. From DEC and Jenkins airphotos. JCJ, 1995.

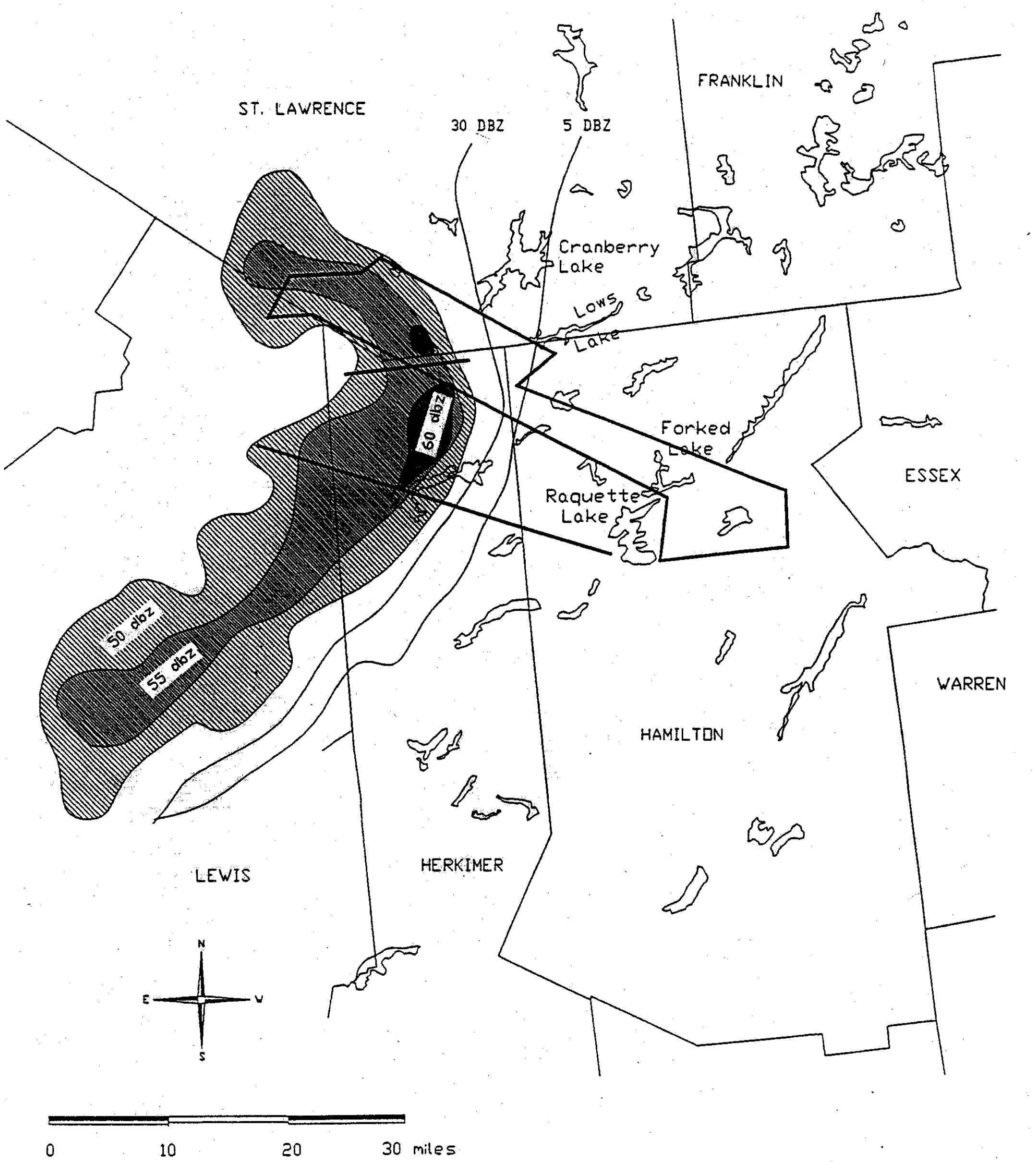


MAP 6: AREAS BLOWN DOWN IN 1950 and 1995

Hatched areas are outlines, probably much generalized, of light and heavy blowdown in 1950, from a DEC map, reprinted in McMartin, 1994. Dark bands are swaths of most intense damage in 1995, from adapted from Landsat image and DEC map. JCJ, 1995.

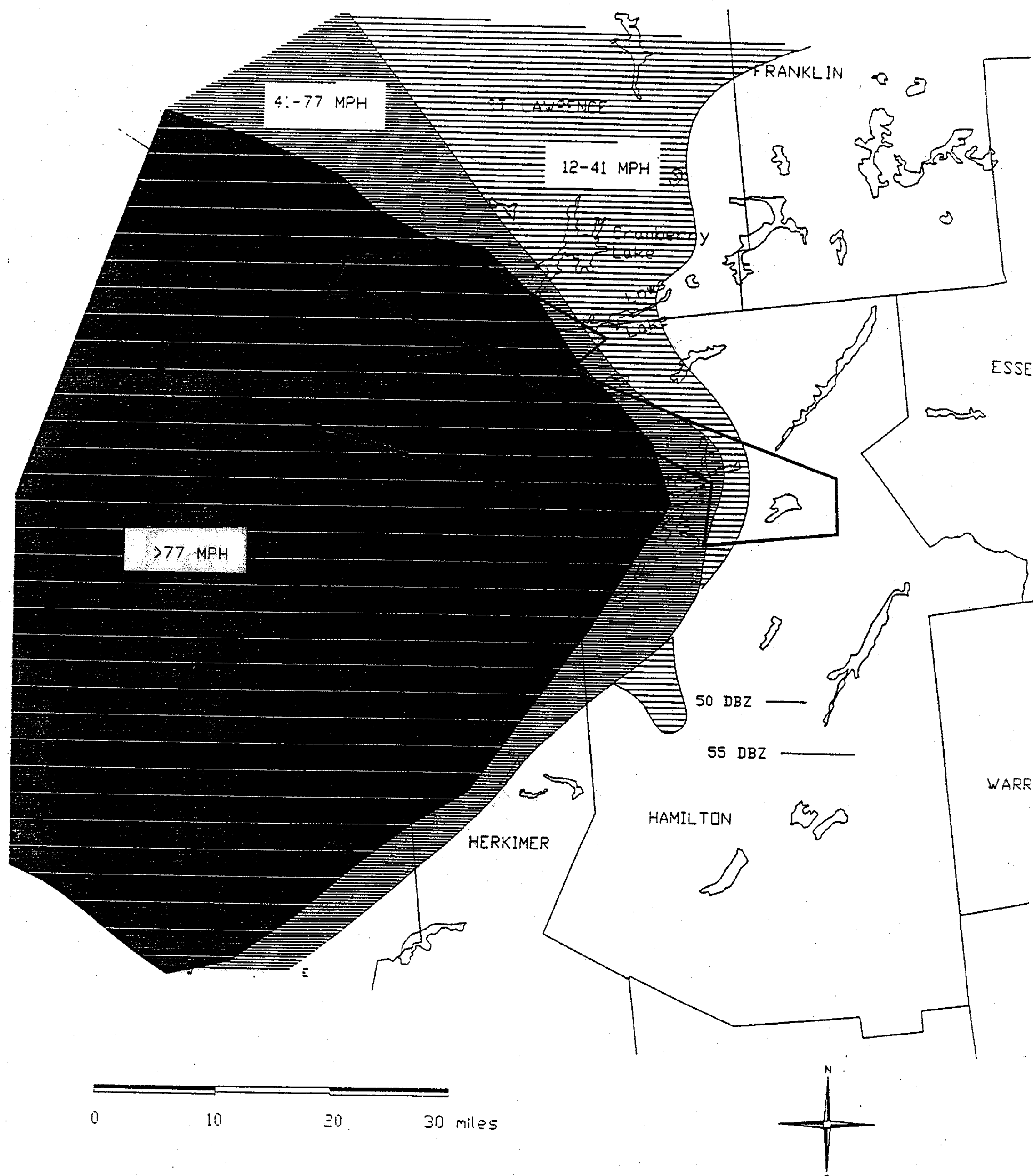


1995 BLOWDOWN, MAP 7; BLOWDOWN NEAR FIVE PONDS
Horizontal hatching is blowdown visible on air photos, vertical hatching approximate areas with orange or light red signature on Landsat change image. Air photos by DEC and Jenkins, Landsat image prepared at St. Lawrence University. JCJ, 1005.



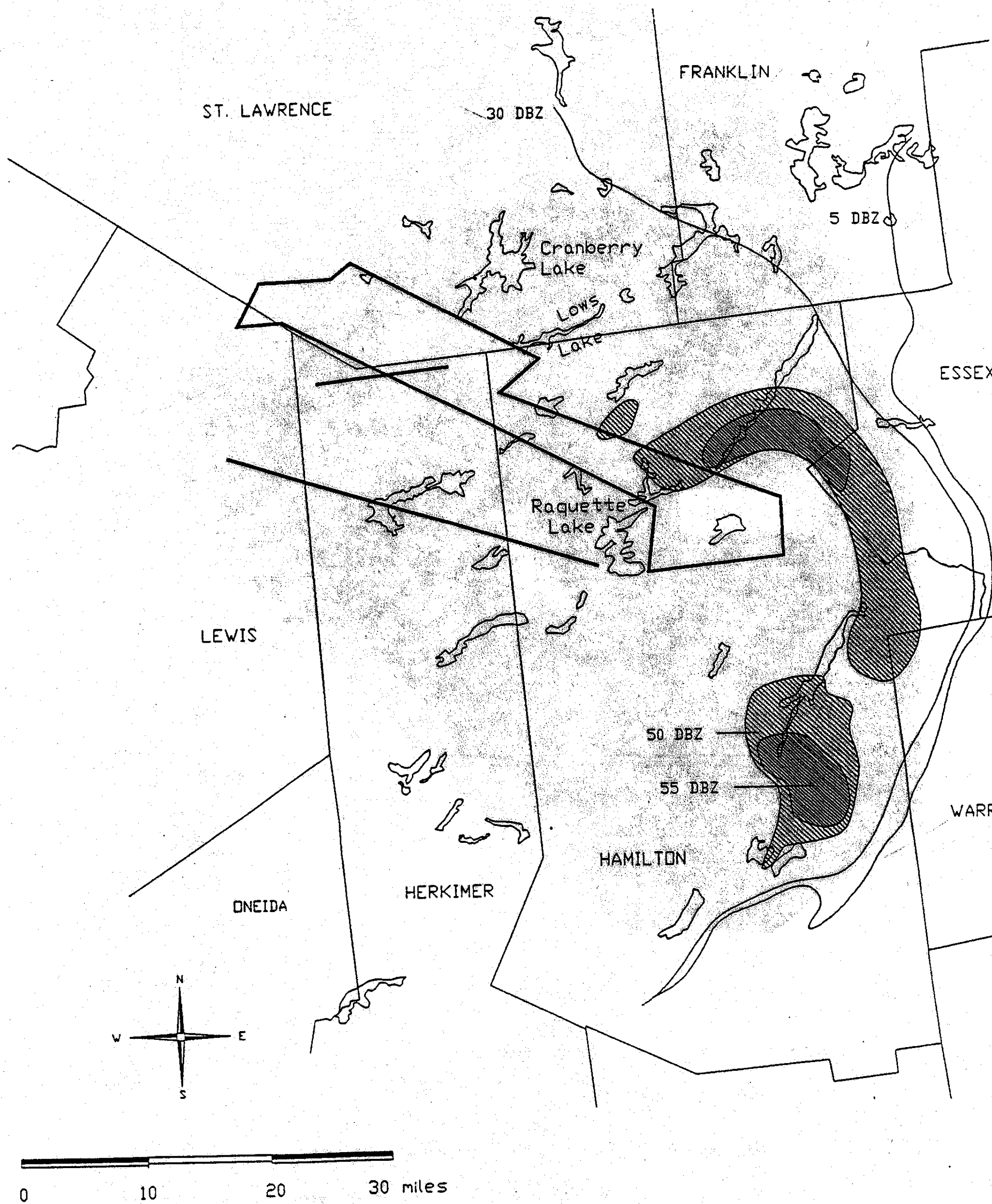
1995 BLOWDOWN, MAP 8: NORTHERN SEGMENT OF STORM AT 5:11 A.M.

Shaded figure is the northern portion of the bow echo; shaded zones correspond to radar reflectivities of 50, 55, and 60 DBZ; lighter lines in front of the storm are the 5 and 30 DBZ contours. Heavy angular lines are the approximate boundaries of swaths of heaviest blowdown. Reflectivities taken from archived images from the National Weather Service doppler radar at Berne, N.Y., courtesy of NWS, Albany. Damage generalized from maps by DEC and Jenkins. JCJ, 1995.



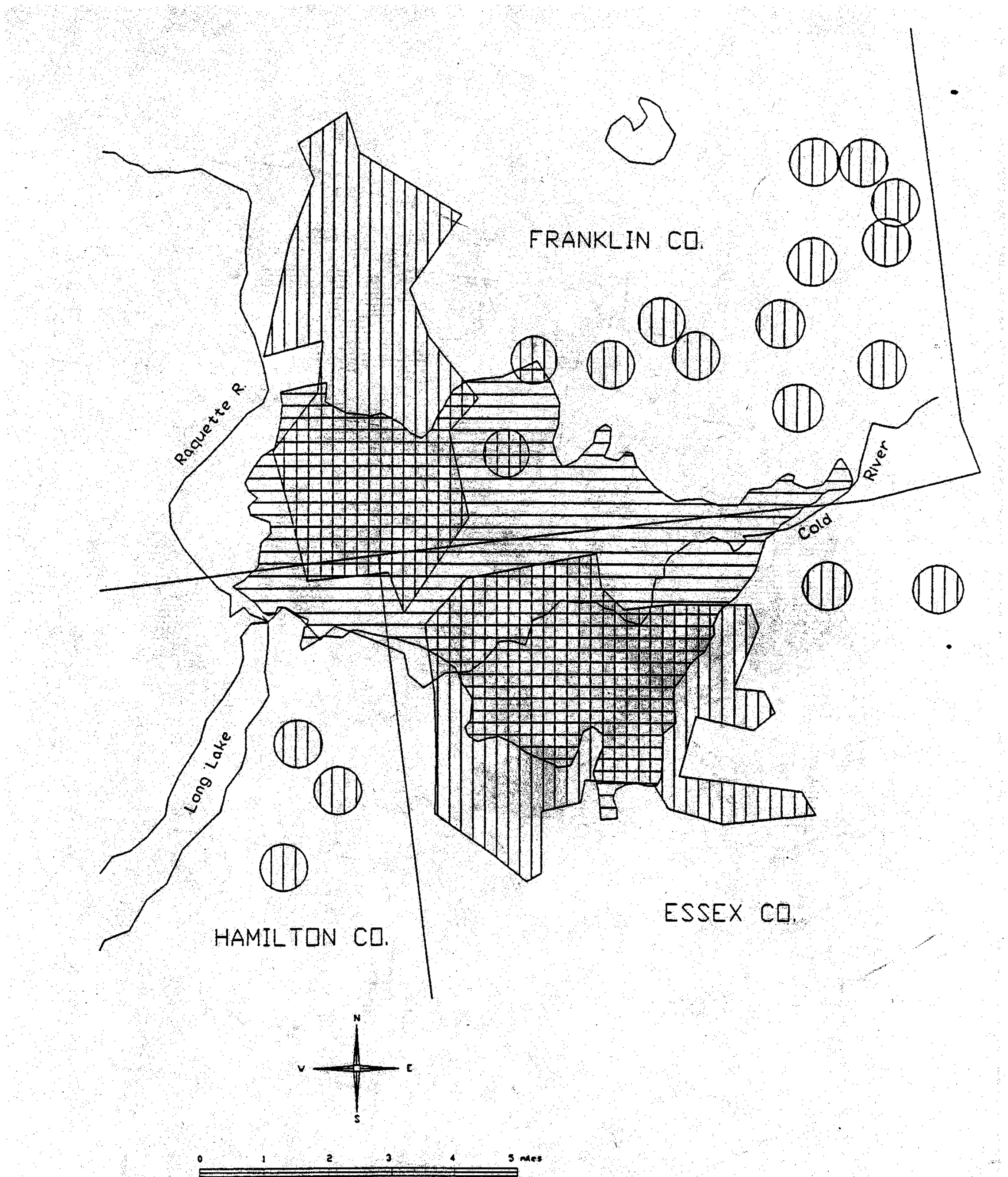
1995 BLOWDOWN, MAP 9 VELOCITIES IN RADAR ECHO AT 5:26 A.M.

Wind velocities measured by the National Weather Service doppler radar at Berne, N.Y. The radar measures velocities along a line connecting the point of observation to the radar, which is about 90 miles @ 332 degrees from the center of the storm. Approximate region of heaviest blowdown shown in heavy angular lines. Sources as in Map 8. JCJ. 1995



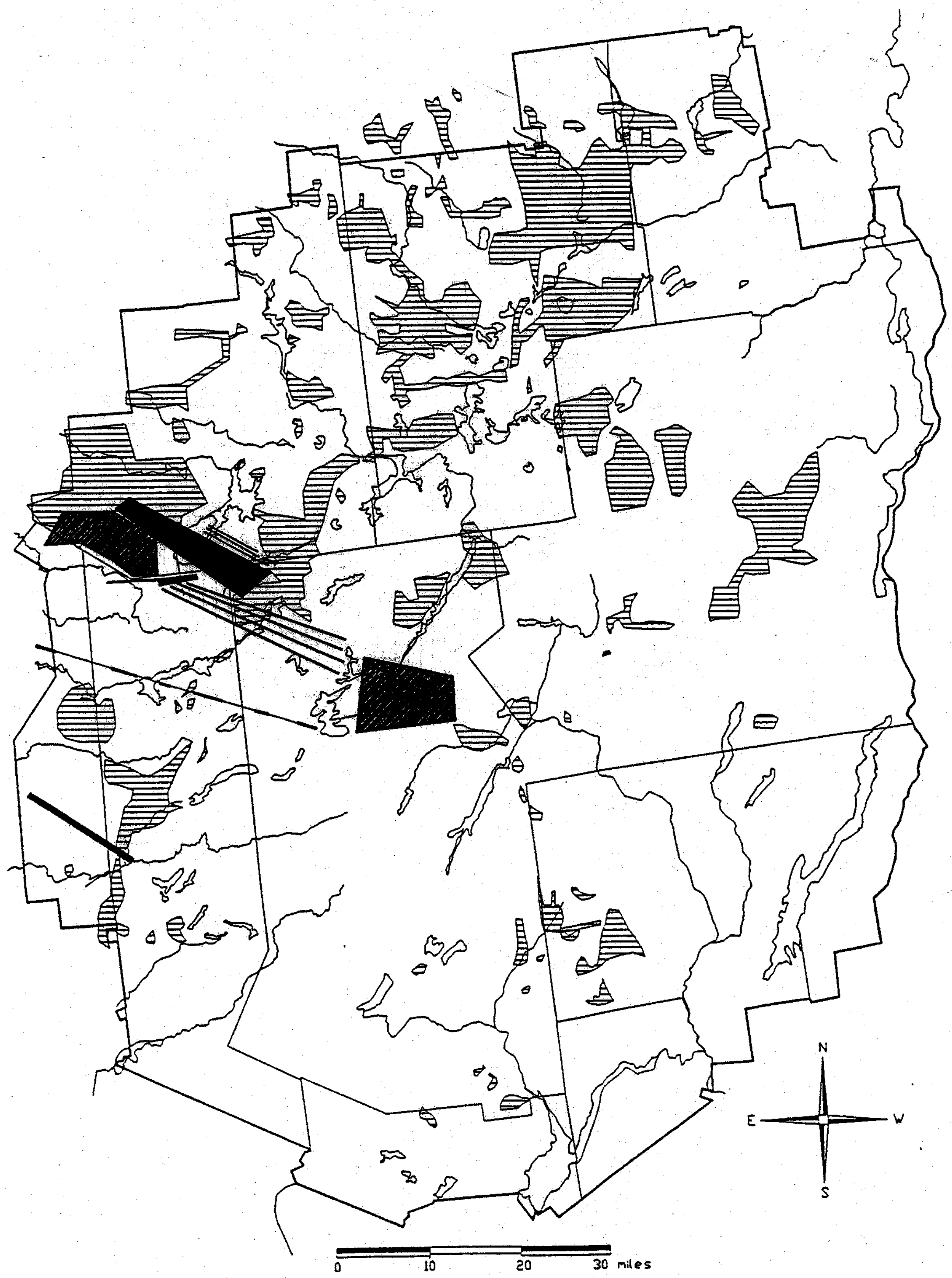
1995 BLOWDOWN, MAP 10: BOW ECHO AT 5:46 A.M.

Sources and legend same as Map 8 except there is no 60 DBZ zone. JCJ, 1995.



1995 BLOWDOWN, MAP 11: TWO VERSIONS OF COLD RIVER BLOWDOWN OF 1950

Vertical hatching is heavy blowdown from DEC's large-scale map of the 1950 blowdown, as reproduced in McMartin (1994). Horizontal hatching is the area of 50-100% blowdown shown in the New York State Conservationist, August-September 1953, p. 2.



1995 BLOWDOWN, MAP 12: CURRENT BLOWDOWN AND 1903, 1908 FIRES

Outlines show fires of 1903 and 1908 from Schmidt map of 1916.
1995 Blowdown swaths are superimposed. JCJ, 1995.

5. The Storm

The storm, as a remarkable geophysical event, is of considerable interest in itself. Obvious questions are where it came from, how big and strong it was, and why it caused intense damage in some places and none in others. Less obvious but more revealing questions are where it got its energy from, why it moved so fast, and how it could move so far without dissipating.

The meteorology of the storm is also of clear ecological importance. To understand the biological damage we need to know something about the physics and behavior of this sort of storm. And to understand how storms like this affect the overall history of the forest we need to know whether this was a typical or an unusual storm, and whether storms like this are common or uncommon events compared to the lifetimes of trees.

This storm has been variously called a derecho, a squall line, a microburst, and a downburst. Which was it?

It was all of these. ***Derecho***, from the Spanish for straight or direct, means a storm with straight line winds, in contrast to a storm with twisting winds, or tornado. The term was apparently coined in 1888 by Gustavus Hinrichs, an American meteorologist. It does not seem to have been widely adopted until the 1980's, and in fact is not found in any of the standard dictionaries of meteorology and earth sciences, or in most unabridged dictionaries. It was given a more precise definition in 1987 by Robert Johns and William Hirt of the National Severe Storms Forecast Center in Kansas. In their sense a derecho is a mesoscale convective storm (Box 2, p. 9) that produces a family of downburst clusters (individual concentrations of wind damage).

Currently a large convective storm is included in the Severe Storms Forecast Center derecho database if it: a) progresses in a linear fashion; b) shows evidence of substantial wind damage or winds over 58 mph in a concentrated area at least 250 miles long; and c) has within the large area of damage at least three smaller areas, separated by at least 40 miles, of winds of 74 mph or greater, or of damage rated F1 on the Fujita scale (Box 2, p. 9).

Squall lines are linear groups of convective storms, often but not always associated with a cold front, that have a ***gust front***, a zone of high gusty winds, preceding them. By the above definition, a derecho is a large, long-persistent squall line that does damage over a wide area.

Downburst and ***microburst*** were first used in the 1970's to describe certain violent downdrafts from convective storms that had been associated with aircraft accidents. The terms gained a more general application when it was realized that most of the damage-producing winds from convective storms were in fact caused by downdrafts. The terms downburst and microburst are now used for any damaging downdrafts, or for the resulting pattern of damage. The difference between the two is mostly a matter of size: a downburst is from 2.5-25 miles long and lasts over five minutes; a microburst is under 2.5 miles long, and lasts less than five minutes. Short local patches of intense damage, under 1,300 long, may be called ***burst swaths***.

Summing up: A derecho is a big, fast, long-lived, progressive convective storm, which may contain a number of separate damage areas. The July 15th storm was clearly a derecho. The individual blowdown areas in the Oswegatchie are clearly microbursts (Map 5); the larger swaths

Box 2: Severe Storm Glossary

bow echo a narrow, elongate, curved radar signal often associated with severe, rapidly moving, convective storms; very characteristic of derechos.

burst swath, microburst, downburst damaging surface winds below a downdraft, differing only in size and duration. Burst swaths are under 1300' long; a microburst under 2.5 miles long, and lasts less than 5 minutes; a downburst is from 2.5-25 miles long and lasts over 5 minutes.

convective storm a storm, for example a thunderstorm or derecho, that derives its energy from the rapid ascent of moist air in an unstable atmosphere.

cyclonic storm a storm, commonly 100 miles or more in extent, that rotates around a low pressure center.

derecho a mesoscale convective storm, commonly fast-moving with a long, curved gust front, that travels several hundred miles and produces several downburst clusters. See p. 5 of the main report for a formal definition from the Severe Storms Forecast Center.

downburst cluster a group of separate or contiguous downbursts extending for more than 25 miles.

Doppler radar weather radar that can detect precipitation, and measure the velocity of the precipitation along the line between the storm and the radar. Northern New York is covered by two doppler radar stations, at Rome and at Bern.

downdraft a vertically descending column of air from a convective cell, created when evaporating or melting precipitation cools a layer of relative dry air within or at the base of a convective cloud. Intense downdrafts create microbursts or downbursts.

F-scale a scale created by T. T. Fujita of the University of Chicago that relates observed windstorm storm damage to inferred wind speeds. An F0 gust is from 40-77 mph, an F1 gust from 77-110 mph, an F2 gust from 110-155 mph, and F3 gust from 155-206 mph. F0 gusts cause minor damage and tear off leaves and twigs, F1 winds begin to break or overturn trees, and F3 gusts essentially level everything in their path. F0 gusts are gale force, F1 and F2 hurricane force, and F3 gusts equal to moderately powerful tornadoes.

gust front a line at the front of the storm where the high velocity cold air descending and fanning out from downdrafts within a convective cell meets the warm, typically stationary warm air. Gust fronts have high wind velocities and wind shear, and often much turbulence. They may be a few miles long in a single thunderstorm, or 100 miles long or more in a derecho.

hurricane a cyclonic storm (essentially a large atmospheric vortex several hundred miles across) with sustained winds of over 78 miles per hour in the center.

mesoscale convective complex a large traveling group of thunderstorms, typically covering 50,000 square miles or more, and usually with a large shield of associated clouds.

outflow horizontal surface winds generated by a downdraft. The gust front is the region where the outflow meets the surrounding air.

rearjet a jet of cool, dry air, originating at moderate altitudes, and entering a convective storm from behind; characteristic of derechos, and thought to be critical to the persistence and propagation of the squall line. When rear jets descend to the surface they add their momentum to the gust front, and generate high winds and violent wind shear.

Box 2., cont.

unstable atmosphere an atmosphere where the lapse rate (rate of cooling with altitude) is sufficiently high that ascending parcels of air become more buoyant, and so ascend faster, the higher they go.

warm advection horizontal movement, typically followed by ascent, of warm surface air; warm advection feeds energy into convective storms, and is commonly present in the areas where derechos initiate.

wind shear rapid changes of wind direction of velocity over short distance. Horizontal wind shear is very characteristic of downbursts. Vertical wind shear, coupled with an unstable atmosphere, is thought to be necessary for the occurrence of derechos.

of damage, like the one from Star Lake to Lows Lake (Map 3) are downbursts; and the area of intense damage containing a number of separate damage swaths (Map 3) is a downburst cluster.

What kinds of damage do derechos generate?

Derechos commonly create areas of intense wind damage (burst swaths), variously oval or elongate, aligned in a linear fashion along the storm's track. The damaged areas may vary greatly in size, and may be nested, with smaller areas of intense damage inside larger areas of lighter damage. Within the burst swaths the damage pattern usually shows clear evidence of parallel or regularly divergent streamlines (wind directions), quite unlike the chaotic damage patterns seen in tornado swaths.

What conditions led to the storm?

Physically a large (synoptic-scale) storm is a traveling vortex or wave that extracts energy from gradients of atmospheric moisture and temperature. The preconditions for a storm are thus a moisture supply, and something to initiate the wave.

In our common large-scale cyclonal weather systems, the energy source is the horizontal juxtaposition of air masses of different temperatures and humidities. In convective storms, on the other hand, the energy source is a vertical gradient. This gradient produces an unstable atmosphere (Box 2, p. 9) in which a rising parcel of air becomes more buoyant the higher it goes. In such an atmosphere small vertical movements are self-amplifying, and can lead to violent up- and downdrafts. Unstable atmospheres are the classical environments for violent thunderstorms, tornadoes, and derechos.

On the evening of July 14 the atmosphere over much of New York was very moist and very unstable. The dew point was near 80, temperatures at Albany reached 99 F., and there was moderately strong low level shear (change in wind speed with height). These are exactly the conditions believed to encourage the formation of derechos and damaging downbursts. There were no strong fronts or weather systems in the vicinity, but it is a characteristic of derechos -- and one that makes them almost impossible to forecast -- that they can arise from a 'quiescent synoptic situation'.2 Jeff Waldstreicher, a meteorologist with the National Weather Service in Binghamton, said that the atmosphere was 'primed' to produce some sort of violent storm, and that the last time he had seen an atmosphere this moist and unstable had been just before an outbreak of tornadoes in the early 1990's.

How did the storm originate and what did it do?

The storm originated somewhere over Ontario, probably through the interaction of a weak cold front and an upper altitude trough. A 'mesoscale convective convex' (large group of thunderstorms) was moving northeast along the front. This situation probably generated 1 warm advection (ascending warm air from converging surface flows) which the derecho used as an initial energy source. (Derechos seem often to need a 'synoptic-scale' flow pattern to get started. Once they have started they can draw energy from the vertical moisture gradient and become independent of large-scale atmospheric flow.)
The outflow (aggregated downdrafts) from the thunderstorm complex triggered the formation of a squall line, which intensified as it moved across the Lake Ontario and became the derecho. It tracked east-southeast across the Adirondacks at about 50 mph (Maps 8-10, Box 3, p. 14). This is substantially faster than the average mid-atmosphere wind of ca. 30-35 mph, and indicates that the storm was propagating as a convective wave, rather than moving with the boundary of an air mass. It did most of its concentrated damage in a one-hour period (4:45 a.m. to 5:45 a.m. EDT) when it was over the western Adirondacks. After that it continued to track east into south Vermont and then across Massachusetts and Rhode Island, eventually dissipating over the ocean. After it left the western Adirondacks it damaged a number of individual trees and caused small blowdowns but nothing of comparable scale or severity.

What was the structure of the storm?

The storm was essentially a narrow line of thunderstorm cells, roughly 120 miles long and about 30 miles wide, trailed by a mass of clouds and scattered rain ca. 60 miles wide. Doppler radar images (Maps 8-10) show a bow echo about 50 miles long and 15 miles wide within the northern part of the storm. This is a curved band of high reflectivity, with a steep reflectivity gradient at the leading edge. The reflectivity (strength of the radar echo) indicates the area of the densest rainfall, and hence the most intense convection.

Bow-echoes are characteristic of intense linear storms that have strong updrafts and downdrafts, and are a signature of derechos. In the case of the July 15th storm the radar image (Map 8) has a very abrupt front edge, with reflectivity gradients of 65 dbz3 over 6-7 miles at the angle of the bow. This indicates, strong horizontal pressure gradients, and hence the likelihood of extremely strong outflow winds.

The radar echo shows two other important features of the storm, a book-end vortex and a weak ***echo channel***.

The book-end vortex is the counter-clockwise curvature at the north end of the bow echo in Map 8. It indicates that the storm is starting to rotate around the north end, with the angle where the bow bends moving rapidly southeast while the north end of the bow drags behind. In essence, the end of the bow is becoming a small cyclonic storm (meso-cyclone).

The 'weak echo channel' is the low reflectivity bay in the back of the bow, near the three-county junction in Map 8. It indicates an area where convection is weaker, possibly because this is where a jet of dry upper air is flowing into the storm from the northwest.

End-vortices and weak echo channels are common features of intense, straight-line windstorms. The rotation around the vortex adds to the horizontal speed of the gust front, and also increases the horizontal wind shear by adding a tangential component to gust front winds. The rear-to-front inflow of cool air associated with the weak echo channel adds its momentum to the momentum of the descending air in the downbursts, intensifying them, and increasing the-velocity of the outflowing air in front of the storm.

What was the storm like on the ground?

In the western Adirondacks the storm began with heavy thunder and much lightning, followed by gusty winds and a brief period of heavy rain. One witness spoke of a series of gusts, each lasting for a minute or two, with brief periods of calm between the gusts. Others experienced more extended periods of high winds, with even stronger gusts. The storm moved quickly, with rain lasting only a few minutes and the intense winds lasting at most 15-30 minutes (Boxes 3-4, p. 14, 18).

I observed the storm in Washington County, N. Y., at the eastern edge of the Adirondacks. There it had less thunder and almost no rain, but very strong gusty winds, probably 50-70 mph. The gusts were intermittent, and it was almost calm between them. They arrived very suddenly, and seemed almost periodic. I remember that I could feel the whole house shake when each gust arrived, and that I thought some of windows might blow out.

What is known about the mechanism of such storms, and what is the source of the damaging winds?

Figure 1a, probably familiar to many readers, shows a single thunderstorm cell. The cloud is moved horizontally by the winds aloft. This movement of the storm, combined with the outflow of cold air from downdrafts, triggers the rising of surface air above and ahead of the gust front.

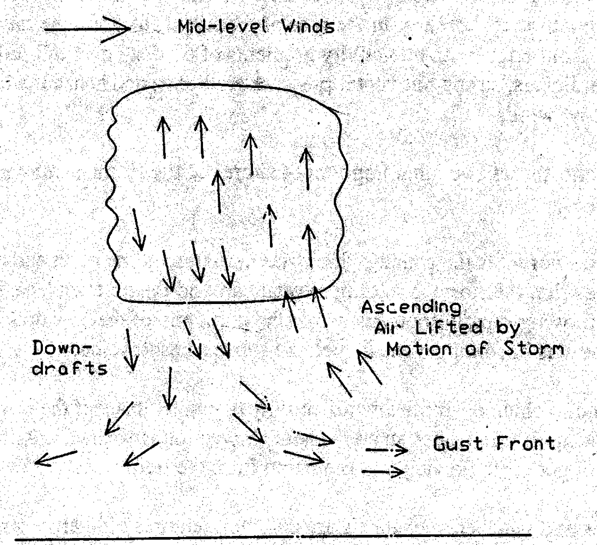


Fig. 1a Single Thunderstorm Cell

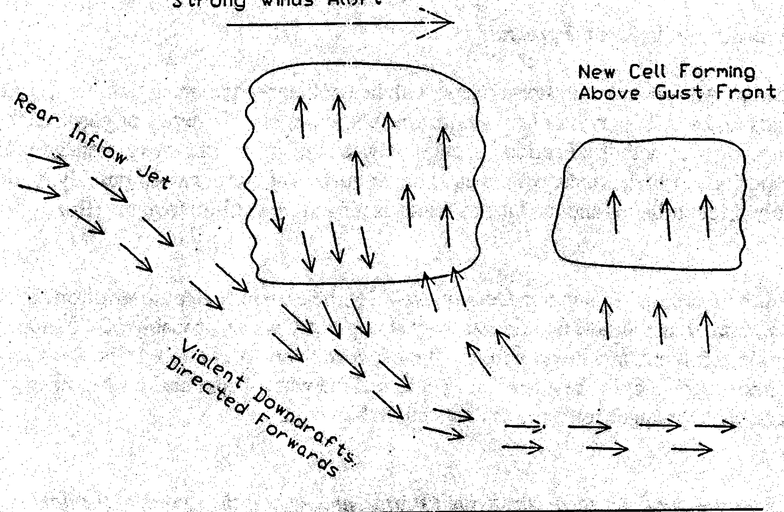


Fig 1b. Cross-section of the Squall Line of a Derecho

Figure 1: Local Structure of a Thunderstorm Cell and a Derecho

Box 3: The July 15 Storm

13-14 July For two days meso-scale convective storms (MCC's) have been moving northeast out of the Great Plains, turning north when then encounter an upper-altitude ridge of high pressure, and dissipating over Ontario. Dewpoints have risen to 80 degrees, and there is moderate vertical wind shear, both indicating an extremely unstable atmosphere. Forecasters are worried about the possibility of tornadoes, and are considering the possibility that one of the MCC's may turn southeast and become a fast-moving, violent storm.

15 July, 2 a.m. SELS, the Severe Storm Forecasting Center, warns of a possible derecho exiting Georgian Bay on Lake Huron.

3 a.m. SELS warns that the derecho may turn right into New York. The National Lightning Detection Network shows a very heavy concentration of lightning associated with the storm, indicating intense convection.

4:30 a.m. The storm crosses Lake Ontario and comes within the range of the doppler weather radar stations at Rome and Bern, N.Y. It displays a classical bow echo, ca. 130 miles long, with particularly intense winds and precipitation at the north end, which is aimed at the northwest Adirondacks. SELS issues a severe storm warning, and indicates that the storm is potentially life-threatening. The Rome radar shows a detached thunder cell ahead of the line.

4:50 a.m. The north end of the squall line is about 10 miles from the Lewis Co.-St. Lawrence Co.-Herkimer Co. comer, traveling at about 50 miles an hour, and generating around 3500 lightning strikes per hour. Some observers report that the lightning is so intense that the whole sky has a yellow glow. Winds behind the storm front are at least 77 mph, the largest the radar is set to measure. Gusts are probably well over 100 mph, probably driven by a rear inflow jet that appears as a clear bay behind the radar echo. The north end of the bow echo has started to curl counter- clockwise; there is a definite point, about 15 miles south of the north end, that is propagating faster than the line as a whole. The bending may have been triggered by the storm's encountering the outflow (residual downdraft winds) from the detached storm cell seen earlier. In any event, the north edge of the echo now has a cyclonic rotation which increases the wind shear at the leading edge. The storm is generating violent downbursts, and begins to blow down conifer forests in continuous bands.

5:11 a.m. The leading edge of the echo has just entered the Oswegatchie drainage. In the next 12 minutes the storm will flatten or damage some 12,000-15,000 acres of trees in the basin, approximately 18% of the total area. The bow echo continues to show rotation and a sharp leading edge. The track of the most intense radar echo coincides fairly well with the major swath of concentrated damage.

5:36 a.m. The gust front has just crossed Raquette Lake. A major 'weak echo channel' behind the bow echo, probably indicating a strong rear-inflow jet, is aligned with the major damage swath.

5:45 a.m. The leading edge of the storm is crossing into Warren County. The bow echo is straighter, with a less abrupt leading edge and, while still intense and life-threatening, is no longer causing extensive blowdown. A thickened section of the bow echo just east of Indian Lake has become partially independent of the main echo, and may be drawing energy away from the main part of the bow echo.

Box 3, cont.

6:30 - 7:30 a.m The northern parts of the storm cross Lake George and then enter Vermont, where they fell individual trees and cause a few isolated patches of blowdown. The southern parts pass over Albany, enter Massachusetts, cause some damage on to the crest of the Taconic Mountains, and eventually dissipate near the coast. Albany airport records sustained winds of over 50 mph for 15-20 minutes, and a gust of 73 mph, the second highest ever reported there. The lightning detection system records an average rate of 2000 strokes per hour and five-minute rates of 3000 strokes per hour. As the storm passes there is a brief but intense burst of positive strokes.
Positive strokes are a noteworthy, and apparently unexplained, feature of the trailing edge of many violent storms.

This air accelerates because of the unstable lapse rate and because it is heated by condensation as it rises, creating a strong updraft which may reach seven miles high or more. Precipitation forms high in the cloud. Some of it melts or evaporates as it passes through the drier air below, typically at heights of two to four miles. This in turn triggers the descent of cool or drier air, which, again because of the unstable lapse rate, accelerates downwards, creating a downdraft. The cool air spreads in front of the storm as a gust front, driven by its own downward momentum, plus the forward momentum of the advancing storm, and the local pressure gradient under the downburst. The descending air below the downdraft commonly radiates in a highly divergent pattern characteristic of downbursts. The spreading gust front creates local turbulence (horizontal vortices) which trigger the further ascent of low-level air, completing the cycle.

A derecho (Fig. lb) is essentially a linear group of such cells, but with the following special (and dangerous) peculiarities:

> The atmosphere is very unstable and so the updraft and downdraft velocities can be very high. Downdrafts can exceed 25 mph; updrafts 70 mph.
>
> The strong downdrafts trigger new convective cells ahead of the storm, and so the storm propagates as a 'gravity wave', triggering new cells in front of it as it goes, rather than as a moving group of individual storm cells. In consequence it can move substantially faster than the average environmental wind speed.
>
> The pressure gradients created by the forward motion of the storm and the descending air entrain a jet of cold air that enters the cloud from behind, descends to the ground with the downdrafts, and then moves forward as part of the gust front. This 'rear jet', which seems to be a critical feature in computer simulations of derechos, increases the convective lifting at the leading edge. This serves to make the storm self-sustaining and more long-lived than a normal thunderstorm. It also adds forward momentum to the gust front and so increases the speed of the gusts and the potential for wind damage. Because of the rapid forward movement of the storm and the momentum added by the rearjet, the streamlines in the damage swaths of the downbursts of derechos tend to be more parallel than those in the downbursts of more slowly moving storms.

To sum up, a derecho is a propagating wave, generally moving faster-than the mean wind, that triggers an intense line of convective storms. Like thunderstorms, the damaging horizontal winds of derechos originate from downdrafts driven by negative buoyancy created by precipitation- driven cooling. They derive their strength from a combination of the storm's motion, horizontal momentum from the rear jet, pressure gradient forces on the ground resulting from a local high under the downdraft, and wind shear from a rolling motion at the leading edge of the gust front.

How well understood are such storms?

The general physics of thunderstorm cells has been understood for over a hundred years, and the processes that create downdrafts for about 60 years. The detailed mechanisms of individual downbursts received much attention in the 70's and 80's because of their association with aircraft accidents. At present the microphysics and dynamics of air currents within clouds are fairly well understood. In the last 10 years realistic computer simulations of thunderstorms have been possible, and in the last five years realistic simulations of derechos and other meso-scale groups of convective cells. The simulations can be compared with doppler radar images and seem to produce fairly accurate pictures of the velocity fields and behavior of individual storms.

Derechos, as a newly recognized class of storms, still have mysterious aspects. One is that, like any "sub-Rossby scale" straight-line wave, they should radiate energy in gravitational waves and disperse. Since this is just what they don't do, they have to draw on a substantial energy source as they move. Simulation studies suggest that substantial amounts of vertical wind shear and a strong rear inflow jet are necessary to keep the derecho from dispersing. It may also be that their rapid forward motion, approximately the speed of a gravity wave, limits forward energy loss.

Can derechos and microbursts be predicted?

While the conditions (instability, advection and sheer) leading to severe storms are measurable, currently neither microbursts nor derechos are predictable far in advance. In 1990 William Abeling wrote:

> ***A key element in the formation of derechos is an organized downdraft sufficiently strong to penetrate the surface and reach the gust front. Identifying synoptic conditions which will facilitate the growth of the downdrafts is difficult if not impossible since this is largely a meso/microscale process.***

The July 15th storm is an example of this. Forecasters had recognized for several days that there was a substantial possibility of a violent storm, and watched, somewhat apprehensively, a number of candidates that proved harmless. It was only at about 1 a.m. on July 15, after the storm developed a bow echo and started to move, that a warning could be given. Even so, while it was clear to forecasters that this was a very dangerous storm, it was not possible to determine whether the winds were descending to ground level and causing damage until actual field observations became available. This was exacerbated by the fact that the northwest Adirondacks completely lack weather observing stations, and so no ground-level information on the storm was available from the time it left Watertown till it reached Binghamton and Albany.

How strong are the gusts in derechos?

Unlike uniform wind fields in hurricanes, downburst gusts are very local and rarely measured directly. Usually the best that can be done is to estimate them from the kind of damage observed.

Prior to Fujita's work in the 1970's it was believed that convective storms mostly produced FO (40-77 mph) or (occasionally) F1 (77-110 mph) winds, and never produced F2 (110-150) or higher winds. He studied 142 downbursts and found that fully a third had F1 winds, a fifth had F2 winds, and at least two had F3 winds (over 150 mph). This means that moderate hurricane force winds are common, strong hurricane force winds occasional, and tornado force winds rare but possible.

No detailed analysis of damage in the July 15th storm has yet been made. Based on Fujita's descriptions of damage levels and my air photos and observations, I think it likely that many of the downbursts in this storm were F1, and that at least some may have been F2.

Could tornadoes have been associated with this storm?

Derechos in the central U.S. often create tornadoes. These may be true tornadoes with funnels descending from the main storm clouds, or shallower and more transient gust-front tornadoes associated with vortices at the edge of the out-flow.

While both derechos and tornadoes require warm wet surface air, strong vertical wind sheer, and an unstable lapse rate, tornadoes seem also to require that the wind direction shifts with height, so that vertically moving air parcels begin to twist. This was not present on July 15, and so no tornado warning was issued.

How frequent or infrequent are derechos in the U.S.?

Johns and Hirt collected data on derechos from National Weather Service records from 1980- 1983. Derechos were most common in the Midwest, which has weather to make up for the other things. They are most frequent in the summer months and tend to concentrate along an axis from the Dakotas to Ohio. Plotting the frequency in two degree (90 miles x 120 miles) squares they found that the tornado-belt of the central states averaged ten or more derechos per square per four years period, and some places had 16 or more in four years. Northern New York and New England are out of the derecho belt, but still had two storms in the four-year study period.

Box 4: Accounts of the Storm

Luckily we're ok after spending an hour watching bolts of lightning, driving rain and wind gusts that brought these trees crashing around us; thanks for the lean to DEC Glenn R. & Steve D., Oswegatchie River, Site 34;

At 5 in the morning there was a huge thunderstorm. My sister and I were stuck in a tent and my mother and father were stuck in another. Trees and bushes were blown down and our tents were about to be blown away. Blake Blakley, Oswegatchie River, Griffith Rapids.

We woke at 5 am and zipped the flies on our tents. It rained like crazy. Then the wind started. It almost blew our tents over. Trees fell all around and there was lightning everywhere. The campsite is a mess this morning and the skeeters are ruthless and the chipmunks are attacking. PS another tree just fell. Carla Blakley, Oswegatchie River, Griffith Rapids

The storm lasted about an hour and a half, during which the night was lit up as if it were day. Cranberry Lake is normally quite a placid lake but that night its surface was covered with whitecaps crashing against the shore. Throughout the storm I heard branches cracking and our aluminum canoes bouncing around outside of our tents. The next day we paddled into town and found all of the power was out and people told us we had been in a tornado. Noah Weber, Jo Indian Island, Cranberry Lake

Timing and increment of the storm do not come clearly to mind. It seems rather that the thing came all at once! The most powerful impression was of the wind which came in waves, each one louder and more violent than the previous, all coming in from my left, from the west. There were not many trees visible through the half open door of the tent, but those I could see were lashed and whipped as in a hurricane! ... As the blasts of wind came with ever-increasing noise and intensity I was reminded of my Mother's words from Oklahoma and Missouri days, "If it sounds like a freight train that's a tornado!" There were four 'freight trains' that morning and each one seemed louder than the one before. Between each, there were perhaps two minutes of elapsed time, just enough to catch a breath before the next. I heard nothing above the roar of the wind. If trees began to snap the noise of the wind completely covered the sound. It wasn't until the fourth wave, the most intense, by far, that I heard some sounds and became aware that branches were coming down all around my tent. There was no way I could see if there was anything bigger attached to the falling branches, and instinctively I put my arms up over my head, as if I could have stopped anything from hitting me. Those moments were truly frightening... At just about the same time I realized there was something up against my tent. It turned out to be a 14 " red maple right across the door, with one branch pinning down one side of the tent!

And quite suddenly it was all over and very quiet. Remarkly my tent was not ripped or even punctured and I was able to wriggle out the front door. Only then, as I looked around, did I realize the severity of what had taken place: trees snapped off or uprooted, everywhere, one car buried under two trees, one car totaled, powerlines down. There were near misses throughout the campground but, thankfully, not one personal injury. Nancy Dill, Lake Durant State Park, ca. 5:40 a.m.

Box 5, Known Adirondack Windstorms

From information supplied by C. Cogbill and B. McMartin

1805	Windfall of ca. 3000 acres in Oxbow Patent
1816	Windstorm clears the 'Pine Orchard' in Wells
1845	Great Windfall: tornado or derecho; storm travels from Niagara County to Burlington, Vermont, leaving two parallel swaths of blowdown
1916	Windstorm near Nehasane destroys ca. 5% of timber over a large area.
1950	'Big Blow' of November 24: a cyclonic storm, of hurricane force but originating over Appalachians, tracks northeast; its northeastern quadrant passes over the Adirondacks, leaving moderate to severe damage on ca. 400,000 acres.
1954	Hurricane Hazel, 15 October: a tropical storm that moved inland crosses central and western New York, causing some damage in Adirondacks; no details of damage seem to exist.
1995	Derecho of 15 July: a fast-moving line of intense convective storms damages ca. 140,000 acres of timber, most in the north central Adirondacks.

Are there historical records of Adirondack derechos?

No, but this may only be because the historical record is not detailed enough to distinguish derechos from other storms. The 'Great Windfall' of 1845, often described as a tornado, had two parallel swaths, one described as extending some 300 miles from Niagara to Vermont. This is very long for an eastern tornado and might have been a derecho.

How frequent are severe windstorms in the Adirondacks?

The historical frequency of windstorms is poorly known. It can be estimated either from historical records of storms, or from the amount of blowdown recorded in early surveys. Written records of individual storms give dates and some sense of severity, but little information about geographical extent. Early surveys tell something about the extent or severity of the storms, but little about their dates and (in my opinion) very little about their frequency.5 Box 5 (P. 19), from Charley Cogbill and Barbara MacMartin, summarizes the historical evidence for Adirondacks, and Box 6 (p. 20) the presettlement survey evidence for several areas in the northeast.

Box 6: Blowdowns Recorded in Early Surveys.

Western Adirondacks, New York : 5 % blowdown in mixed hemlock-spruce-hardwoods forests in 12 towns in Totten & Crossfield and Moose River Tracts in the Adirondacks (C. Cogbill, unpub.).

Michigan: 0.7% blowdown in pine forests (44).

Allegheny Plateau, western New York: - 0.5% blowdown in ca. 10,000 square miles of mixed hardwoods-hemlock-spruce forests in the Allegheny Plateau (45).

Finger lakes Area, central New York: 0.3 % blowdown in mixed maple- beech-basswood-oak forests (38).

Wisconsin, 1834-1873: 1.2% blowdown over ca 2.2 million acres of hemlock hardwoods forest (32).

Northern Maine: 2.5% blowdown in mixed hemlock-hardwoods- spruce-fir forests (37).

Northwestern Pennsylvania: 1.5-3% blowdown, hemlock pine hardwoods (45).

The evidence shows that there are a number of records of damaging storms from the Adirondacks and that the percentage of land in blowdowns was substantially higher in the Adirondacks than for any area for which we have historical records (Box 6). This has been interpreted to mean that the frequency of windstorms is higher in the Adirondacks than neighboring areas. But it could also be a sampling effect -- a chance coincidence between the surveys and severe storms. I think that, given the limited data available, we can neither prove this nor refute it. But the data clearly show that windstorms were frequent historically, and make it probable that they have played a major role in Adirondack forest history.

6. The Geography of the Blowdown

First a cautionary note about the accuracy of maps and damage estimates. The blowdown is a geometrically complex object, hard to describe, and so very hard to map. There are two sorts of difficulties. The first is practical: to map something you must see it, and the blowdown is hard to see. Neither satellite images (resolution of ca. 100') nor reconnaissance-scale air photography (scale ca 1: 18,000, resolution ca. 150') can show you individual fallen trees, and so you have to interpret them by looking for color or texture changes that correspond to places where groups of trees have fallen. As with all false-color interpretations of imagery, the signature colors and textures vary from place to place, and there is often substantial uncertainty.

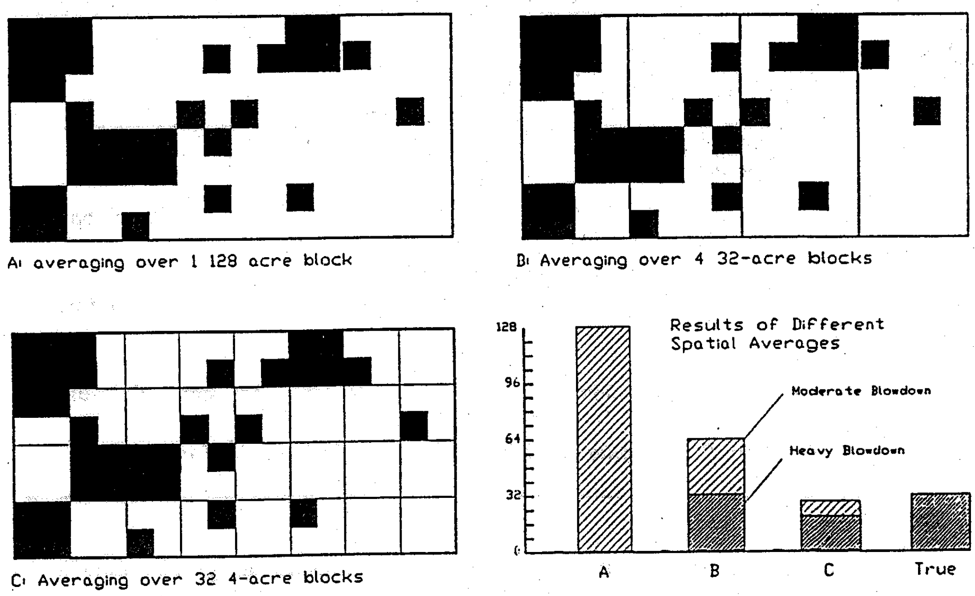


Figure 2: Nasty Effects of Spatial Averaging

The three squares show 35 acres of 100% blowdown within a 128 acre rectangle. We estimate the blowdown area by averaging over the whole block (A), four 32-acre blocks (B), and thirty-two 4- acre blocks (C). If a block has less than 26% blowdown we call it intact; if it has 26-50% blowdown we say it is moderately damaged; if it has 5 1 % or more we say it is heavily damaged. The bar graph compares the results of the three different spatial averages with the correct value of 35 acres of heavy blowdown.

The second difficulty, which is less widely appreciated but even more daunting, is conceptual. Mapping works best with things that have sharp edges and homogeneous insides and are all roughly the same size. The blowdown, on the other hand, consists of patches of damage that vary greatly in size (from a few yards to a few miles), in intensity (from <10% blowdown to 100% blowdown), and which often grade into the surrounding woods, and so don't have clear edges. When the concentration and intensity of the damaged patches are fairly uniform it is easy to make a consistent map. But when the concentration of damaged areas and the intensity of damage change continuously across the area you are mapping, you must make fairly arbitrary assumptions about what levels of damage to recognize, and how to draw boundaries between them.

The difficulties have several important consequences. The first is that, depending on the imagery used and the way it was interpreted, different maps of the same place can look quite different. And the second is that, because you rarely are working with either completely damaged or completely intact forests, mapping the blowdown is a kind of spatial averaging. This is consequential because spatial averages are annoyingly sensitive to the choice of a threshold level of damage, and to the scale over which you average.

Maps 7 and 11 are examples of the extent to which maps of small areas of blowdown can differ in details. And Map 6, which is supposed to show 430,000 acres of blowdown but in fact shows about 600,000 acres, is an example of the problems of spatial averaging.

Figure 2 is a hypothetical example of a blowdown averaged in different ways, to show how easily the kind of problem exemplified by Map 7 can arise. It represents a 128-acre block with total of 35 acres that are completely blown down. To estimate the amount of damage we need to choose the size of the area we will average over, and to have a rule about how we label different concentrations of damage. Assume that we call any block with 26-50% damage 'moderately damaged' and any block with 51 % or more damage 'heavily damaged. If we average over one- acre blocks we get the correct' estimate of 35 acres of heavy damage. If we average (third diagram) over 4-acre blocks we get 20 acres of severe damage, and six acres of moderate damage. If we average over 32-acre blocks (second diagram) get 32 acres of heavy damage, and 32 acres of moderate damage. And if we average over the whole 128 acres we estimate 128 acres of moderate damage.

Thus, depending on the scale over which we average, our estimate of the total blowdown area varies by a factor of five (26 to 128 ac), and our estimate of the amount of moderate blowdown by a factor of 20. Note that that the estimates generally get better as the scale gets smaller, and that our spatial averaging sometimes overestimates and sometimes underestimates the true area of 32 acres. Not only are we sometimes counting blowdown as forest and sometimes counting forest as blowdown, but we can't predict which we will be doing.

It is instructive, though scary, to play with similar examples. The theoretical lesson is that the blowdown is a fractal object, with detail on many different scales. Spatial averages don't work well with fractal objects. Coloring areas on a map and computing the amounts of damage are heavy-duty exercises in data smoothing and different choices of damage levels and different map scales are in general not comparable. The practical lesson is that while we use the maps of the blowdown for a general picture of what the storm did, we should be very cautious of attaching much weight to quantitative estimates of damage involving spatial averaging. If we really need an estimate we should be prepared to use some version of point sampling which does not depend on spatial averages.

What information is available about the overall geography of the blowdown?

Initial field reports and survey flights suggested that most of the damage was within a triangular area (Map 1), with more intense damage in an oval within the triangle. The triangle is about 50 miles on a side and is bounded, roughly, by Gouverneur, Blue Mt. Lake, and Lyons Falls; it contains about 900,000 acres. The area of intense damage lies between Star Lake and Brandreth and Little Tupper Lakes; it is about 10 x 20 miles and contains about 90,000 acres.

The triangle is not uniformly filled with blowdown, but is rather a rough boundary to the areas with intense blowdown. Outside of it there is damage to individual trees and a few local patches of an acre or two of blowdown, but no extended areas in which many trees are damaged. Using the F scale (Box 2, p. 9), essentially all areas showing Fl or F2 intensity damage are within the triangle; outside of it the damage is mostly F0.

These initial appraisals were useful but fairly crude. The 'severe damage' oval contains much severe damage, but also large areas where a high percentage of the land is damaged, but the intensity of the damage is less. The 'moderate damage' triangle is mixture of large areas with almost no damage at all, plus smaller areas where the damage is fully as intense as that in the 'intense damage' oval. In the language of the preceding section, this map is based on a type of smoothing, in which the percentage of land with some damage counts more than the local intensity of the damage. The result is a map that suggests that the damage varies with distance from a center, like a bomb blast or an earthquake. And this is to some extent a misrepresentation: it doesn't reflect either the linear nature alignment of the damage fans (Maps 2,3), or the interspersion of severely damaged and undamaged areas, two features very characteristic of derechos.

More detailed information came from air photos and Landsat Thematic Mapper images. The air photos were flown by the DEC in late July and early August. The Landsat images came from August 1994 and August 1995 and were combined and used to prepare a change or difference image. The image was prepared by comparing the images pixel by pixel and assigning arbitrary colors that depend on the color differences. It suggests that the intense damage, far from being an oval blob, is actually concentrated in linear bands aligned with the storm track. The bands run in several different directions, and seem to represent different, independently moving, parts of -the storm. The widest band is ca. three miles broad, the narrowest under 1/2 mile. The two largest bands have definite structure, and are composed of narrower bands, which are almost, but not quite, parallel.

My Map 2 was prepared from the Landsat change image by the author, with some additional information from air photos. It suggests that the storm moved along a bearing of approximately I 10 degrees, created scattered damage (burst swaths or microbursts) over a large area, and concentrated most of the damage in several narrow, elongate, somewhat fan- or wedge-shaped paths which can be called downbursts. The downbursts range from 10 to 20 miles long, and about 1/4 to three miles wide. As mapped here, the areas of intense damage total about 130,000 acres and are presumably the tracks of particularly intense part of the storm.

Map 2 is very generalized. The change image shows the elongated features in great detail, and reveals that they are not continuous swaths of damage, but rather a series of smaller, complexly shaped, patches of heavy damage interspersed with undamaged or more lightly damaged areas. This is shown in Maps 4 and 5. They were prepared for this report and combine data from the DEC air photos and two sets of low altitude oblique air photos taken by the author. They show more detail than either the Landsat images (pixel size of 100' x 100'), or DEC photo interpretation, which was based on 50 acre (ca. 1,500' x 1,500') blocks.

As noted in the introduction to this section, more detail doesn't necessarily mean a more truthful picture. Some of this detail in Maps 4 and 5 is a reasonably accurate representation of air photos, which show that the blowdown is composed of many individual blowdown patches, and that these often have sharp and fairly mappable edges. But some of the detail is made up, and is in fact an arbitrary imposition of boundaries where the photo shows gradational changes.

How closely does the Landsat change image agree with air photos?

I have not been able to make a detailed study of the whole Landsat image, but was able to examine a blown up image of the Five Ponds region and compare it to fairly detailed air photos I had taken on two different flights. The colors in the change image represent many possible 1994- 1995 transitions, and can be interpreted in a many different ways. I found that if the orange and light red colors were interpreted as blowdown (Map 7) the resulting Landsat estimate of blowdown generally was coincident with, but smaller than, the estimate of blowdown that I obtained from air photos.

What meteorological features of the storm were associated with the onset and cessation of damage?

Based on discussions with John Cannon of the National Weather Service at Albany, and a comparison of archived doppler radar images of the storm to my damage maps, it appears that:

> The main band of severe damage began when the storm began to develop a cyclonal rotation at the north end (Box 3, p. 14 Map 8). "This happened just when the main squall line reached a point where there had previously been an isolated storm cell.7 The interaction of an active storm cell with the outflow boundary of a previous cell has been implicated in a number of downburst related aircraft accidents (87), and may have intensified the gust front here, or caused it to curve.
>
> The swath of most intense damage coincides with the track of the leading angle of the bow echo (Map 8). This is the fastest moving part of the storm, has the most intense radar signal and the steepest gradient in radar reflectivity, and has a clear weak echo channel behind it. It is also the part where the cyclonal rotation and consequent tangential wind shear was greatest.

The areas of most intense damage coincide with the areas where the radar estimate of total storm precipitation is 1.5 inches or more; but there are other areas of intense precipitation westwards, paralleling the shores of Lake Ontario, that do not coincide with damage areas. The doppler estimate of winds within the storm shows that the leading edge of the high- velocity air entrained behind the bow echo coincides with the swath of maximum damage (Map 9). The end of the swath of concentrated damage occurs at a point when the storm no longer has a clear leading angle aligned with the storm track (Map 10). At this point the radar reflectivity, and presumably the intensity of convection in the bow echo, have decreased substantially, and a part of the bow echo has detached itself and is moving southward, perhaps drawing energy away from the main echo.

What is the meteorological interpretation of the fine structure in the Landsat image?

The hypothesis that I find most plausible is that each microburst line is the track of a separate unit (cell) of the storm, propagating for 10-20 miles in a constant direction. Each cell produced a number of damaging gusts, all approximately in the same direction. The individual patches of blowdown within the line may represent either the damage caused by a single gust, or may be areas that, by virtue of topography, received a number of successive bursts as one storm cell tracked over them. By this hypothesis the overall linear pattern is produced by storm cells, and at least some of the small-scale pattern by individual gusts. But other hypotheses are certainly possible. The question is interesting because it could potentially tell us whether the trees in a blowdown patch all went down at once, or even whether adjacent blowdown patches were the results of single gusts. It will take detailed study, and can probably only be answered by someone familiar with the physics of this sort of storm.

What are the quantitative estimates of the area damaged?

As expected, the estimates vary greatly with the scale of the mapping, the finer scales usually giving smaller estimates.

The very generalized representation of the storm in Map I gives a total damaged area of 900,000 acres, containing 90,000 acres of heavy damage and 810,000 acres of moderate damage.

The DEC's working maps, which average the damage for each 50-acre square, have 39,000 acres of heavy damage and 104,000 acres of moderate damage. If this damage (143,000 acres) was spread uniformly through the triangle we would have 16% damage throughout. But as Map 2 shows, it is not spread uniformly, and is in fact concentrated in the central 90,000 acres triangle in Map 1. On the conservative assumption that the damage is at least twice as concentrated in the center triangle, as in the outer, this gives an estimated 30% of the central triangle with moderate or heavy damage, and 14% of the outer triangle with moderate or heavy damage.

My map of the Five Ponds and Wolf Mt. quads (Map 5), which have some of the most continuous and intense blowdown in the Adirondacks, shows ca. 11,500 acres of blowdown in 6 1,000 acres, or 18% blowdown. For comparison with the DEC estimate of damage we might assume, again conservatively, that the inner triangle has 18% damage throughout, and the outer triangle at most 9%. This gives 0.18*90,000+ 0.09*810,000 = 90,000 acres of moderate or heavy damage, 61% of the DEC estimate.

Some quantitative samples by Michael Bridgen and his students at the James Dunbar Forest, just north of the Five Pond Quad, and again in an intensely damaged area, show blowdown on 450 out of 2,800 acres, or approximately a 16% concentration of blowdown, roughly comparable with our estimate just to the south. Using the same extrapolation as above, this would give an estimate of 80,000 acres total damage.

Bridgen and his students also measured the actual reduction in forest overstory on 115 acre plots. This is equivalent to measuring the blowdown on a scale of individual trees. Interestingly enough, this results in a substantially smaller estimate of total damage. They found that the basal area had been reduced an average of 7%. If we extrapolate as above by assuming that 7% is the actual canopy reduction over the central 90,000 acres, and that the remainder of the 8 10,000 acres triangle has 3.5% canopy reduction, then we get a total blowdown area of 35,000 acres, 25% of the DEC estimate.

Thus three studies averaging over different scales give very different estimates -- 147,000, 90,000, 80,000, and 35,000 acres -- for the total area damaged. The studies averaging over smaller areas generally give smaller numbers. Policy makers, resource economists, and quantitative geographers please note and beware.

How much of the blowdown is on state land?

Map 3 shows that much of the intense blowdown was on state land, with a majority of that in the Five Ponds wilderness areas. The principal concentrations of damage on private lands were around Star Lake, and between Lake Lila and Forked Lake. The principal large landowners involved were International Paper, Whitney Park, and Brandreth Park.

How does the damage compare, in extent and geography, with that caused by the 1950 storm?

Map 6 shows the damage swaths and triangular damage boundary of the 1995 storm superimposed the DEC map of the damage from the 1950 storm.

Clearly the two storms had very different patterns. The 1950 storm was a large cyclonic system (essentially a weird, inland hurricane) which passed to the west of the Adirondacks. In storms of this sort the intense winds are regional rather than local, and the damage is correspondingly more widespread. The 1950 map shows broad areas of damage in the southwest quarter of the park, and more scattered, but locally intense, damage northwards and eastwards. The 1995 storm was, by comparison, a narrower, non-cyclonic storm tracking directly across the park.

The accuracy of the 1950 map is not known. The damage patterns of hurricanes and other cyclonic storms are essentially always patchy and influenced by topography, and so it is unlikely that the large 10-20 mile wide blowdowns shown in Hamilton or Herkimer Counties are as continuous as the map makes them. And even when more local detail is given, the accuracy may be suspect. Map I superimposes two different maps of the blowdowns in the Cold River Area, both from the early 1950's. Both are generally similar, but show decidedly different shapes and areas.

DEC estimates of the area damaged in 1950 were initially 250,000 acres, subsequently raised to 400,000 and then 432,000 acres. Presumably these figures were based on a mixture of air-photo and ground estimates, but no details of the tabulation exist. The digitized area on Map 1 is about 600,000 acres, 40% larger than the state's figure. This is too large to be the result of errors in digitizing, and may reflect either the very generalized mapping of the large blowdown tracks in the southwestern Adirondacks, or errors in the areas computed for the original tabulation.

7. The Blowdown in the Oswegatchie Basin - General Features

This summer and fall I and a group of graduate students did about three weeks of field work in the Oswegatchie basin and at Lows Lake. Besides doing general work on plant communities, we attempted to visit a number of different parts of the blowdown to get a picture of what the damage was like, and to try out techniques for making ecological measurements in the blown down patches.

What follows is a preliminary account of the blowdown, based on our observations. We hope they may supplement, or in some cases be a corrective to, more general pictures of the blowdown derived from photo interpretation and the ecological literature. The numbers are based on a very few samples, and are offered for illustrative purposes only. Be aware that we were only able to visit low elevation blowdowns near rivers and lakes, and so our observations are representative neither of the whole range of blowdowns in the Oswegatchie area, nor of blowdowns elsewhere in the park.

What is the overall pattern of damage?

Most of the damage in the Oswegatchie drainage is part of the heavily shaded, wedge-shaped damage swath shown in Map 3. A 61,000 ac (7.5' x 15') section of this swath is shown in its regional setting in Map 4 and in detail in Map 5. It originates near Star Lake, crosses the - Oswegatchie near Inlet, runs parallel and north of the river to the Oswegatchie Plains, and then forms an almost continuous corridor of damage along the river for about three miles from the Plains to the upper forks beyond High Falls. A narrower band of damage extends eastwards through and beyond Five Ponds; a third band, oriented northwest-southeast like the first, begins near Five Ponds and extends to Lake Lila.

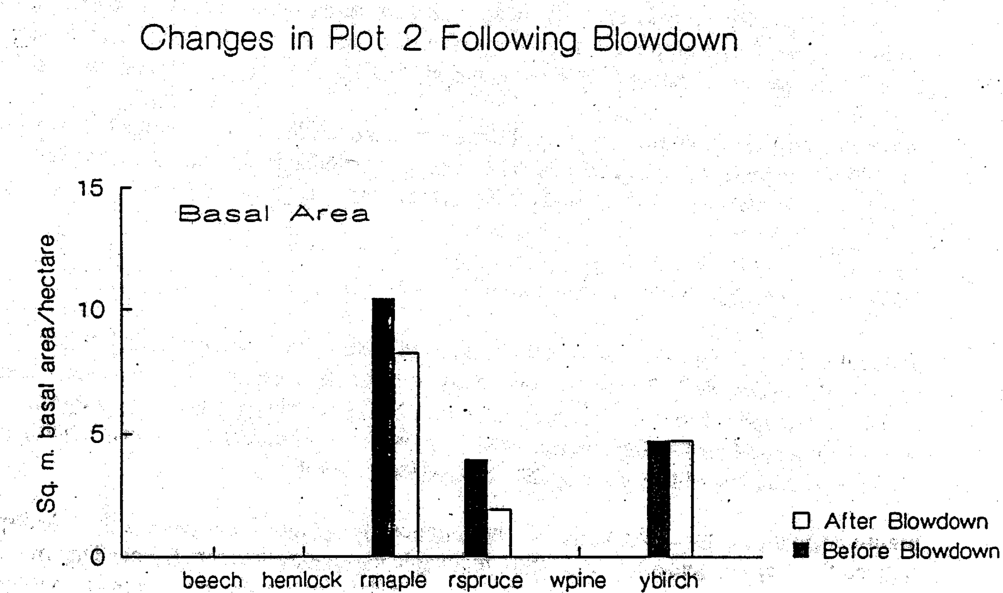


Figure 3: Changes in canopy composition on a 0.1 hectare (0.25 acre) plot in northern hardwoods forest on Three Mile mountain, northeast of the Oswegatchie Plains.

Pre-blowdown composition reconstructed from fallen trees with their bases in the sample plot. Basal area is in square meters per hectare; multiply by 4.4 to get square feet per acre.

How intense is the damage, and what types of timber were involved?

The large patches of damage form the band extending diagonally across Map 5 are mostly in hardwood forests on highlands and northwest- facing ridges. The blowdown here is moderately intense but not complete. The damage along the river at the south edge of this band, and also the damage close to Five Ponds, is mostly in softwood stands on lower slopes or in basins, and is moderately heavy to complete. T11e group of blowdowns south of Griffin Rapids and those from Five Ponds west are mostly partial blowdowns in conifer swamps or conifers on low flat lands.

A rough measure of the intensity of the blowdown is the residual canopy. In the hardwood blowdowns there is typically about 30-60% canopy remaining; in the softwood blowdowns there is commonly much less, with typically 0-30% remaining.

Were some trees affected more than others?

It appears that they were, but so far we don't have quantitative data that establish this. Big white pines were spectacularly vulnerable; spruce also vulnerable, especially when it grew in dense stands; less maples, beech and cherries vulnerable but of heavily damaged; yellow birch apparently a survivor, perhaps because it often grew in sparse stands; and larches, whether because of their low situations or sparse foliage, clearly survivors.

Figure 3 shows the pre- and post-blowdown composition of one of our sample plots. Red spruce showed the greatest percentage mortality, red maple less, and yellow birch none. This might reflect properties of the species involved, or might reflect the relative sizes of the individuals in this particular stand.

How big and continuous are the blowdown patches?

Many of the blowdowns near the river corridor are 100 to 200 yards in the longest direction. Others, especially along the upper river and on the ridges, are more continuous and extend for a mile or more. The continuity - or lack of it - is often a matter of perspective. Many of the larger blowdowns appear continuous when seen from the air or an adjacent ridge, but have enough standing trees to appear segmented or divided into rooms when you are in them.

Was there dispersed damage that was not concentrated in patches?

Very definitely. Individual fallen or damaged trees are found throughout the forests, even in areas where the air photos show no concentrated blowdown. Considering that 80% of the woods ate apparently unaffected, this dispersed damage may be a consequential, but currently unestimated, fraction of the total damage.

How do the blowdowns relate to topography?

Many of the Oswegatchie blowdowns, including essentially all the most extensive hardwood blowdowns, are on the tops, west, or northwest slopes of hills or ridges. The air photos and satellite images look like someone spray-painted the ridge tops, pointing the can east-southeast and tipping it down at about a forty-five degree angle.

In some places the blowdown extends over a ridge and slightly down the lee side. In other cases there are blowdowns on east or southeast slopes, especially on small knolls that did not create much of a wind shadow. These suggest that lee-slope turbulence and wind shear can initiate small blowdowns, but not generate extensive ones.

Table 1: Descriptive Data From Oswegatchie Blowdowns

Site	Size (m)	Species	Residual Canopy (%)	Azimuth; Aspect (magnetic)	Wetness	Height (m)
C45	150 x 40	BF; RS,WP	0	105; 195	moist	1-2m
C44	100 x 100	RS,VrP,BF RM,QA,YB	10	40,80,110;0	moist	1-2m
C35	100 x 150	RM,BC	5	100,110,135; 0; 300	dry-moist	2-5m
C34	40 x 100	WP,RS,BF BC,RM,	10-25	100,110; 0	moist	2-3,4
C32-I	lOOx2OO	BC; BF,RM	10-50	65,70,100-130 190,290;0	moist	1-2
C32-II	>100	WP, RS, BF	10-20	45,80,110,160; 0	moist-wet	1-2
High Falls	100+ x 100+	BF; RS,WP	5	120,160; 160,340	dry to moist	2-3(5)
Lost Knoll	100+	RS; RM	50-80	170 (80); 0	Dry to moist	1-2
Plot 1	50 x 100	RS,WP; BF	5-25	120-170; 300	moist	1-3
Plot 2	50 x 100+	RM; RS	25	60-190; 290	dry	1-1.5
Conifer Sw	150 x 75	RS; BF	0-5	30,55-65,95-125; 0	wet	1-1.5
Camp22		RS; WP	70-75	95; 0	moist	

Sites marked with C are campsite numbers along river. Size is linear extent of area observed; species BC = black cherry, BF = balsam fir, RM = red maple, RS = red spruce, WP = white pine; species following semicolon are secondary species. Azimuths are average bearings of fallen logs, aspect is principal downslope direction, if any; height is average maximum height of fallen trunks.

Another common pattern, commonly seen on islands, peninsulas, and small hills, is for the top of a convex feature to be flattened, but the sides, both upwind and downwind, to be much less damaged. This may reflect the strong vertical gradients of wind speed that have been reported for downbursts.

Velocities can be substantially higher at 100' above the ground than at 50' or 75', and so a small difference of elevation -- especially on a small topographic feature with a flat area around it -- may make a big difference in the winds to which the canopy is exposed.

There is also much blowdown, mostly of softwoods, in low flat areas, and even in areas in the lee of ridges. Some of these low blowdowns may have been places where winds were channeled along a river valley, as in the upper Oswegatchie southeast of High Falls where there is 3-4 miles of almost continuous blowdown on both sides of the river. Others may have been classical microbursts -- the impact areas of individual parcels of descending air.

What plant communities occur in the Oswegatchie Basin, and how were they were affected?

The Oswegatchie Basin contains a fairly normal Adirondack mix of dry and wet forests, shrub- dominated wetlands, and open grass- or sedge-dominated wetlands. It lacks open rock outcrops and large open bogs, but does contain an open, sandplain community, probably created by a fire.

The blowdown affected both upland and wetland communities, but certainly did more damage to uplands and wetland edges than to the wetlands themselves. The most heavily affected communities were dense softwood forests with tall trees. In these communities the trees seem to have fallen in groups, and it seems quite possible that, once initiated by the falling of a few trees, a blowdown wave could propagate through a stand. Areas of sparser and lower trees, even if poorly rooted and therefore susceptible, were often spared.

The effects on individual communities may be summarized as follows:

> The open wetlands and alder swamps were almost entirely unaffected. No alders blew over; occasional isolated pines and cherries within the wetlands blew over, but many were left standing.
>
> Lowland spruce-tamarack swamp forests were sometimes blown down, but more often lightly affected or unaffected. Many of these forests have relatively low trees and sparse canopies, and so are less exposed to the winds, and less susceptible to propagating failures.
>
> Lowland spruce-fir forests on flats or lower slopes were heavily affected. These forests often have dense stands of tall but slender trees and often were completely flattened.
>
> Pine stands on flats and knolls were also heavily affected. They tend to be on dry shallow soils, and to have tall trees with big crowns. Propagating, failures almost certainly occurred, and 100% blowdowns are common.
>
> Isolated pines on rocks or islands were often blown down. They tend to be fairly strong, but have large canopy areas and shallow root systems. Sometimes the roots had clearly broken; in other instances it looked like the whole root system had just peeled off the rocks.
>
> Hardwood forests, which are mostly on slopes and ridges, showed many different levels of damage. They are the most extensive community in the area, and so contribute the most to the total area of the blowdown. But they are typically sparser than softwood stands and only rarely were they leveled the way the dense softwood stands were. In many places failures did not seem to propagate as much, and substantial amounts of residual canopy remain. In other places, particularly on exposed ridgetops, or on flats where hardwoods and softwoods were mixed the damage level was higher.
>
> The sandplain community in the Oswegatchie Plains, which consists of two shrub-dominated openings surrounded by a ring of young white pines 25 to 45 feet high, was unaffected by the blowdown. (The openings were probably created by a pre- 1900 fire, and may have been maintained by occasional fires since then. There have been no known fires in the last 40 years; the USGS Five Ponds quad, based on 1966 air photos, shows the openings of over twice the present size.) As was noted in the 1938 hurricane in New England, windstorms mostly kill large old pines. The small pines in the Oswegatchie Plains suffered essentially no damage, while larger pines on adjacent knolls or in the swamp to the north suffered severe blowdown.

To summarize: all communities except open wetlands and shrub swamps suffered some damage. Dense softwoods at the edges of channels and hardwoods on ridgetops were the most thoroughly flattened; softwood swamps had sporadic damage that was only occasionally intense; hardwood stand., and mixed upland woods occupy the greatest area and probably incurred the greatest total amount of damage, but not the most intense damage.

Did the blowdown affect rare species or communities?

Apparently not. The only rare plants that I know in the upper Oswegatchie basin and the Lows Lake area are the milfoil ***Myriophyllum verticillatum*** (verticillate milfoil), and the two grasses ***Oryzopsis canadensis*** (Canada wild rice) and ***Calamagrostis pickeringii*** (Pickering's Reedgrass). The milfoil is a submerged aquatic, the wild rice a plant of open sandy soils, and the reedgrass a plant of boggy shores. None of these habitats are likely to have been affected by the blowdown.

Much the same is likely to be true for the blowdown as a whole. Essentially all the rare plants in the central and western Adirondacks are found in openings, open wetlands, or deep water, and are very unlikely to have be affected by the storm.

The Oswegatchie Plains are regarded, probably incorrectly, as a rare plant community. Whether rare or common, they were unaffected by the blowdown.

How was recreational access affected?

All the trails in the northern two-thirds of the Five Ponds Wilderness Area were blocked by the blowdown. Some segments had only scattered blowdown, and were still usable if you were willing to climb over fallen trees and detour around small blowdown patches. Other segments of the trails pass through major blowdowns. In these areas the trail and the trail markings are obliterated. You can get through them if you know the area and are determined and willing to climb. But it may take 10- 15 minutes of tiring and potentially dangerous climbing and crawling to progress 100 yards, and some of the trails are blocked for a mile or more.

During our October trip we made several attempts to bushwhack from point to point, using a compass and air photos of the blowdown for guidance. We found that this was an interesting way to see things we would not have otherwise seen, but not an effective way of going anywhere in particular. The major blowdowns were formidable obstacles. When we tried to use our photos and skirt them, we often discovered dispersed but still consequential blowdown which we could not see in the photos. On one trip near High Falls we took 90 minutes to move 2,000’ (0.25 mph). We were obliged to turn back because of rain and dark, and were fortunate to find a better exit route which allowed us to make the return trip in 70 minutes (0.32 mph). In a trip south near the Five Ponds Outlet, we were more successful and traveled 2,500' in about a half hour (0.95 mph). In all our blowdown trips we were sensible of the exertion and risk involved, and felt that only an exceptionally fit and careful party could travel for more than three or four hours -- and hence at most a few miles -- through the blowdown without becoming exhausted. We note that we were carrying only light (< 20 lb.) packs, and that a heavy pack would make it almost impossible to move through the blowdown at all.

Boat access was less affected. Several hundred trees fell into the river between Inlet and High Falls. Most of these did not extend fully across the river, but enough of them did that the river was temporarily blocked, and parties that were camped up the river on July 15 had considerable trouble working their way out. Many of the fallen trees were cut or cleared away by boaters in the next few weeks, and by 15 August you could travel to Griffin Rapids without a carry, and from there to the Five Ponds Bridge with two or three carries or pullovers. Between the bridge and High Falls there were still a number of down trees, and above High Falls, at least by report, many. When we returned in mid- October many of these had been cleared away, but, even with high water, we still needed perhaps two carries between Griffin Rapids and the Plains, and another two between there and High Falls.

How were campsites and shelters affected?

At least seven campsites and three shelters are immediately adjacent to blown down areas. All of these, and several others not adjacent to blowdowns, have fallen trees within or immediately adjacent to the camping area. Many of these have been partially cleared, either by the DEC or by camping parties.

What are the blowdowns like to work in or go through?

In the most intense blowdowns the trees all fell in one direction, and are now piled on top of one another. The trees are commonly somewhat crisscrossed. With care you can often climb up on one trunk and then move about using crossing trunks or jumping from tree to tree. Much depends on your balance and on whether you carry health insurance. Typically the trees are one to two yards from the ground, but at the highest point you may be three or four yards up, and have a dozen or more trees crossing below you. The trunks commonly have numerous branch stubs, which could produce a serious injury in a fall. Fallen trunks and canopy branches are densely intertwined, making it quite hard to go under or between the trees; when we were measuring the lengths of trees in these tangles, it often took some time to figure out what trunk went with what branches and what base.

Was there any evidence of tornadoes?

We saw none. Tornado scars are typically elongate and have down trees lying in all directions. The damaged trees are often clearly twisted or broken halfway up. Most of the blowdowns we saw were oval or rectangular rather than elongate, had the fallen trees more or less aligned, and had trees that were broken near their bases. And we saw no instances at all of the twisted or spirally broken trees so characteristic of tornadoes.

Does any of the blowdown occur on areas previously affected by the 1950 blowdown?

Map 6 suggests that much of -the damage in the 1995 blowdown lies north of the area affected in 1950, but that the current and old blowdown overlap just south of the river at High Falls.

We spent several hours investigating this area, partly out of curiosity and partly because we could not get out any faster. We found clear traces of the 1950 blowdown: forests of fairly slender spruce and fir with many standing dead snags, a dense layer of conifer saplings, and many old down trees that had fallen west or southwest. Many of these forests had been heavily damaged in the 1995 blowdown, and some were completely flattened. It was clear that the pre-July 15th forests had a lot of dense skinny trees, and we speculate that some of the 'devastation' noted by visitors to High Falls is because the forests here were still in comparatively early stages of recovery from a previous storm.

Does any of the blowdown occur on lands that burned in 1903 or 1908?

The 1903 and 1908 fires were largely on cut-over lands. Comparing published maps of the fires with our maps of the July blowdown (Map 12), it appears that little of the upper Oswegatchie Basin (which was not cut until after 1903) burned. There were large fires in the lower Oswegatchie basin, north and west of Cranberry Lake, in 1903. One of these fires apparently reached the upper Oswegatchie a few miles west of Inlet. The great Lows Lake fire of 1908 also reached west to the southeastern headwaters of the upper Oswegatchie. Both of these areas are in the main 1995 blowdown swath. We did not visit either, and have no field observations.

8. The Blowdown in the Oswegatchie Basin - Quantitative Features

This is a preliminary account. The numbers are from a few plots and should be considered illustrative, not exemplary.

How much has forest basal area been reduced?

Basal area is the cross-sectional area of the trunks of the living trees in a stand, measured about 5' off the ground. We can estimate the basal area blown down from the pre-blowdown basal area and the percent of damage, or measure it directly on sample plots.

Good pre-blowdown basal areas for old-growth stands are available from John Roman's 1980 Ph.D. thesis (61). He found basal areas in the Five Ponds area to average about 131 square feet per acre (sq.f./ac.) for yellow birch-dominated stands, 144 sq.f./ac. for beech-and sugar maple-dominated stands, 170 sq.f./ac. in spruce-dominated stands and 196 sq.f./ac. in hemlock-dominated stands. The grand average was 153 sq.f./ac.

Much less information is available for second-growth stands. From studies elsewhere, second-growth stands over 100 years old should approach old-growth stands in the same area. 711le second-growth forests in the upper Oswegatchie basin are about 80-90 years old, and should be 10-20% lower in basal area than the old-growth forests. Six plots of second-growth hardwoods that we measured this summer ranged from 87 sq.f./ac. to 162 sq.f./ac., averaging 122 sq.f./ac. or 20% lower than the old growth, in line with our estimate. A white pine-spruce stand we measured this fall had 153 sq.f./ac., the same as the average for old-growth.

The percentage of basal area blown down varies from 100% in some softwood stands to less than 10% in lightly affected hardwood stands. Our observations suggest that 75% or greater reductions in basal area are common in dense softwoods. This would be a reduction of 100 sq.f./ac. to 150 sq.f/ac., depending on the age of the stand and the severity.

Basal area losses in hardwoods are harder to estimate. Many hardwood stands, especially on hills, had patchy canopies before the blowdown, and so you can't tell the amount the canopy has been reduced by looking at the residual trees. In one birch stand we estimated that 75% of the canopy was open, but found that the measured loss in basal area in the blowdown was only 25%. Thus the stand must have had only 50% canopy before the blowdown.

Given these uncertainties, probably the best we can say at present is that hardwood stands that appear on air photos to have been at least moderately affected by the blowdown may have lost as little as 20 sq.f./ac. of basal area, or (rarely) as much as 150 sq.f/ac.

What volume of wood has been blown down, and what portion of the ground is covered?

Measuring the volume of the down wood is simple in principal, but hard, or at least slow, in practice. We measured all fallen stems over 10 cm diameter in two 0.45 acre (1 / 10 hectare) plots, using tape measures, DBH calipers, and hand-held electronic distance measuring equipment. This took four people about two hours per plot in hardwoods and 4-5 hours per plot softwoods. The work needs to be done with some care; in particular you need to locate the base of each trunk to determine whether it was in the plot, and to identify trees that were dead before the blowdown.

The hardwoods plot we measured (the patchy hillside stand mentioned earlier) had about 1,200 cu. feet of down timber per acre (ca. 10 cords per acre). The softwood stand, a dense stand of big pines, had about 5,600 cu. ft./ac., or roughly five times the amount.

Figuring areas instead of volumes, we estimate that about 8% of the ground is covered by down timber in the softwood blowdown and 3% in the hardwoods. In contrast, an undisturbed old-growth forest we examined had 2% of the surface covered by down wood.

How are the fallen trees oriented?

Most of the fallen trees had a strong east-southeast to southeast orientation, though often with scatter. It was common to find groups of trees crossing each other at angles of 30-60 degrees.

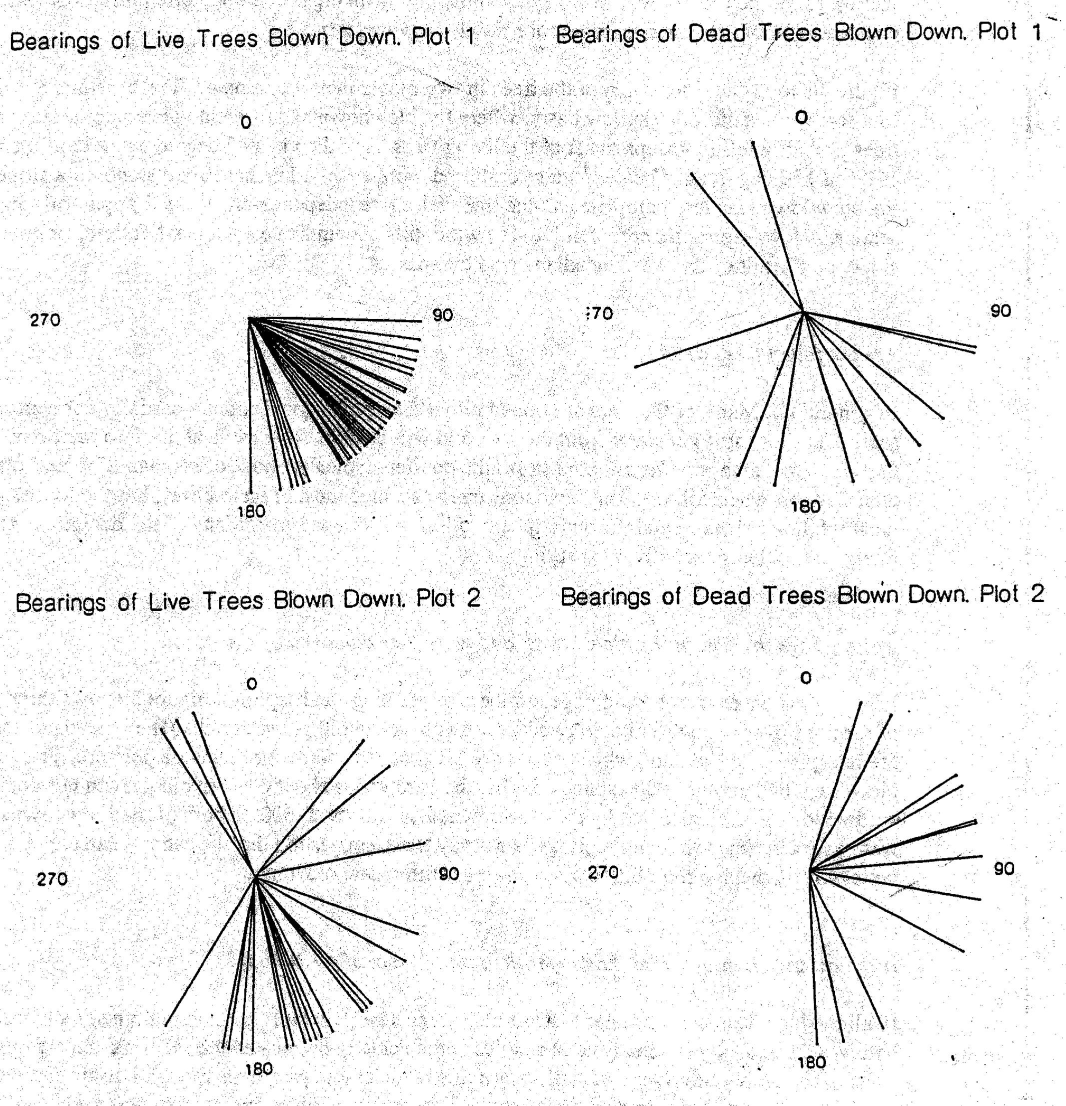


Figure 4: Orientations of Blowdown Trees in Plots 1 & 2, Oswegatchie Basin, October 1995

Vectors give orientations in degrees magnetic. Declination is 13 degrees. Plot I is a dense softwood stand east of the Oswegatchie Plains, Plot 2 a sparser hardwood stand on Three Mile Mountain, northeast of the Oswegatchie Plains.

But we found no blowdowns that displayed the highly divergent, fan-like orientations of fallen trees characteristic of downbursts from more slowly moving storms.

Figure 4 shows the orientation of the trees in two blowdowns we sampled. The bearings are magnetic. In a softwood stand in a shallow basin, where the blowdown had essentially been complete and the trees probably fell in groups, most of the living trees had fallen in a 45 degree band, bearing between 110 and 150 deg. mag. The dead snags scattered more widely. In a hardwood stand on a slope where the blowdown was less complete and the trees fell more independently, there is apparently more scatter. A few trees apparently fell into the wind; this may indicate a whiplash failure, or an effect of slope, or a result of the way Canadians read compasses.

Are the fallen trees dead?

In general no. Many of the trees are tipped rather than broken, and still are partially connected to their roots. They can still get water from the soil, and will be able, for a while at least, to maintain some of their leaves. Three months after the storm the conifers typically showed less than 25% and often less than 10% browned foliage. The deciduous trees had shed most of their leaves, but the leaves had mostly fallen normally and the buds appeared living and functional. Many of the deciduous trees will likely leaf, at least partially, next spring.

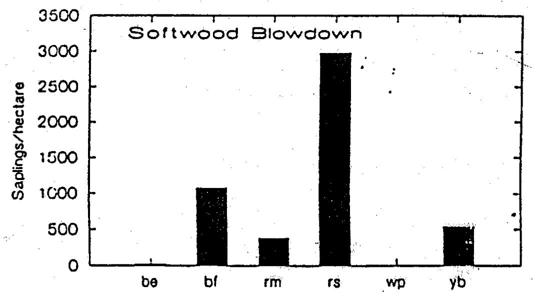
Are saplings present in the blowdowns, and were they damaged by the storm?

All the plots we examined had large numbers of seedlings and saplings. Figure 5 shows the numbers of saplings over one yard high in two blowdowns and an old growth stand. (The legends of the graphs are in saplings per hectare, which is roughly 2.5 times the number of saplings per acre. The softwood blowdown had about 2,000 saplings per. ha, the hardwoods about 600. An old growth hemlock-hardwoods stand, unaffected by the blowdown, also had about 600. In both of the blowdowns there were over ten times as many saplings as canopy trees, suggesting that the canopy can easily be replaced by advance reproduction, without recruiting new seedlings.

Is the composition of the sapling layer the same as that of the canopy?

In all the instances we examined it was not. Spruce saplings were common in both spruce, pine, and hardwood stands, and in many communities spruce clearly dominated the seedling and sapling layers. Balsam firs were common, especially as seedlings under one yard high, though balsam firs were uncommon canopy trees in our area of study. Essentially no pine reproduction was seen. Red maple was unpredictable. It was under-represented in some hardwood stands with a red maple dominated canopy, over-represented in some softwood stands without adult red maples. It is a classical successional opportunist, and probably takes its chances where it finds them. Yellow birch was a common sapling in many forests, though often less so than spruce or fir.

Figure 6 gives the pre-blowdown composition of three study plots, reconstructed from measurements of standing and down trees. Comparing these to Figure 5 shows that the blowdown is likely to cause composition changes in all these plots. The softwood blowdown has apparently lost white pine, but



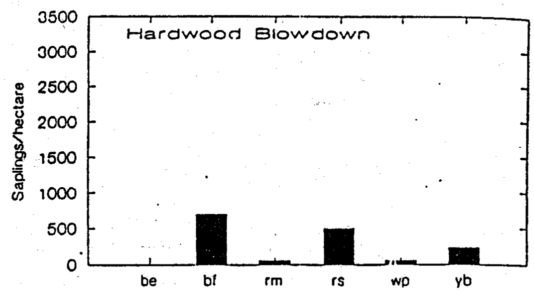
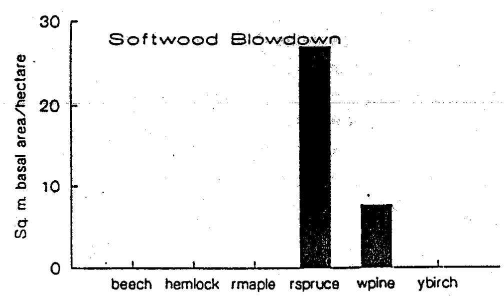


Figure 5: Numbers of Saplings Over 1 Meter High in Two Study Plots

be = beech, bf = balsam fir, rm = red maple, rs = red spruce, wp = white pine, yb = yellow birch. Locations of plots as in Figure 4. Saplings counted on a 1/10 hectare (0.25 acre plot), extrapolated to 1 hectare (2.47 acres).



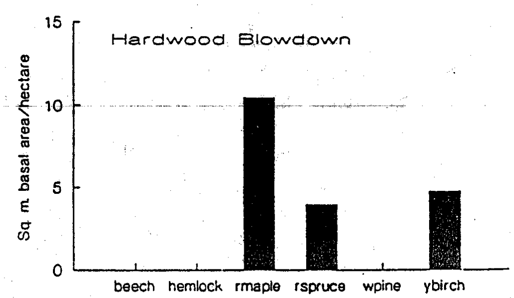


Figure 6: Pre-blowdown Composition of Two Plots.

Locations of plots as in Figure 4. Basal area reconstructed for a 1/10 hectare (0.25 acre) sample by combining standing trees with down trees whose bases were in plot.

may gain fir, yellow birch and red maple, none of which were present in the pre-blowdown canopy. The hardwood stand was dominated by red maple but has little advance red maple reproduction and may become a mixed spruce-yellow birch stand. The old growth stand is currently dominated by yellow birch and hemlock. Neither of these are reproducing within it, and it may eventually be dominated by spruce.

How prevalent were tipovers, and what percentage of the ground has been disturbed?

Most of the blowdowns were on thin soil and the trees shallow-rooted. Typically the softwoods have large but thin tipovers, commonly two yards or more high, and sometimes, especially in large white pines, five yards high or more. Hardwood tipovers were substantially smaller.

In the softwood blowdown we studied we estimated roughly 100 tipovers per acre, of both living and dead trees, covering 8% of the ground surface. In the hardwood blowdown we estimated about 60 tipovers per acre, covering 3% of the ground.

Are early successional species present in the blowdowns or adjacent forests?

Early successional species are species that require openings to become established, and usually do not persist for more than one generation in undisturbed forests. Blowdowns may be colonized by early successional species, but do not have to be. The extent to which this will happen depends on whether there are undamaged adults of these species in the general vicinity, or viable seeds in the seed bank within the blowdown.

Much of the Oswegatchie basin has been undisturbed since the Rich Lumber Company (which operated the railroad from Wanakena to High Falls) ceased operations in 1912. Consequently there are very few openings, and very few early successional species. Quaking and big tooth aspens are rare or absent in the forests, but do occur on some shores and in the Oswegatchie Plains (Box 7, p. 40). Gray birch and pin cherry are apparently absent, white birch almost absent. Sumac and gray dogwood are apparently absent. Red elderberry has been reported, but was not seen in our studies. Meadowsweet and steeplebush are common, but largely restricted to wetlands. Red raspberry and Canada blackberry are the commonest upland shrubs; Allegheny blackberry, which is ubiquitous in the lowland Adirondacks, is present but scarce. Blueberries are common but usually in small quantities. A few early successional herbs (pearly everlasting, rough-stemmed goldenrod) occur in forest gaps, but usually in very small quantities.

Do alien plants and animals occur in the upper Oswegatchie basin?

They almost do not. We have noted only four European weeds in the upper Oswegatchie basin (Box 7, p. 40). Three are restricted to the yards around lean-tos and other intensely used campsites. Only one, the sheep sorrel, has been reported outside of campsites, and even it seems always to be associated with trails.

The situation is much the same with alien birds. Breeding bird data are available from the early 1980's. Breeding cowbirds have been reported for 5 km-blocks that include the parts of the Oswegatchie near Cranberry and Star Lake, but not for the upper parts of the river or for the wilderness areas to the east and south. Starlings and English sparrows are not known anywhere in the upper Oswegatchie basin.

The extremely low diversity and infrequent presence of aliens suggests that the Oswegatchie basin, like many Adirondack wilderness areas, is biologically pristine to an extent that is extremely unusual in the U.S. as a whole. It is especially interesting to note that many plants (common veronica, common buckthorn, European honeysuckle, and Canada bluegrass ...) which are ubiquitous woodland invaders elsewhere, and which are reasonably common in parts of the Adirondacks with more settlement and roads, are apparently completely absent here.

Box 7: Status of Early Successional Woodland and Opening Species in Oswegatchie Basin

Trees

Populus grandidentata	Big-tooth Aspen	rare
Populus tremuloides	Quaking Aspen	rare

Shrubs

Corylus cornuta	Beaked Hazelnut	rare
Diervilla lonicera	Bush Honeysuckle	occasional
Rubus allegheniensis	Common Blackberry	rare
Rubus canadensis	Canada Blackberry	common
Rubus idaeus	Red Raspberry	common
Sambucus pubens	Red Elderberry	rare
Vaccinium angustifolium	Early Lowbush Blueberry	common
Vaccinium myrtilloides	Velvet-leaf Blueberry	common

Herbs

Anaphalis margaritacea	Pearly Everlasting	rare
Aster divaricalus	White Wood Aster	rare
Carex umbellata	Umbellate Sedge	local
Danthonia spicata	Wild Oats	local
Pteridium aquilinum	Bracken Fern	common
Solidago rugosa	Rough-stemmed Goldenrod	frequent

European Weeds

Arcticum minus	Burdock	rare
Poa annua	Annual Bluegrass	rare
Rurnex acetosella	Sheep Sorrel	rare
Trifolium repens	White Clover	rare

From survey work by the author

9. How much has the blowdown increased the risk of fire?

The risk of fire can be estimated by quantitative models, or treated approximately by case histories and historical records.

I strongly favor the second treatment. Models of fire risks have mostly been developed in the western U.S. We don't have models that have been calibrated for eastern forests, and, even if we did, would have no way of knowing whether to trust them. They may work in the west where forests are more uniform, lightning ignitions common, and summer weather predictable. In the humid east, with unpredictable weather and a spatially complex and poorly quantifiable mosaic of damaged and undamaged forests, I think it very unlikely that any existing model can tell us anything meaningful.

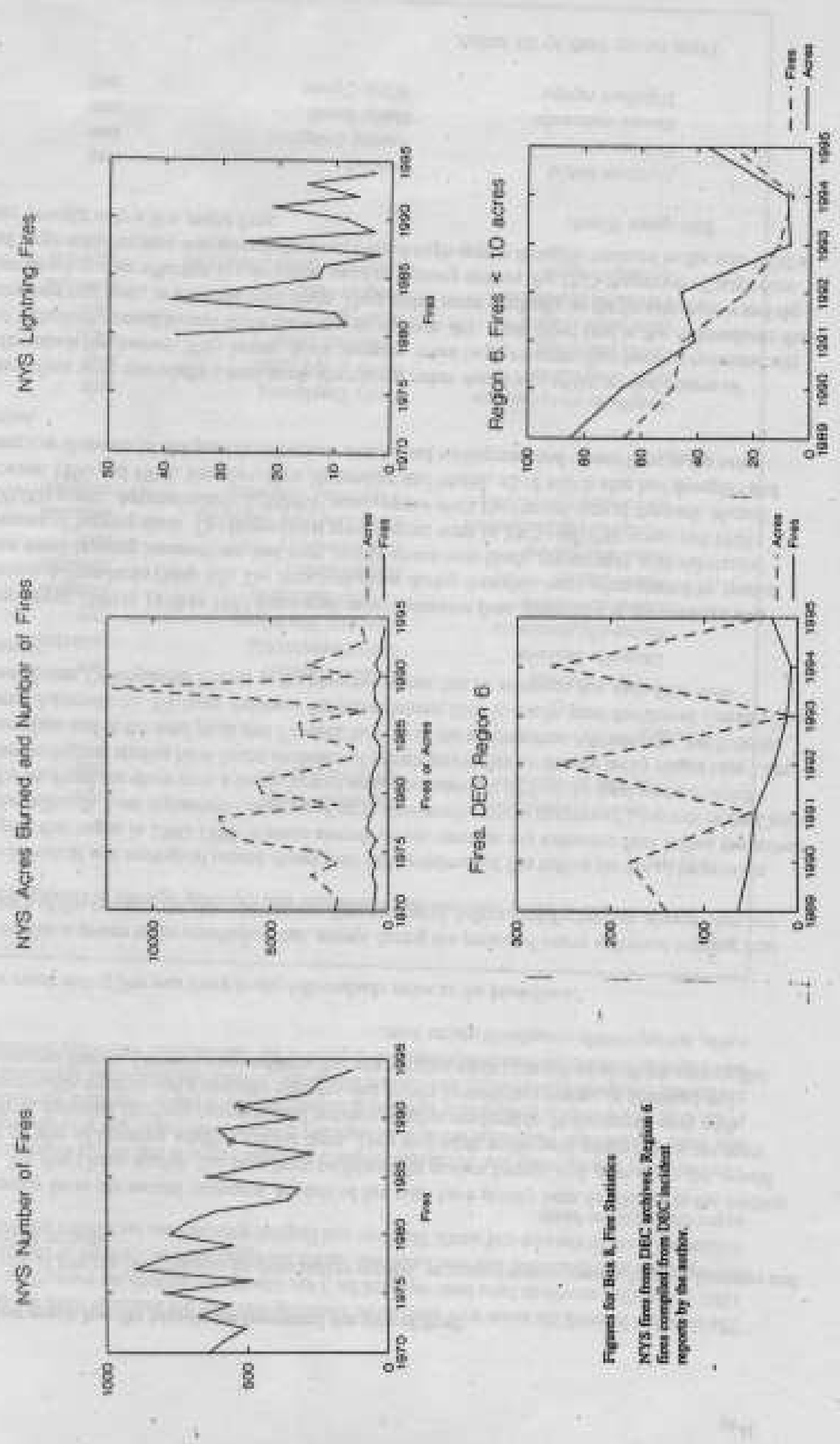
How much risk of fire was there in the Adirondacks prior to the blowdown?

All evidence points to the conclusion that, except during the period of heavy softwood logging near the turn of the century, the risk of extensive fires in central Adirondack forests has always been low.

The historical and ecological record shows very little evidence of fire before the era of large-scale logging that began in 1880-1890. Written records do not mention any extensive fires before the arrival of the railroads. Late eighteenth century and early nineteenth century surveys of 12 towns in the Cross & Totten Purchase show only a single burned area, comprising 0.07% of the total area surveyed. Paleo-ecological studies have found evidence of presettlement fire on the dry rocky ridges near Lake Champlain and in the sand plain and flat-rock barrens of the northeastern Adirondacks, but little in central Adirondacks. We have evidence for presettlement fires in sandy, pine-dominated forests (Five Ponds Esker, Oswegatchie Plains) in the blowdown area, but no evidence that such fires were common.

From about 1880 to 1910 or 1915 there were many extensive fires, especially in the northern and western Adirondacks (Map 12). The fires took place during droughts, were often started by sparks from wood-burning locomotives, and were mostly or cut-over lands, presumably with substantial amounts of logging slash. The largest total areas burned were in 1903 (400,000 acres) and 1908 (300,000 acres). Approximately 1,000,000 acres, or one sixth the current area of the park, burned between 1890 and 1914. Vermont, New Hampshire and Maine, all of which also had droughts and extensive clearcuts in old-growth softwoods stands, had widespread and severe fires in the same period.

These fires were essentially a man-made aberration, rather than a part of the normal course of Adirondack fire history. They began, fairly abruptly, when large clearcuts first became economically and technically possible, and when there was more open, dry, slash-filled land in the Adirondacks than there ever had been, or ever has been since. They ended more gradually as the forests regrew and the state developed an effective fire detection and fire fighting system. By 1925 the period of large fires and large-scale logging was essentially over; even though severe droughts returned in the mid 1930's, they brought only a few major fires.



Figures for Bite & Fire Statistics

NYS fires from DEC archives. Region 6 fires compiled from DEC incident reports by the author

Box 8: Recent New York State and Region 6 Fire Statistics

The graphs show numbers of fires- and area burned for Region 6 (northwestern Adirondacks and adjacent Champlain Valley) and New York as a whole. The number of lightning fires for New York State is also shown. The time periods (7 years for Region 6, 26 years for NYS) were determined by the data available in the DEC Fire and Safety Office in Albany.

Note the fluctuations in acreage and number of fires; the general decreases statewide in the last 15 years and in Region 6 in the last seven years; correlation between fire numbers in NYS and

regions 6; correlation between fire number and area in NYS, and in Region 6 when the large fires are removed; lack of correlation between either NYS fires or Region 6 fires and the Palmer index of drought severity (the index is negative in drought years so a good correlation would be negative; and moderate correlation between lightning fires and drought index.

Spearman Correlation Coefficients For Yearly Fire Statistics

	NYS Acres	Reg 6 Fires	Lightning Fires	Palmer Index
All NYS Fires	0.886	0.943	0.116	0.290
				Palmer Index
NYS Lightning Fires				-0.456
	Reg. 6 Acres	Reg. 6 Sm. Ac.		Palmer Index
Region 6 Fires	-0.257	0.886		0.580

NYS data 1970-1994; Region 6 data 1989-1995; Lightning data 1980-1994; Fires = number of fires, Acres = total acres, Reg. 6 Sm.Ac. = total acres in fires of 10 acres or less, Palmer = Palmer drought index, which is negative in drought years.

Since the 1920's there have been no giant Adirondack fires and relatively few of more than 500 acres. But there have been plenty of small fires. These is partly because there has been an increase in the number of people using the woods, and partly because we are detecting and recording many small fires in the 0.1 to 5 acre range that were previously overlooked. The result has been a characteristic change, both in the Adirondacks and in the forested northeast as a whole, in the demography of wildfire. The area burned per fire and the aggregate areas burned per year have decreased dramatically. But the number of fires actually climbed in the first part of the century, and since then has fluctuated or shown a gradual decrease (Box 8, p. 43). Either this means that people are getting no wiser or dumber, or that we have somewhat wiser people but a lot more of them.

Currently the majority of wildfires are small and occur on open rural lands, rather than wilderness, areas. In DEC Region 6 (western Adirondacks, St. Lawrence Valley, Tug Hill) there were 233 reported fires from 1989 through November 1995, or 30-40 per year. The median size was 0.75 acres. Seventy- eight percent of these were under two acres, and 97% (all but 6) were 10 acres or less. Most of these fires, including most of the ones over two acres, were in grass, brush, or conifer plantations. Relatively, few were in native woodlands.

The change in the size of fires has changed the way forest managers view fire risks. Essentially they expect to put out fires on a routine basis, but don't worry about them the way they used to. The woods, especially in the forest preserve, are much taller, thicker and wetter than they were 70 years ago, and have much lower accumulations of dry fuel. Logging on private lands is cleaner and much more dispersed than it used to be. And the state has a demonstrated capacity to reach small fires and put them out quickly. The current perception, both among the general public and the officials in charge of fire safety, is that fires are difficult to start, and, once started, are usually slow-moving enough that they can be put out before they bum large areas.

The clearest evidence of the changing perception of the risk of large woodland fires is that in the last 20 years the state has abandoned all the fire towers and discontinued routine air surveillance of forest lands except in the driest years, thus voluntarily decreasing its ability to detect fires when they are small. Rangers say 'I only learn about the fires in my district when someone in the next county finally sees the smoke.' In 1920, when the woods were still filled with slash and fire crews walked to fires, early detection and response were considered crucial and our current ***laissez-faire*** approach to fire detection would have been unacceptably dangerous. In 1995, with relatively slow-burning forests and crews reaching fires by aircraft, the general feeling seems to be that early detection, except possibly in the driest periods, is not really necessary. And this is born out by the statistics that show we are not seeing an increase in the incidence of large or dangerous fires. For example, in 1995, an exceptionally dry year, there have thus far been only 30 fires in DEC Region 6, burning a total of 38 acres. The largest fire was a grassland fire of four acres. Only 14 of the 1995 fires have been in woodlands; they burnt a total 14.4 acres, or 1.1 acres per fire.

Are lightning-caused fires important in the Adirondacks?

Lightning strikes are common in the Adirondacks; there were probably over 6,000 cloud-to-ground strikes during the July 15th storm alone. But fires from lightning strikes are rare and are believed to account for only a few percent of the reported fires. In DEC Region 6 (western Adirondacks and adjacent St. Lawrence Valley, there are believed to have been six fires caused by lightning in the last seven years. This is 2.5% of 0 the fires in that period. The total area burned in lightning fires was 3.5 acres (0.6 acres per fire), 0.4% of the total area burned by all fires.

The low incidence of lightning fires is probably because most Adirondack lightning strikes are 'wet strikes' that occur during rainstorms, and the combination of the rain and the normally wet ground layers of Adirondack forests make it hard for a fire to spread. In consequence, many lightning fires are not discovered until after they have gone out. It is not uncommon to find a snag or stump in the woods that has been charred by a lightning fire. But there is rarely evidence of the fire spreading from the tree that was struck, and often when crews respond to a lightning fire they find a single smoking tree.

This does not mean, however, that there are no consequential lightning fires. The Cold River fire of 1953 (Box 1, p. 3), which is the only major fire known to have occurred in a blowdown in the Adirondacks, was a lightning fire. A second lightning fire was discovered in the same blowdown while the crew was fighting the first one. And there were in fact several minor lightning fires in the July 15th storm.

It is conceivable that the blowdown might increase the number of lightning fires, both by increasing the fuel load and by leaving standing dead snags exposed in the middle of blown down areas. I know no way of determining whether this is a real risk except to wait and see.

What are the major sources of ignition for Adirondack fires and are any of these significantly altered by the blowdown?

Most Adirondack fires, both in settled areas and in the back country, are known or believed to be caused by people. The following table gives a summary of the fires in the western Adirondacks and adjacent parts of the St. Lawrence Valley for the last seven years, which is the period for which archived incident reports were easily available.

Table 2: Wildfires in DEC Region 6,1989-1995

Cause	Number	Total Acres	Acres/fire
Outdoor Burning	77 (29%)	204 (20%)	2.6
Incendiary	57 (24%)	320 (32%)	5.6
Campfires	44 (18%)	22 (2%)	0.5
Miscellaneous	38 (16%)	83 (8%)	2.2
Smoking	18 (8%)	301 (30%)	16.7
Lightning	6 (3%)	4 (4%)	0.6

Data from DEC incident reports. Outdoor burning includes trash barrels, burning brush, escaped fires from the deliberate burning of lawns and fields. Incendiary fires include known arson and other suspicious fires. The average area per fire for smoking is misleading; most of it was in a single large 255-acre fire.

Outdoor burning (trash, debris, leaves, lawn fires that got away) and arson caused the largest numbers of fires, and together are responsible for about half of the area burned. Both of these categories are largely restricted to settled areas. Unextinguished campfires caused 20% of the fires overall and are the major cause of fires in wilderness areas. But notice that the total area burned was only 22 acres, or 0.5 acres per fire. The largest individual fires caused by campfires were three and five acres; all the rest were one acre or less. This suggests that, like lightning fires, fires started by campfires move relatively slowly, and often don't spread very far beyond the campground itself.

Does the 'fire danger' control the number and extent of fires?

The 'Fire danger' reported by the DEC is an aggregate measure, analogous to 'degree-days', of how dry the weather has been and thus how dry the fuels are likely to be. In areas like the intermountain west where natural fires predominate, the number and extent of fires correlates well with the fire danger. But in the northeast, where human activity causes about 97% of the fires, there seems to be a lot of statistical noise in the data, and there is at most a weak relation between weather and the number and extent of fires (Box 8, p. 43).

I looked for weather-fire relations in a variety of ways, but was hindered by limited data sets, and will need to repeat the analysis when I have more complete data. The following summary is provisional.

The total annual number of fires in DEC Region 6 correlates well (Spearman correlation coefficient of 0.94) with the total number of fires in New York State, suggesting regulation by weather. And the annual number of lightning fires has a moderate correlation (Spearman = -0.46) with the Palmer drought index, suggesting that weather in part regulates the number of lightning fires. But no overall measure of the incidence of fires -- neither the number of fires in New York nor their total area nor the number in Region 6 nor their area -- correlates at all with the Palmer index. Furthermore the number of fires in Region 6 did not rise strikingly in either 1988 or 1995, two years when the woods were very dry and the fire danger perceived to be high.

Thus we have the interesting situation that the woods clearly vary in inflammability from year to year, but these variations apparently have little effect on the number or extent of fires. This may either be the result of the small overall inflammability or effective fire detection and suppression. In any case, it appears that the weather-related changes in inflammability don't matter nearly as much as they did 90 years ago, when droughts and serious fires were strongly correlated. And it also suggests that the blowdown, which given a dry year will definitely increase the inflammability of the woods, may not have as much an effect on the incidence of fires as we might otherwise expect.

Does the total area burned depend on the total number of fires?

The total area burned has more statistical noise than the total number of fires because it depends strongly on the number of large fires, which are rare and apparently unpredictable events. In New York as a whole the annual number of fires and the total area burned correlate well (Spearman = 0.89); in Region 6 the number of fires correlates well with the total area burned by fires of 10 acres or less (Spearman = 0.89), but does not correlate with the total area when large fires are included.

Have there been recent trends in the incidence of fires and the area burned?

Both the number of fires and the total area burned in New York state have decreased from 1980 to 1995. A similar tendency is shown by the number of fires in Region 6 for the last seven years (no tabulated data before that), and by the area burned in Region 6 when the effects of the sporadic large (>10 acre) fires are removed. I have no explanation for this trend.

Will people cause fires in the blowdown?

I think it quite possible that they may. The main damage swath of the blowdown includes three of the most popular backcountry camping areas in the Adirondacks, has many campsites within a few yards of intense blowdowns, and has (or had) many popular trails that cross large blowdowns. It is probably unlikely that too many people (ecology instructors and graduate students excepted) will chose to bushwhack very far through the blowdown, but it is certain that many people will camp near it. Many of these people will use open fires, and some of their fires will likely send sparks into the blowdown. Thus there will clearly be the possibility of fires. Whether serious fires occur will depend on how inflammable the blowdowns are, and on whether people are permitted to use fires, or to be near the blowdowns at all, in dry periods.

What effects has the blowdown had on fuel loads and fire risks?

The blowdown has clearly increased the amount of fuel available. The state has estimated total fuel loadings of 10-150 tons per acre on a number of plots. As noted above, we measured ca. 1,100 cu. ft./ac. of fuel 4" in diameter or greater in a partial hardwood blowdown, and 5,300 cu. ft./ac. of fuel in a complete blowdown of a dense softwood stand. Taking a density of around 25 pounds per cubic foot for dry softwoods and 45 pounds per cubic foot for dry northern hardwoods gives roughly 25 tons per acre for the hardwood stand and 60 tons per acre for the softwoods, well within the range of the DEC estimates. Wet weights, or total fuel estimates including fine branches, would be substantially greater.

Right now, six months after the blowdown, the fuel is still wet and green and so doesn't constitute an increased risk. In a sense all the storm has done so far was to put parts of the forests on their sides. They were not very inflammable when they were upright, and are not substantially more inflammable now.

The increased risk will come when the small branches, the most inflammable part of the blowdown, begin to dry. Just how much the risk will increase depends on:

How long it takes for individual trees to die, and whether they sprout and so remain partially alive.

How long it takes for the down wood to fall to the ground and begin to rot.

Whether there are continuous periods of low humidity weather during the fire season.

How fast saplings re-establish a canopy (which retains humidity and prevents drying) over the blowdowns.

This leaves us with a complex problem. There is no doubt that the fuel loading has, but considerable doubt about how to translate increased fuel into increased risk. The important thing to note is that while with the right circumstances (drought weather in the period after the branches have dried but before they have rotted) the risk will be high, there are many other circumstances (moist weather, slow dying of the fine branches, rapid development of a foliage canopy from saplings and sprouts) in which the risk will be low. Unlike the western U.S., where dry weather is the norm, in middle-altitude northeastern forests increased fuel, by itself, does not automatically give increased risk.

Can the increase in risk from increased fuel loads be modeled?

Some aspects of the increased risk can be modeled. There are models that estimate the intensity of the fire and the flame height from the concentration, dimensions and dryness of the wood. And there are models that relate the dryness and hence inflammability of branches and logs of specified dimensions to the sequence of temperatures and humidities to which they have been exposed. But so far as I know there are no models that account for the more complicated process by which a blown down forest gradually dies, compacts, and dries, or for the way that living sprouts and saplings will modify the humidity and slow the drying.

Are there other ways to look at fuel-related risks without modeling?

Lacking a model, the best we can do is cite history and experience. Experience tells us, very simply, that there is a lot of fuel here, and given a sufficiently dry summer -- for instance a summer like 1995 -- the blowdowns could certainly bum. Furthermore, the concentrations of fuel involved suggest that the dense softwoods blowdowns might well bum very hot, with high flames and strong fire-induced winds. But history tells us, also simply, that very few Adirondack blowdowns have ever burned, and that the 1995 blowdown is concentrated in a region, and at elevations, and even in communities (softwoods on moist soils near wetlands and river plains), where rainfall and humidity are typically high, and periods of prolonged drying weather rare.

To me this suggests that the risk of fire in the blowdowns will probably be low on most days of most years, but might, episodically, be very high. If this is correct, it means that we can assume that while blowdowns are not overall very dangerous, under the right conditions they can be dangerous indeed.

Can the inflammability and hence the risk of fire be monitored?

Yes. The risk of fire can be monitored indirectly by measuring the duration of periods with temperatures above a certain minimum and humidity below a certain minimum. This was formerly done at a number of 'fire weather' stations in the Adirondacks, including one a Cranberry Lake. This monitoring could be re-instituted, and, by using automated weather stations, could be done within the blowdown itself.

The risk of fire can also be monitored directly by measuring the water content of sample logs of various sizes. This can also be automated, and could, by providing a direct measure of how inflammable the fuel was, determine how accurately or inaccurately weather monitoring was predicting the dryness of the fuel.

Are large blowdown-related fires of 10,000 acres or more a possibility in the western Adirondacks?

The official view following the 1950 storm was that they were (Box 1, p. 3). The New York State Conservationist said that the 1950 blowdown had created an 'unprecedented fire risk', and there was the possibility of a 'holocaust.' William Foss of the DEC wrote in the report of the Joint Legislative Committee on Natural Resources in 1955 that it was apparent in 1950 that unless a timber salvage operation was undertaken 'disastrous fires could be expected.' He said that fires like the large New Hampshire and Maine fires of 1953 could easily happen in New York, and that 'one careless individual, under the proper weather conditions, could touch off a fire such as has not been witnessed in New York for nearly half a century.'

Given that no large fires occurred after the 1950 blowdown, and indeed that no fires much over 1000 acres have occurred in the Adirondacks for over 80 years, it is easy to take these views as politically or economically motivated overstatements. But historically there has been ample reason to fear large fires, especially in conifer forests. In 1825 there had been a three-million-acre fire in the Piscataquis region of Maine and New Brunswick that destroyed several towns and took 160 lives. In 1871 the Peshtigo fire in northern Wisconsin, probably the most lethal wild fire to in North America, burned 1.3 million acres and took 1,500 lives. Between 1871 and 1910 four other major fires or groups of fires in the pine lands of the Great Lakes burned a total of some six million acres and took over 500 lives. And in 1903 and 1908 there were two bad fire seasons in the Adirondacks in which a total of about 700,000 acres burned.

There are thus clear historical reasons for prudence and fear. But before we assume that fires like these could occur in the Adirondacks in the 1990's, we need to note that:

> All the really large historical fires were in conifer forests. Most were in areas which, unlike the western Adirondacks, are now known to have had a substantial presettlement history of natural fires.
>
> All of the late 19th century fires were associated with periods of extremely heavy softwood logging.
>
> None of the major eastern blowdowns in the last 50 years (1938 hurricane, 1950 big blow, 1977 Wisconsin derecho), has produced a large fire.
>
> While some of the historic Adirondack fires, like the ones around Lows Lake, were intense and fast-moving, others were smoldering, relatively slow-moving ground fires that burned large areas only because no one tried very hard to put them out.

In summary: we know that large fires have occurred in sandy, conifer dominated landscapes, and in post-logging landscapes. The 1995 blowdown is mostly in a deciduous landscape, much of which has not had logging for 80 years or more. Even given the large fuel loads, the absence of historical fires in blowdowns suggests that fire behavior in this landscape may be different from fire behavior in the landscapes that supported the giant turn-of-the-century fires.

How continuous is the blowdown, and could large fires cross the gaps in it?

This is a difficult question to answer because the edges of many of the patches of blowdown are poorly defined, and our maps correspondingly approximate. Based on Map 5, in the Oswegatchie basin the largest single patches of blowdown are over two miles long; several corridors, like those along the Oswegatchie and on either side of the Five Ponds could be traversed for 4-6 miles with no more than a 1/4 mile gap at any place; and the whole 12 mile damage swath in Map 2 could be traversed with little more than a 1/2 mile gap.

This does not mean that a fire could bum continuously for 12 miles. Many of the gaps are substantial barriers -- wetlands, river corridors, steep rocky slopes. A fire could quite possibly jump them, given enough heat and convective (fire-induced) wind to carry burning material (fire brands) aloft, but in many cases it could not bridge them.

How likely is a big spreading fire in the Oswegatchie?

As with the effects of increased fuel load, there does not seem to be any reliable scientific way of answering this. Models for the spreading of fires exist, but they have not been calibrated for eastern deciduous forests, and probably can't simulate the complex interspersion of intact and damaged forest that we have here. The best that I can do here is to list the factors that would promote and retard the spreading of a large fire, and leave it to readers to evaluate them as they may.

The factors that seem conducive to a spreading fire are that:

> There is a 12 mile swath of between Star Lake and Lows Lake in which the total concentration of blowdown patches is ca. 50%, and in which the gaps between patches are mostly less than 1/4 - 1/2 mile.
>
> Within this area there are fairly continuous bands of softwood blowdown along the river.
>
> The fuel loadings in the softwood blowdowns seem high enough to generate convective winds that could carry burning branches into the air, and allow a fire to jump gaps.
>
> Because there is almost no road access in this area, because the blowdown patches lie close together, and because the blowdown has made it is very difficult to move through the woods, it may be difficult to establish firelines or fight a large fire on the ground.

The factors that would tend to reduce the spreading of a large fire are that:

> With the exception of the main damage swath, most of the areas of concentrated blowdown damage are at most a few miles long.
>
> While a dry year the intact forests surrounding blowdown patches can certainly burn, the have relatively little fuel and will probably bum slowly, with a low flame height.
>
> The hardwood blowdowns, which compose the majority of the main damage swath, have lower fuel loadings and more residual canopy than the softwood blowdowns, and so are less conducive to a fast spreading fire.
>
> Many of the blowdown patches in the main damage swath are separated from one another by wetlands or beaver flows.
>
> Surface water is abundant in the main blowdown area, making it possible to fight fires effectively from the air.
>
> Fuel loads, while high, are dispersed vertically and will, by the time they are dry, be surrounded by saplings. This will keep them moister and reduce their inflammability compared to cut-over lands which were the sites of the great historic fires, where the fuel loads are concentrated and the regenerating layer temporarily destroyed.

In thinking about the significance of the fire promoting and mitigating factors, my own feeling is that we are looking at a worst case fire of several thousand to 10,000 acres, traveling perhaps 5-15 miles,' likely northwest to southeast, mostly in wilderness, not threatening towns or settlements. Such a fire would take fairly special circumstances, and, though certainly severe by modem standards, would be very small by the standards of 80 or 100 years ago.

To sum up the discussion of fire risks: fuel loading is substantially increased in the most intensely effected areas, and there are large continuous patches of blowdown where a fire could spread several miles, and possibly, with fire brands, 10 or more miles. But the fuel is only dangerous for a few years, and only in periods of dry weather. The period of maximum risk is probably 1-5 years after the blowdown, and, unless the year is exceptionally dry, mostly confined to spring and fall. My guess is that much of the time the increased risk will not be significant, but that there may be periods of several months or more when it may be very significant.

10. Short-term Ecological Effects

What kinds of short-term effects may occur, and how much do we know about them?

By short-term ecological effects I mean those that result from the breakage and uprooting of trees, and from the soil disturbance and the openings this creates. These include subsequent mortality to trees that survived the blowdown, changes in the habitat and food available for animals, changes in woody plant and herb diversity, and the initiation of forest regeneration. Soil acidification, discussed in the next section, may either be a short-term or a long-term effect.

To predict ecological effects, we have recourse to a body of empirical principles developed mostly in the 1970's and 1990's. I call it the 'standard disturbance model.' Forest ecologists, partly in reaction to older models of fairly static forests gradually approaching a steady state, proposed that disturbances are frequent in many forests and play major roles in determining forest composition and structure. They hypothesized that in most temperate forests the interval between successive disturbances for a given stand is typically only a few forest generations, that the principal ecological effect of these disturbances is to create gaps, and that the frequency of gap-making and gap-filling determines the frequency of disturbance-tolerant species. From this viewpoint, major disturbances like the 1995 blowdown cease to be viewed as exceptional events, and become instead part of the normal historical routine to which the forest community is adapted.

The standard model predicts that:

The small blowdown patches caused by the fall of one or a few trees will allow the temporary proliferation of understory vegetation and release understory trees and saplings, but will not cause substantial changes in forest composition.

The larger gaps, especially when associated with soil disturbance from tip-over mounds, will encourage the immigration or proliferation of early-successional trees, shrubs and herbs. This in rum will cause a temporary increase in overall diversity, and, since some of the early-successional trees will reach the canopy, a more persistent increase in canopy diversity.

The larger gaps will persist long enough and have enough low vegetation to be important habitats for animals and birds.

The treefall mounds and pits will increase the variety of habitats available for herbs and tree seedlings, and so contribute to the diversity increase.

Since the blowdown kills trees, it 'reorganizes' the ecosystem by causing a temporary imbalance between growth rates and decay rates, during which the ecosystem will leak nitrogen and other nutrients into ground and surface waters.

It is important to realize that while the standard model has been supported by many empirical studies (and also more-or-less supported by large numbers of review papers quoting one another), at present we don't know whether it is generally true of windstorms, much less whether it will be true for forests with the particular history and composition of those in the west Adirondacks. This is because large windstorms are rare events. Only a few have been studied and never one in a large area of continuous, relatively undisturbed forest.

Our incomplete understanding of windstorm ecology is worth emphasizing, both because it limits our ability to make predictions and because it illustrates what a remarkable scientific opportunity this storm affords. Box 9 (p. 53) summarizes the studies I have found that deal with the ecological effects of windstorms in northeastern North America. Six real storms and one simulated storm have been studied: a hurricane, two tornadoes, a derecho, a thunderstorm, a windstorm of unknown type, and a simulated hurricane. The studies have resulted in about 11 primary papers and one thesis. One study had 40 years of data, one six years, two two years, and the rest a single year. For three of the seven storms there was pre-blowdown data available for the study area, for the other four there was not. Only two studies have herb data, only one looked at animals, and only one addressed chemistry. And only one study was in the Adirondacks, and this was a very sketchy early 1916 study which deals only with tree mortality in managed woodlands.

In the following, discussion I begin with predictions based on the windstorm literature, but then suggest ways in which the specific conditions in the west Adirondacks may modify these predictions. Readers should bear in mind that this is necessarily speculation. Until we have an ecological study of an Adirondack windstorm, we won't really know what effects to expect.

Will there be a short-term increase in plant diversity?

The standard model predicts that total plant diversity increases after blowdowns because early successional species colonize the openings. For example the 5-acre simulated blowdown at the Harvard Forest acquired 14 new species between 1990 and 1995. The 1977 blowdown in the Flambeau River natural area acquired at least seven new species in the first two years after the blowdown. The new species in both cases included both shrubs and herbs.

Whether a similar increase will occur in the Oswegatchie basin will depend on whether there are in fact early-successional species available to colonize the openings. The two studies just mentioned took place in moderate diversity landscapes that were mosaics of young and old forests; the Oswegatchie, on the other hand, is a low diversity landscape that is continuously wooded and has had no fires or logging for almost 100 years. This may greatly limit the pool of potential early-successional immigrants, and hence the diversity increase that occurs.

A second factor that will affect the observed diversity increase is the average pre-blowdown diversity of the forests. My experience has been that diverse forests (which usually have high-pH soils and substantial within-stand microhabitat variation) often show greater diversity increases after

Box 9: Blowdowns in Eastern Temperate Forests That Have Had Ecological Study

May 1916*, *unknown windstorm in Nehasne Area, Adirondacks, NY One paper, describing the effects of previous thinnings in a managed forest on survival (92).

September 1938, F2 hurricane in central New England, studied at Harvard Forest, Petersham, Mass. Four major papers (102,103,106,116) plus others cited in those, with before and after data from permanent plots, including reconstructions of peak wind speeds and describing patterns of mortality, vegetation responses, long term succession over 38 years.

August 1969, tornado in Boundary Waters Canoe Area, Basswood Lake, MI. One paper (30), describing small mammal abundance and ground layer vegetation, for four years following the storm.

4 July 1977, F2 derecho in Wisconsin. One paper (82), based on permanent plots sampled twice (1967, 1973) before the blowdown and once (1979) after; good data on trees, partial data on shrubs and herbs. One master's thesis (93), on damage patterns.

July 1983, severe thunderstorm in Itasca State Park, MI. One paper (113), based on a single-year study, looking at post-blowdown tree mortality and regeneration in two stands of different composition.

May 1985, F4 tornado, in Tionesta Scenic Area, PA. Two papers (107, 109) from a six-year post-blowdown study which contrasts vegetation responses, including sprouting and buried seeds, both within the tornado swath and in undisturbed forest next to it.

Box 9 con't.

1989, F3 tornado in Litchfield Co., Ct. Two unpublished studies, analyzing the storm and the consequent damage.

1990, simulated hurricane, Harvard Forest, central MA. Five acres of trees pulled down with winches; no pre-blowdown data, but continuing studies of chemistry and vegetation on permanent plots in blowdown and adjacent control area. One paper on greenhouse gas fluxes (91) has been published, others are in preparation

disturbance than low diversity forests. I assume is that this is partly because the larger specie's pool results in richer seed banks and more potential immigrants, and partly because the high pH and small- scale habitat variety can accommodate a more diverse group of colonists.

In our field work this summer, we attempted to inventory the total woodland species pool in the Oswegatchie basin, measure local forest diversity, and to determine what early succession species are available to colonize the blowdowns. Our results suggest that the pool is small, the forests not very diverse, and the pool of possible immigrants very limited. We found that:

> The total pool of woodland species in dry and moist upland woods (not bog woods) in the Oswegatchie basin is about 90 species, of which 10 are quite rare and perhaps unavailable as colonists. Typical diversities in upland woods range from 18-30 species per quarter acre (= 0. 1 hectare), and are commonly below 25 species.
> Only about 11 of the herb and shrub species found in woodlands are sun-requiring species that can be expected to expand in or colonize woodlands (Box 7, p. 40). Five of these are rare, and may not play a large successional role. The others are frequent or common, and can be expected to increase temporarily after the blowdown.
>
> Natural openings are very rare, and only about 6-7 species occur in these openings that don't occur in the woods.
>
> Only three species of European weeds have been found in the Oswegatchie drainage, and these are limited to fairly small areas around campsites.

Based on these results, my prediction is that we will see at most a small post-blowdown diversity increase. I suspect that, unless the seed bank holds unexpected numbers of rare native species, much of the colonization of the openings will be by species like blueberries, raspberry and bracken fem, which are already widespread within the woods and so don't increase diversity. I think we will see a relatively small number of new native colonists, and almost no colonization by European aliens.

In other areas that are embedded in more diverse landscapes or have more extensive seed banks, the immigration rate and consequent diversity increase may be considerably larger. The 'Maple Valley' area near Lows upper dam was an industrial site 85 years ago and still has extensive openings and early successional forests. It also contains 15 species of weedy aliens and five species of weedy natives, none of which are known from the Oswegatchie drainage. In areas like this with a pre- established weed pool the post-blowdown immigration could be quite different from that in old- growth or undisturbed forests.

What species will dominate the forest regeneration process?

The standard model predicts that large gaps will allow early successional trees like white birch, aspens, ash, red maple and pin cherry to invade older forests. There is empirical support for this from several post-blowdown studies: yellow birch, elm, basswood and red maple seedlings invaded a blowdown in a hemlock forest in Wisconsin; birch seedlings were abundant in a tornado swathe in Pennsylvania; buried seeds, of pin cherry germinated abundantly after the 1938 hurricane in Massachusetts and after the simulated hurricane at the Harvard Forest in 1990; and white birch, aspen and ash dominated the regeneration of one of two blowdown stands in Minnesota.

As with the studies that reported diversity increases, all of these studies are from landscapes where there was a mosaic of fairly small patches of early and late successional forests. In the Oswegatchie basin, which is embedded in a larger area of over a hundred thousand acres of forests without recent disturbance (all the shaded areas in Map 3), early successional colonists may be less important, and advance reproduction (saplings surviving the blowdown) of late successional species more important.

In particular, our fieldwork suggests that:

> Many of the common early successional species are rare or absent in the Oswegatchie basin(Box 7, p. 40). Ash and pin cherry are apparently absent, white birch absent or very rare, aspens rare and local. Unless there are substantial reservoirs of buried seeds from earlier successional stages, none of these species are likely to be important in regeneration.
>
> Every blowdown we examined contained large numbers of sapling trees. Spruce was common in every plot, both in hardwoods and softwoods and dominated both our quantitative plots. Fir, red maple and yellow birch were also common, though never as common as spruce. The majority of these saplings survived the blowdown, and total sapling and seedling densities are currently quite high (Fig. 5).

My prediction is that the species already present as saplings in the blowdowns will dominate the regeneration process. I think that we will see a substantial number of yellow birch and red maple seedlings germinate on the tip-up mounds, but that these seedlings will be at a disadvantage compared to the saplings already present. We are also likely to see some sprouting from damaged hardwoods, particularly beech and maple.

If existing saplings control regeneration, then spruce will be the dominant tree in regenerated softwood stands, and some mixture of spruce, yellow birch and red maple in regenerated hardwood stands. Balsam fir will probably form an understory, but, unless it can outgrow the spruce, is likely to be important only in some of the stands on low wet soils where at present there is a dense carpet of young firs. Beech and sugar maple sprouts will grow more slowly, and are likely to remain in the understory. Some of the red maple and yellow birch seedlings on the tip-ups will have an advantage because of the height of the mounds and are likely to be a part, but not dominate, the new canopy.

Will white pine and hemlock regenerate?

We saw almost no pine or hemlock seedlings, even in areas where one or the other had been the pre-blowdown dominant. Pine is supposed to need large openings and mineral or post-fire soils to establish; it will probably not reproduce in the blowdown patches. Hemlock is mostly limited to the old growth, and we saw only a few stands. It is supposed to be able to reproduce in its own shade, but in the stands we examined it was not doing that.

Will the blowdown advance or retard forest succession?

If the advance reproduction is a guide to the future history of the stands, in the second-growth parts of Oswegatchie drainage the blowdown may replace pine stands with spruce and fir, replace spruce stands with spruce, and increase the percentage of spruce in many hardwood stands. In all these cases it will either advance the successional stage or leave it unchanged.

We did not examine any blowdowns in old-growth forests, and we can't predict what will happen here.

In other basins, and in particular near settlements and on commercial timberlands where there are many more early successional species, the blowdown could easily move the forest to an earlier successional stage.

What effects will the blowdown have on wildlife?

There is essentially no information available on what animals use blowdowns. Much will depend on how long the openings persist, and how much food they contain. The persistence of the opening is important because animal populations need time to find and respond to a newly provided resource.

The most important resources provided by the blowdown will probably be bark insects and hardwood sprouts, and so the most immediate beneficiaries should be bark insectivores like chickadees, nuthatches, creepers, woodpeckers, and browsers like hares and deer. Birds using fruit (waxwings, grosbeaks, ...) and birds nesting in brushy openings (mourning and Nashville warblers, white-throated sparrows ...) are also likely to benefit, but this will depend on the relative abundance of shrubs and tree seedlings, and on how fast the young sapling trees grow up.

What will the short-term effects on nutrient cycling and acid base balance be?

The standard picture of changes in nutrient cycles in temperate forests following disturbance is almost entirely derived from clear-cutting experiments at Hubbard Brook. These experiments suggested that in the first one to two years following a cut the reduction in living biomass and increased ground temperatures resulted in more nutrients being released through decay than are taken up in growth, causing the system to leak nutrients. The lost nitrogen appeared in the ground water as nitrate, which decreased acid-neutralizing capacity and contributed to acidification.

The blowdown differs from a clearcut in that only a few of the trees are dead yet. It will likely take several years for them to die, during which time the biomass and nutrient uptake of the sprouts and saplings will increase. This could limit the 'loss of ecosystem function', and so the nutrient release, and consequent acidification, may be less significant in the blowdown than in the Hubbard Brook experiments.

Some support for this model comes from studies of greenhouse gas evolution in the simulated blowdown at Harvard Forest. Here carbon dioxide and methane production and net nitrification (production of oxidized nitrogen) were largely unchanged in the first two years after the trees were pulled down, showing that there was no major change in the balance of growth and decay.

To sum up the above sections. We have few empirical studies of blowdowns, and none in a landscape like the Oswegatchie. My predictions, which are at best guesses, are that there will be few changes in overall diversity, mostly because the plants needed to make the changes aren't there. Advance reproduction, particularly by red spruce, may well dominate regeneration, and the successional stage of the new forests will be the same as before the blowdown or more advanced. Pine will not reproduce in the blowdown patches, and hemlock may not. Blowdown areas may afford important new resources for animals, but it remains to be seen whether animal populations can respond to those resources before the regrowth of the canopy makes them unavailable. Conventional models predict a transient nutrient loss and some associated acidification, but the survival of living trees may mitigate this, and there is no way, pending observation, to know whether any effect will be observable.

11. The Long-term Effects

By long-term effects I mean those manifest after the blown down trees have died and started to decay and the canopy is restored. This means somewhere between 20 years and several forest generations. Since only one group has ever studied a blowdown for more than six years, and since those studies only dealt with forest succession, we have very little empirical information about long-term effects of blowdowns. What I have tried to do here is to present a reasonable, though admittedly speculative, picture of what may happen, based on what I could find in the disturbance literature, and to indicate the areas where our information is not sufficient even to speculate.

The primary effects of the blowdown that are Rely to have long-term consequences are that it:

Generates a lot of dead timber ("coarse woody debris", CWD) which then slowly rots.

Replaces one cohort of forest trees with a new one.

Generates pits and mounds.

These in turn may affect diversity, forest composition, nutrient-cycling, and possible the acid-base balance of the watershed. Forest composition has been considered, at least as well as I can consider it, in the section on regeneration on p. 39 above. The other effects follow here.

Will there be long-term changes in plant diversity?

My assumption, from the discussion on p. 40, is that long term effects on vascular diversity will be small because the local species pools in the forests surrounding the blowdown are small. Elsewhere this might be different, and it is reasonable to speculate that in some areas a big blowdown might replenish the buried seed pool, especially for disturbance-associated herbs like violets, composites, many sedges, etc. These seeds would then be available to maintain diversity during the normal cycle of small gaps and gap-filling. The Oswegatchie basin, because it is very poor in vascular herbs, may be something of a special case.

The situation with non-vascular plants -- mosses, liverworts, higher fungi -- could be quite different. Many of these live on or are involved in the decay of rotting wood. There will be a lot more rotting wood, and so, possibly, room for a lot more species. Whether these species will arrive or not- depends again on species pools and immigrations -- things that we currently know very little about. The problem is an interesting one and could well repay study.

Will there be long-term changes in animal diversity?

Here a 'gain we know very little. The new forests developing in the blowdown will have smaller trees and lower canopies. This will exclude some bird species that like mature woods. But they will have more down wood, and, at least in some cases, more standing dead snags and this may encourage other animals -- cavity nesting birds, wood decay insects, ground beetles, possibly amphibians and small mammals that use rotting logs. The ecological roles of rotting logs have been much studied in the western U.S., but not in the east. It is possible that they are important habitats and that their presence alters animal populations. It is also possible that animals use them opportunistically when they are available, but don't depend on them.

How big and long-lasting will the long-term effects on ecosystem properties be?

The most long-lasting physical effect of the blowdown is probably that it increases the amount of coarse woody debris on the forest floor. This will have an important transient effect over periods of 25-50 years, but may not have long-term effects beyond that.

To see this, consider the accumulation and turnover of CWD in two forests (Figure 7). The first is a 100-year-old hardwood forest. It might have roughly 100 tons per acre of biomass in the living trees, half of this in the leaves and fine branches, the other half in trunks and big branches. If this has matured naturally and not been cut, it might have about 15 tons per acre of logs and dead snags. The logs and snags compartment (the CWD) would be roughly in equilibrium: old logs would rot about as fast as new logs fell down, and so

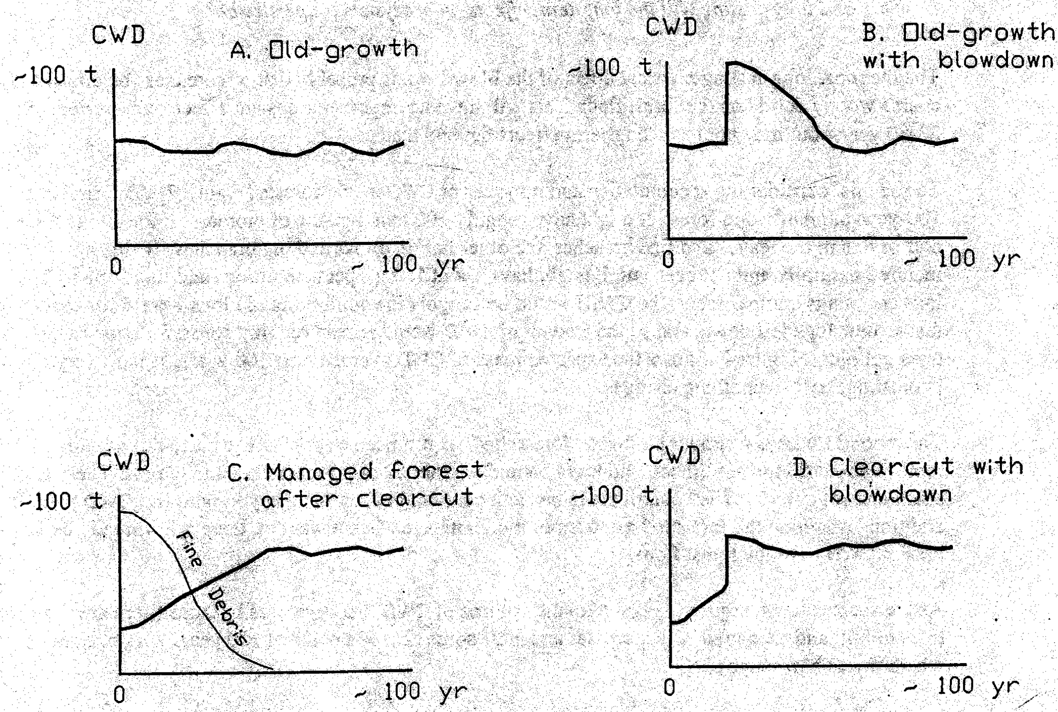


Figure 7: Hypothetical Changes in Coarse Woody Debris in Cut and Old-growth Forests With and Without A Blowdown

CWD = coarse woody debris. See text, p. 43 for explanation.

the amount of CWD would remain roughly constant, even as the trees got older. Figure 7a shows the expected mass of CWD over the next 100 years. It isn't very interesting, because nothing changes.

The second forest is a similar hardwood forest that has just been clear-cut. The clear-cut would remove about 50 tons of timber, and leave behind another 50 tons of branches and leaves. These are small and rot quickly. They contribute to nutrient cycling, but don't add anything to the CWD pool. In addition, assuming the forest to have been of moderate age when it was cut, there will already be 15 tons of CWD over the forest floor.

As the second forest regrows (Figure 7c) the volume of CWD first decreases because there aren't any trees to fall, and then gradually increases and after some time -- a nominal 100 years -- is back to where it was before the cut.

Now imagine a heavy blowdown in each forest. In the first forest (Figure 7b) the blowdown adds 50 tons of timber to the CWD pool, increasing the size of the pool by four times. (Like the clear-cut it also adds a lot of branches and leaves; as before, they are not part of the CWD pool.) But it also stops the input to the pool, because there are no trees left to fall. Over the next 100 years the pool will either decay back to its original size, or possibly even fall below its previous size and then rebound, depending on how fast the logs decay and when the new canopy starts dying.

In the second forest (Figure 7d), imagine that the blowdown takes place 50 years after a cut; there is about half as much wood in the canopy as in forest A, and perhaps half as many, or maybe -fewer logs on the ground. Once again the pool of CWD jumps maybe four times or more, and then the story is pretty much the same. The inflow is cut off, the pool decays, and after 100 years you can't tell the difference.

The upshot of all of this is simple, but fairly important. First, the blowdown increases the CWD a lot, but only for a little while -- maybe 50 years in our model, maybe more or less in real forests. Second, the blowdown allows the post-logging forest to acquire the CWD pool of an old-growth forest somewhat before -- 25-50 years in our model -- it would acquire it otherwise. And third, and most important, while the blowdown increases temporarily the rate at which wood is decaying and releasing nutrients, it can't change the average rate over periods of say 100 years, because what falls down now isn't available to fall down later. This means that, at least with this simple model, the ecosystem level effects of the blowdown on carbon cycles aren't really very long-lived, and in fact last for only part of a forest generation. Thus they are not really long-term at all, but rather somewhere between short-term and long-term.

Now consider the effects of CWD cycling on the rest of the ecosystem. As we noted above, studies of standing and down wood in the western U.S. have shown it to have many ecological roles. Biologically it is a substrate for epiphytes, a habitat for many decay insects and fungi and hence the base of many food chains, and a habitat for cavity nesting species. Physically it holds much water and alters surface and subsurface flows and so has hydrological effects and anti-erosive effects. And chemically, through its decay it is a source of carbon, nutrients, and organic acids.

The biological effects of increased CWD pools have barely been studied in the east. The increase in CWD is substantial, and so there should be measurable, and probably interesting, post-blowdown effects. But most of the biological effects will only develop after several decades, when the logs begin to rot. So far, such effects have never been studied.

The hydrological effects of increased CWD pools have also been studied in the west but not in the east, and so can't be dealt further. And this leaves the chemical effects, to which we now turn.

How much of an effect will the increase in CWD have on carbon fluxes?

A simple-minded look at average forest nutrient fluxes suggests that it will have an effect, but that the effect will not be enormously large.

Forest soils get carbon from litter-fall, from the decay of CWD, and from the death and decay of roots. An overall budget for a northern mixed forest might be approximately as follows.

Average litter fluxes in northern forests are 1.3-1.4 tons per acre per year. Root turnover is much less well known; estimates min from 1-2.7 t./ac-yr, which would make the total litter+root flux of 2.3-4.1 t/ac-yr. To this we have to add the decay of the pool of existing CWD. If this pool is 15 t/ac., and if we assume it decays over 30 years, then this would add 0.5 t/ac./year to the above, giving a total carbon flux from vegetation to soil of 2.8-4.6 t/ac/yr. The CWD contributes only 11- 18% of this flux; it is a conspicuous carbon pool, but, because it decays slowly, a minor part of the carbon flux.

The crude model in the previous section suggested that the blowdown might increase the pool of CWD four times, giving a CWD contribution of 2.0 t/ac-yr rather than 0.5 t/ac-yr, or a total decay flux of 4.3- 6.1 t/ac. yr., which in turn is a 30-50% increase over pre-blowdown conditions, for a period of thirty years. 11 In this case the CWD would be contributing 33-50% of the total carbon flux, and might, for a period of time, be the largest term in the annual carbon budget.

The increase in carbon will likely be substantial, but whether this is important or not will depend on how much carbon there already is in the soil. Older forests, wetland forests, and softwood stands in general are carbon rich and often have large amounts of carbon in their soils; the additional flux may mean very little to them. Post-fire forests or forests recovering from other forms of soil disturbance may have lower soil carbon pools, and here the effect may be more significant.

Are other nutrient fluxes increased with the carbon flux? If so, how significant will they be?

The decay of CWD releases other nutrients in the wood, and so results in increased fluxes of calcium, nitrogen, and phosphorus, as well as carbon. 'Me percentage increases in the fluxes of other elements may well be smaller than the increase in the carbon flux because CWD is relatively less rich in minerals and nitrogen than leaf and twig litter.

The significance of the increased fluxes from the CWD will probably be different for different nutrients.

Adirondack forest soils are normally low in calcium, and so the increased calcium flux may be of biological importance. But it remains to be seen whether it will in fact increase the calcium in the soil, or be taken up by the young trees and so returned to the living biomass compartment, right where it was before the blowdown.

Northern forest soils in general have in the past been low in nitrogen, and the release of nitrogen from debris has been thought to be an important part of the disturbance-regeneration cycle. But since acid rain contains nitrates the nitrogen inputs to eastern forests have greatly increased, and it has been conjectured that nitrogen may now be in oversupply in some forests. If this is true, then the release of nitrogen from the decay of debris may no longer be ecologically important.

Finally, it is quite possible that quantities of nutrients that are not significant when averaged over the whole forest may be locally significant; a log may enrich a small patch of soil, or change it chemically, and this may supply a habitat or regeneration niche for a species which might not otherwise be. Thus the local effects of CWD and nutrients on individual species might be more significant than their ecosystem-scale effects.

In summary, the blowdown will probably have at least temporary effects on nutrient cycling. These may be most pronounced in recovering forests where soil carbon and nutrients have been depleted by fires and harvesting in the past. We cannot really evaluate how important they are, because we don't know enough about soil nutrient budgets. Carbon and calcium may be important, nitrogen may not be. Local effects on individual species may be more important than overall ecosystem effects.

What long-term effects will the blowdown have on watershed acid-base balance?

By acid-base balance we mean the distribution of acids and bases (proton donors and acceptors) within the ecosystem. In thinking about acidity it is important to note that biological processes within an ecosystem can move acids and bases from compartment to compartment within the system, but cannot acidify or de-acidify the system as a whole. If an acid molecule is created by adding a proton to something, the proton came from somewhere and a base has also been created. Only processes that transport acids into the system or bases out of it can acidify the system as a whole.

The standard picture, based on many studies of forest chemistry, is that living trees sequester basic ions in wood, leaves and bark. When they do this they release protons, which acidify the soil. At steady state this in turn is offset by leaf- and litter-fall and, when the forest is old enough, by the decay of logs. Bark and small branches are relatively rich in bases, wood and leaves (except for sugar maple leaves) relatively base-poor. Thus litter-fall counts a lot towards offsetting soil acidification, while logs and other coarse woody debris count for somewhat less.

It follows from this picture that blowdowns, after a brief period in which the soil may leak acids into the watershed (p. 51), release bases by increasing the pools of dead roots, twigs, and CWD, and that these bases then will neutralize soils and surface waters.

But note that, by the arguments of the preceding section, the long term averages should not change. All blowdowns should really do is first accelerate, and then retard the release of bases from CWD. They do not tap source of new bases, and, just as they do not change the average carbon flux over a 100-year time scale, they don't change the average base flux either.

Will the blowdown affect the rate at which the acids from acid rain move through the forests and into watersheds?

Adirondack forests currently receive substantial amounts of acid ions, particularly nitrate and sulfate, from acid deposition. Actively growing forests seem to retain some of the nitrate, thus decreasing the amount of acid that appears in surface waters. Essentially they have been offered a new nitrate source, and are stocking up. Presumably, because the nitrate inputs are substantial, they can't do this forever. At some point nitrogen loss through decay will eventually balance nitrogen uptake from growth, and then roughly the same amount of nitrate will leave as arrives. At this point the forests will reach nitrogen saturation.

This leads to a recent hypothesis that blowdowns, by opening the canopy and releasing a lot of young trees, can reactivate nitrogen storage in forests that have reached nitrogen saturation.

This hypothesis is interesting, but hardly proven. Certainly the new trees will start to take up nitrogen, but, equally certainly, the old dead ones will release it. What the balance will be seems hard to say. At present even the concept of nitrogen saturation is still problematic; we don't know what sorts of forests are already saturated, if they can be unsaturated, or where, if they get unsaturated, they will put the additional nitrogen than they take up.

Are there alternate models of blowdowns and acid-base balance?

Several authors have asserted that acid deposition is not a full explanation for the observed acidification of Adirondack lakes and offered alternate explanations, but none of these explanations have been worked out in quantitative detail or could be called models.

Some interesting geographical work on alternative explanations has been done by researchers associated with Oak Ridge National Laboratories and East Tennessee State University (J. E. Dobson. R. M. Rush, and R. W. Peplies). They have attempted to correlate observed acidification in some Adirondack lakes with the extent of the watershed affected by the 1950 blowdown, and contend that:

a) Acidification in many watersheds began after the 1950 blowdown,

b) Blowdowns increase acidity by decreasing transpiration and killing tree roots, thus increasing water flow through channels in the upper, more acid parts of the soil

c) Blowdowns also increase acidity by allowing the decay of large quantities of logs, which supply organic acids to watersheds.

d) Salvage operations decrease acidification by removing logs.

e) The extent of the 1950 blowdown in a watershed correlates to the current pH and acid neutralizing capacity of the lakes in the watershed.

These assertions, while interesting, are largely without theoretical or empirical foundation, and have been criticized by other workers. Assertion (a) is at most weakly true; some lakes did acidify after 1950. Since acid deposition was increasing in the 1950's, this could be an accidental correlation. Assertion (b) is theoretically possible, but to my knowledge has not been field tested and may not be relevant in the very thin soils in many Adirondack watersheds. Assertions (c) and (d) contradict the known storage of bases in logs and woody debris, have no direct evidentiary support, and seem to be contradicted by several experimental results.12 Finally assertion (e) is at mostly weakly true: for one group of lakes that they studied the Spearman correlation between acidity and the extent of 1950 blowdown is about as good as the correlation between acidity and the amount of acid deposition. Unfortunately, there was no correlation in the two other groups of lakes they studied. And the observed correlation by itself might only mean that acid deposition and the 1950 blowdown (both of which came from the west) had an accidental spatial correlation. It would be very interesting if the extent of blowdown in a watershed explained a part of the variance in acidity after the effects of acid deposition had been removed, but there is no evidence for this.

To sum up: hypotheses that landscape changes, and particularly the 1950 blowdown, have affected - watershed acidification are interesting, but seem to lack supporting evidence. At present the weight of evidence seems to favor the notion that woody debris contributes to acid neutralization, not acidification.

12. Management Options and Their Ecological Consequences

What are the major problems and opportunities created by the storm?

The blowdown has severely reduced recreational and emergency access to the Five Ponds and Lows Lake areas. It has increased fuel loads and has the potential for increasing the risks of fire over the next few years. It has created a large inventory -- perhaps a million cords -- of down timber, which has potential economic value. And finally, it is in itself an unusual natural event that has a claim to be preserved as part of the natural landscape, and which gives forest managers a unique, but very temporary, opportunity to learn things about forest regeneration that would be very difficult to learn in any other way.

The problems presented by the blowdown are discussed below. Its intrinsic values and the opportunities it presents are discussed in Section 13.

What responses to the immediate problems are available?

For access problems, the possible responses are: Reopening trails by clearing down trees.

Rerouting trails where they cannot be cleared.

Clearing existing roads by removing down trees.

Building new roads.

Clearing landing areas for helicopters.

For reducing the risk of fire, the options are:

Reducing fuel loads by salvaging timber.

Increasing rate at which fuels decay by cutting up or chipping the smaller timber and branches.

Building roads or clearing landing areas for emergency fire access.

Monitoring temperature, humidity and moisture content of fuels within the blowdown areas to determine how great the fire danger is.

Instituting regular fire surveillance from aircraft when the fire danger is high.

Restricting or prohibiting open fires when the fire danger is high.

Prohibiting recreational use of blowdown areas the when fire danger is exceptionally high.

Having aircraft and fire crews standing by when the fire danger is exceptionally high.

For realizing some of the economic value of the down timber, the only alternative is a commercial salvage operation.

Which of these responses are legal on private lands?

Essentially all of them. Normal road and trail work, and salvage operations that do not involve cutting more than 25 acres of standing timber in a single patch, are legal without permits. Building roads across streams or wetlands or clearcutting of more that 25 acres during salvage operations requires a permit from the Park Agency.

Which of these responses are legal on state lands under the state constitution?

This should be an easy question, but it is not.

Article XIV of the New York State Constitution (formerly Article VII of the State Constitution of 1894) says, without qualification, that the lands constituting the forest preserve shall 'forever be kept as wild forest lands', and that the timber on them shall not be 'sold, removed, or destroyed.'

This would seem to forbid timber salvage operations outright on forest preserve lands. In addition, depending on how 'kept as wild forest lands' is interpreted, it might also forbid building roads, clearing landing areas for helicopters, or cutting timber.

As often, however, the courts have created a fairly broad zone of interpretive ambiguity around a clear law (Box 10, p. 66). The controlling decision is ***Association for the Protection of the Adirondacks v. MacDonald***, 1930. In it the appellate court rejected a law that authorized the removal of 2600 trees in order to create a bobsled run. The court found that the cutting of the trees violated the prohibition on the removal of timber, and the development of a man-made setting for sport violated the forever wild requirement. It gave a strong, protectionist interpretation to Article XIV, saying that however the forest preserve was used for 'health or pleasure' it must 'always retain the character of a wilderness.' But it also said that Article XIV need not be literally interpreted but can receive a 'reasonable interpretation.' And it says explicitly that actions necessary to preserve the park, including repairs to roads, maintenance to facilities, and measures to prevent fires, were permitted if they did not involve the removal of timber 'to a material degree.'

Despite the clear language of Article XIV and the strict precedent for limiting the removal of timber in ***MacDonald***, in 1951 the state requested and the legislature authorized a salvage operation that eventually removed close to 300,000 cords of wood from 60,000 acres (Box 1, p. 3). This certainly is the removal of a material amount of timber, and would seem, on any reasonable reading of Article XIV and ***MacDonald***, to have been illegal. Its legality was asserted, less than convincingly, by an Attorney General's opinion that quotes first Article XIV and ***MacDonald*** approvingly, and then goes on to say that there is an emergency and that 'to permit these dead trees to decay and rot away would accomplish no purpose contemplated by the framers of the constitution and would only add to the tremendous economic loss sustained' (Box 1, p. 3). The legislation was never challenged in the courts (even by the Association For the Protection of the Adirondacks, who had been the plaintiffs in ***MacDonald***), and so the constitutionality of the salvage operation was never tested.

An Attorney General's opinion is not a finding by a court, and sets no legal precedent that subsequent courts have to follow. The 1950 opinion authorizing the 1951-1954 salvage operation advances the questionable proposition that the state can limit the applicability of constitutional protections by alleging that it is following what the framers would have wanted had they been alive today. This would probably find little sympathy in most courts today. But its other claim -- that states have broad emergency powers and that the seriousness of an emergency can allow a convenient reading of the intent of a law -- is one that courts have often been supported.

Two subsequent cases (Box 10, p. 66) have more or less affirmed ***MacDonald***, but left some uncertainties. A preliminary ruling in ***Helms v. Reid*** (1977) said that Article XIV allowed reasonable cutting to protect the forest preserve' and to enable the public to safely use the preserve, and that the legislature did not have the power to authorize cutting for commercial purposes, but did have the power to authorize it for public purposes. No standards were set for what was reasonable and what wasn't. A ruling and an appeal in ***Balsam Lake Angler's Club v. NYSDEC*** (1993), which involved a tiny amount of cutting for a trailhead, found that there was no constitutional prohibition on an 'insubstantial' amount of cutting, but that cutting 'to a substantial extent or a material degree' was prohibited.

And there, for all purposes, the matter still stands. It seems that court tests of Article XIV have on the one hand said that cutting is allowed to protect the forest preserve or public safety, and on the other hand that cutting live trees to a material degree may be unconstitutional. The issue of the salvage of dead trees or the cutting necessary to create fire roads has never been tested. A salvage operation on state lands would clearly be open to legal challenge, and might be stopped by an injunction while the case was being tried. But, absent clear precedents, it seems impossible to predict what the outcome of such a challenge would be.

Box 10: Court Cases Relating to Timber Salvage

Association for the Protection of the Adirondacks v. MacDonald (253 N.Y. 234, 1930).

The Appellate Court considered a 1929 law, authorizing the removal of 2600 trees totaling 60,000 board feet of timber on 4.5 acres in order to create a bobsled run for the 1932 Olympics, and held- that it was unconstitutional. They said that the law violated the constitution in two different ways. First, the 'cutting of 2600 trees which must unquestionably be regarded as of timber size' violated the prohibition on the removal of timber. Second the development of a man- made setting for sport violated the constitutional requirement that the Forest Preserve lands be 'forever kept as wild forest lands.'

The decision contains some powerful language supporting wildness, and limiting the power of the legislature to approve uses conflicting with wildness. The forest preserve

must be a wild resort in which nature is given free rein. Its uses for health and pleasure must not be inconsistent with its preservation in a wild state. It must always retain the character of a wilderness.

If it were deemed necessary [as had been previously found to be the case] to obtain a constitutional amendment for the construction of a state highway, the use to which the forest preserve might be put with legislative sanction was greatly limited. Trees could not be cut or the timber destroyed, even for the building of a road.

But it also contains language repudiating, a purely protectionist view:

Some opinions, notably those of the Attorneys General of the state, cited in the briefs and by the Appellate division, have even gone so far as to state that even a single tree, and even fallen timber and dead wood cannot be removed; that to preserve the property as wild forest means to preserve it from the interference in any way by the hand of man.

Box 10 con't.

The words of the Constitution, like those of any other law, must receive a reasonable interpretation, considering the purpose and object in view. Words are but symbols indicating ideas and are subject to contraction and expansion to meet the idea sought to be expressed... The Adirondack Park was to be preserved, not destroyed Therefore all things necessary were permitted, such as measures to prevent forest fires, the repairs to roads and proper inspection, or the maintenance of proper facilities for the use of the public which did not call for the removal of timber to any material degree.

And later:

What may be done in these forest lands to preserve them or to open them up for the use of the public, or what reasonable cutting or removal of the timber may be necessitated in order to properly preserve the state park, we are not at this time called upon to determine.

Helms v. Reid (90 Misc. 2d 583, Supreme Court, Hamilton County, 1977)

This is an attempt to use a strict protectionist construction of Article XIV to achieve the very un-protectionist goal of overturning the Adirondack Park State Land Master Plan. The plaintiff argued that the master plan sanctioned the existence of roads and camp grounds which involved a violation of the wild forest character and the cutting of substantial amounts of timber. The court ruled in a preliminary opinion that the plan was constitutional; the plaintiffs abandoned the case, and the constitutionality of cutting for the roads and campgrounds was never decided. The preliminary opinion sanctions some cutting, saying that a reasonable interpretation of Article XIV, in the sense of MacDonald, would

allow such reasonable cutting as is necessary to protect the forest preserve ... (and) to enable the public to safely use the preserve.

And further, that

although the Constitution has deprived the Legislature of any power to authorize a cutting for commercial purposes, it has not deprived that body of its power with respect to public purposes.

Balsam Lake Angler's Club v. NYSDEC (153 Misc. 2d. 606 at 610 affirmed 605 N.Y.S. 2d 795 (Appellate Division, Third Department, 1993)).

The club tried to prevent the state from constructing a trailhead and hiking trails adjacent to the club lands by arguing that since the construction involved cutting 73 trees over 3" diameter it was unconstitutional. The decision allowed the construction, stating that the cutting involved was 'insubstantial and immaterial.' The decision was affirmed by the court of appeals; the decision implies that activities involving timber cutting to 'a substantial extent or material degree' are prohibited by Article XIV.

What responses would conflict with the Adirondack State Land Master Plan?

The Adirondack State Land Master Plan was required by the Adirondack Park Agency Act of 1971, and approved, in its initial form, by Governor Nelson Rockefeller in July, 1972. It divides forest preserve lands into six categories (wilderness, primitive area, wild forest, intensive use, travel corridors, and canoe areas) and prescribes management goals and guidelines for each category.

The majority of the public lands affected by the blowdown are wilderness areas (Map 3); substantial amounts of wild forest are also involved, plus a small amount of primitive area (not mapped) around Lake Lila.

Management standards for wilderness areas require the state to 'achieve and perpetuate a natural plant and animal community where man's influence is not apparent.' They require that there be no use of motorized equipment, motor vehicles, or aircraft except in emergencies, or for the removal of non- conforming improvements, or for major research projects essential to the preservation of wilderness values and resources. Wood roads are not allowed and are to be closed or abandoned, and snowmobile trails are not permitted.

Management standards for wild forests are less strict. They require an 'essentially wild character' but do not require the 'sense of remoteness' and allow a wider range of use, and in particular use by aircraft, snowmobiles, and motor vehicles. Roads that existed in 1972 or at acquisition can remain open if they are 'compatible with the wild forest character', but there is to be no material increase in the total mileage of roads.

Based on these management standards, it appears that:

> An extensive salvage operation requiring the use of vehicles and power machinery in the wilderness areas would conflict both with the general management goals of the master plan, (keeping man's influence unapparent, maintaining natural plant communities), and with specific prohibitions on powered equipment and road building.
>
> Such an operation might be sanctioned (neglecting conflicts with Article XIV) in wild forests, but could be argued to be inconsistent with the requirement of a 'generally wild character.'
>
> The use of aircraft for fire-fighting and search and rescue operations (as in fact happened this July) is clearly sanctioned, both in wilderness areas and in wild forests. But the clearing of helicopter landing areas in wilderness areas could easily be found to conflict with the sense of remoteness and essentially wild character requirements of the master plan.
>
> The re-opening of trails is clearly sanctioned, though the use of power machinery to do this in wilderness areas requires the written approval of the Commissioner of the DEC.
>
> The relocation of trails or the creation of new trails requires amendments to the 'unit management plans' for the area in which they are located, which in turn probably requires public hearings and comments. A relocation would probably be unobjectionable if it replaced an obliterated trail, but could easily be controversial if it substantially extended the total trail mileage in a wilderness area, or opened an area that had been without trails.
>
> The reopening of wood roads is uncontroversial in wild forests, but would be highly controversial in wilderness areas, where roads are a non-conforming use. The issue becomes tricky because the DEC likes to have roads for emergency access, and to some extent keeps an unofficial wilderness road network that can be used if needed. Any attempt to clear these roads, even if only for emergency use, would be strongly opposed by groups favoring strict interpretation of the master plan. It would also be strongly supported by groups favoring increased vehicle access.

What responses have the owners of private timber lands made?

Our information on this and the next topic is limited. The storm caused extensive damage to timber on three large tracts of private timberland (International Paper lands, Whitney Park, Brandreth Park) just to the east of the Five Ponds wilderness area. The Adirondack Park Agency issued a permit allowing private landowners to salvage down timber, and exempting them from restrictions limiting clearcutting in the salvage areas.

What conservation issues were connected with the APA salvage permit?

The DEC permit was been attacked by conservation groups as being over-broad, and sanctioning unregulated cutting without a detailed plan, or inspection. It has been defended on the grounds that the storm had already done most of the clear cutting, that the timber had to be salvaged quickly to avert economic loss, and that detailed mapping would have been costly and slow.

I have neither strong, opinions nor much factual information on which to evaluate the merits of these positions, but note three things. First, if economic loss was to be averted, time was indeed important. Many paper mills have strict standards for color and moisture content of the pulp wood they buy, timber blown down in the summer spoils rapidly. Furthermore pulp markets were soft (see below) and no one could be sure how long they would hold up. Second, for reasons explained in Section 6, there is no unequivocal way to map an object with the spatial complexity of the blowdown, and so requiring detailed statement about the extent of the damage as a pre-condition of salvage would, have been very unrealistic. And third, the issue of permitting and inspecting a salvage operation is part of a larger question of how cutting is regulated, recorded, and monitored in the Adirondacks. This is an important issue, but one that is far too large to be reviewed here.

How is salvage being accomplished on private lands, and how is the market for salvaged timber holding?

Salvaging down timber has the reputation of being much more difficult and dangerous than cutting standing trees. Private landowners have to some extent compensated for this by asking lower stumpage fees (amount charged per volume of wood cut). In late 1995 it was reported that the crews are doing well; that the work goes slower than normal logging and is practical where the blowdown is concentrated but not where it is dispersed; that there have been no serious injuries; that whole-tree harvesting machines (feller-bunchers) are in limited use but not really suited for salvage work; and that crews have a limited tolerance for this sort of work and it will be hard to keep a particular crew on a salvage job for more than about six months.

During the large salvage operation, in 1951-54, the pulpwood market held for the first year and then collapsed. (Box 1, p. 3) The structure of the pulp market today differs from that in 1952 in that there is a world demand, transport is cheaper, and the customers more dispersed. But the market is still somewhat soft. Spruce, spruce pulp, and softwood lumber are in good demand. Hardwood Pulp, Pulp other than spruce, and hardwood logs have limited markets. Much depends on the skill of the foresters- and their knowledge of potential markets. There is worry that the market will not hold, and a general feeling that a substantial state salvage would depress the market and make it harder for private individuals to salvage their timber.

Given the costs and difficulties of the operation, landowners and forest managers say that they will consider themselves fortunate if they salvage 50% of the down timber before it discolors or spoils.

What would be the ecological effects of a commercial salvage?

A salvage operation cuts up the down trees, both dead and living, and removes the timber. It usually harvests living trees in the blowdown areas as well. And it also, depending on how it is done, creates some amount of soil disturbance and kills some saplings and herbs.

This in turn has the following effects:

> It removes perhaps 50% of the woody biomass of the blowdown, lowering the amount of material eventually added to the coarse woody debris pools, and giving regenerating, post-blowdown forest a carbon distribution more characteristic of a managed forest (lots of small branches, few large logs) and less characteristic of a natural forest.

It temporarily decreases the living biomass, and so temporarily increases the leakage of nutrients into surface waters.

It kills saplings and so slows regeneration and decreases the importance of shade-tolerant (late successional) species in the regenerated forest.

It promotes the reproduction of sun-requiring (early successional) species that can germinate on the disturbed soil.

It may cause short-term diversity increases by increasing the number of early successional shrubs and herbs present.

In all these respects salvage is very similar to an ordinary logging operation. In some cases the individual cuts may be larger, or the rate of harvest greater. In others, given the dispersed pattern of much of the blowdown, and the slowness of the work, the cuts or harvest rate might be smaller.

Where is salvage ecologically appropriate?

None of the effects of salvage are known to be ecologically damaging in the long term, but all of them move the forest away from naturalness and in the direction of a managed ecosystem. Where we accept managed ecosystems there is probably no reason not to accept salvage. Where we wish to have undisturbed natural ecosystems and do not accept management, we should not accept salvage. And in particular, if we hold that there is a legal injunction to manage the state forest preserve to maintain natural ecosystems and minimize the effects of man, then salvage conflicts with this injunction and is highly inappropriate in the Forest Preserve.

In circumstances where we accept salvage in principle, we should, of course think about the details of a salvage operation the way we would any other forest operation. We will want to know the overall rate of salvage and the size of the openings that are created, and about whether we are aiding or retarding the kind of regeneration we desire.

What public responses have occurred?

As of early December, 1995, the DEC has:

Held public meetings about the blowdown.

Done initial cleanup along roads, around campgrounds, and near settlements.

Flown air photos and prepared maps of damage.

Estimated the fuel loadings at a number of places. Prepared a draft ecological assessment.

Flown a crew in to open an emergency trail between the Oswegatchie Plains and High Falls.

Convened an Adirondack Storm Working Group to discuss storm-related issues.

Obtained a permit to use chain saws in the Five Pond Wilderness, and begun clearing the hiking trails.

What trails have been reopened, and how hard will it be to reopen the others?

In the Oswegatchie basin, where the worst blocking of trails occurred, the Star Lake-Boundary Line and Dead Creek-Cat Mountain u-ails are currently open. The 'Truck Road' is open from the Plains to High Falls, and crews were beginning to clear the Five Ponds trail when the first heavy snow came. As of December 1995, the Leary Trail (western part of the High Falls loop trail), the canoe carry trail to Lows

Lake and much of the Five Ponds trail were still blocked. All of these go through heavy blowdown and may have to be relocated, or replaced.

In the areas where the blowdown is light, reopening trails simply requires sawing up fallen trees, and is essentially routine trail maintenance. But in other areas, where the logs are piled several yards high it is not in the least routine: probably it should only be done by professional crews with safety gear, and with provision (radio links, personnel and equipment ready for evacuation) for handling accidents in remote areas. In many cases it will be far easier to route the trail around a blowdown rather than through it. But is some cases -- near High Falls, west of Lows Lake -- this may not be an option, and the choice will be between clearing paths through the blowdown, or abandoning the trail.

How much additional emergency access is needed and how can it be supplied?

This is an interesting and controversial subject. The DEC has been averaging about 50 rescues a year in the areas affected by the blowdown, and so feels that emergency access, either by road, by foot or by helicopter, is essential for public safety. Currently emergency access to a number of popular camping areas is limited. If you believe, as many people do, that the State should be capable of quick, all-weather rescues at any popular destination on state lands, then a clear argument can be made for restoring or creating emergency access routes.

Consider for example, High Falls, the most popular camping destination on the upper Oswegatchie. At present the only way to reach High Falls is either to fly a helicopter to the Plains and then walk 0.5 miles to the falls, or to travel about 12-14 miles up the river by boat. The former can be done within a hour, given suitable weather and assuming that the aircraft and crew are available. The latter takes 4-6 hours, depending on the water level. Emergency access could be improved by reopening the Leary trail, repairing the old road from Wanakena to High Falls, or clearing a helicopter landing area at High Falls.

Clearing the Leary trail would not be controversial, but it goes through heavy blowdown and may not be possible. Opening the old road would require rerouting the road around several beaver flows, and building several substantial bridges. Both the rerouting and the bridge construction are arguably inappropriate in a wilderness area, and would certainly be controversial. And clearing a helicopter landing area would be highly controversial, especially as there is a good natural landing area in the Plains, 0.5 miles away.

In thinking about these issues, what we really face is an ethical choice between two commendable, but opposed, values. On the one hand we have the State's perceived responsibility to look after people, and the undoubted fact that we a dealing with a very popular recreation area, and at least a minority of users who are not self-reliant and have limited wilderness skills. On the other hand we have the requirement in the master plan, which many users would think critical, that the sense of remoteness be protected. And it is also an undoubted fact that the sense of remoteness can easily be compromised by a too thorough provision for mechanized search and rescue.

I have not researched the question of emergency access and don't have an informed opinion. My strong inclination is to question the assumption that we need rapid emergency access to every wilderness area. In this I agree with Laura and Guy Waterman, who argue in their recent book ***Wilderness Ethics*** that overusing the capacity to make quick rescues, especially in non-life threatening situations, tends to create a user group that expects to be rescued, and so necessitates more and more rescues. Before I would consider a proposal that would improve mechanized access for rescues, I would like to see evidence, based on case histories, that the record of accidents and emergencies justified that level of access. And I would also like to see a careful consideration, based on interviews with users and user groups, of how the sense of remoteness might be changed by providing greater emergency access, and of what the ethical and experiential costs of the change might be.

Is the reopening of roads necessary for fire-fighting?

Before helicopters came into widespread use, a good system of wood roads was considered indispensable to any fire management plan. A number of roads -- no one seems to know just how many -- were created during the salvage of the 1950 blowdown. These were considered highly important for fire protection, and one of them was reported to have been crucial in fighting the fire in the Cold River Blowdown (Box 1, p. 3).

There are clear arguments for maintaining such roads, and by extension arguments for opening new ones, or reopening blocked ones, in areas where the fire, danger is high.

But there are also important counter-arguments, which suggest that the roads may not be as important for fire fighting as it might as first seem. In wilderness areas, it is expected that the initial attack on all fires will be from the air. And because it is so hard to move around in the woods near the blowdown, it may be impractical or very dangerous to fight any but very small blowdown fires on the ground, even when roads are available. And finally, some of the most concentrated parts of the blowdown are in areas where there are no roads, official or otherwise. All of these reasons suggest the capacity for fighting fires from the air will be crucial in dealing with fires in the blowdown, and that road access, though still potentially important, may be secondary.

What are the ecological consequences of providing recreational and emergency access?

I do not see that any major ecological issues are involved here. The areas involved in trails or landing areas are very small, and, so far as I know, the effects correspondingly slight. The other issues noted above, particularly those of safety and wilderness values, seem much more important.

What are the basic questions about a fire management strategy?

As noted above (p. 47), 1 think that under certain, perhaps unlikely, conditions, the risk of fire will increase. We can deal with the risk in either of two ways: we can reduce the fuel loads in advance, or wait until the risk increases and then respond with some combination of restrictions on users, increased surveillance, and increased fire-fighting capabilities.

I call the first a fuel-reduction strategy, the second a risk-controlled strategy or a graduated-response strategy. The decision about which to use will involve looking at the components of each strategy and figuring out whether they will work, what their ecological effects will-be, how much they will cost, and whether they will conflict with management guidelines or laws.

Is the commercial salvage of logs an effective way of reducing the risk of fire?

In 1950, it was assumed to be (Box 1, p. 3); today, with different fire suppression capacities, and a different sense of the likelihood of fires in blowdowns, we can't accept this uncritically.

The presumption that commercial salvage can reduce the fire risk depends on the observations that salvage:

> Removes large-diameter material, which is about 50% of the total amount of fuel, thus decreasing the intensity of any fires in the salvaged area.
>
> Leaves the remaining material closer to the ground, thus decreasing the potential height of the flames, and hastening the decay of the residue.
>
> Opens up roads, and so provides subsequent access and better fire suppression.

Generates profits from the sale of the salvaged logs, and so, at least potentially, is an economically attractive method that can be used over large areas.

Unfortunately, there are other observations that qualify its effectiveness.

Salvage leaves roughly 50% of the fuel in place. The fuel that remains is smaller that what is removed, and so easier to ignite and more likely to be dry. Thus salvage reduces the potential intensity of fires, but not the immediate chance of ignition.

By making the fuel bed more compact salvage may eventually hasten decay, but in the short-term could increase the chance of ignition and produce a lower but hotter fire. In this respect salvaged areas, which have large amounts of logging slash, are analogous to cut-over lands, which are notoriously inflammable.

Salvage may in some cases increase the dryness and hence the ignitability of the fuel by removing residual canopy and killing brush and young trees, leaving the area more open and thus more able to dry out.

Because of economic and operational problems (limited markets for pulp, limited useful life for down logs, high costs of salvaging dispersed blowdown, high costs of road-building and salvage in remote areas) salvage operations are likely to reach only a small fraction of the blowdown.

Historical considerations suggest that the problem of the operational and economic limitations of commercial salvage may be very real. The post-1950 salvage was moderately successful in accessible areas where concentrations of virgin softwoods were down, but was essentially unsuccessful at salvaging hardwoods, or in reaching remote blowdown areas. The salvage was economically feasible only as long as the market for pulp remained strong; once these markets collapsed the salvage contractors began to pull out, and eventually only 13% of the estimated area of the blowdown was salvaged (Box 1, p. 3).

Thus the critical questions about commercial salvage seem to be whether you can-do enough of it to make any difference to the fire danger, and what happens to the slash - up to 50 tons per acre on some plots -- that you will leave behind. If the slash rots faster than it would with out the salvage you may have done some good; if you kill the young trees and make a dryer opening where the slash rots more slowly you have may increased the danger. It seems worth reflecting that historically blowdowns have caused very few fires, and logging slash a great many. Since salvage generates slash rather than removing it, it can't automatically be judged an effective risk-reduction tool.

Is commercial salvage consistent with the management goals for wilderness areas and wild forests?

I think the conclusion is inescapable that it is not. A salvage operation would involve the creation of roads and the extensive use of machines for a period of several years or more. Its effects would involve substantial changes in ecosystem structure and forest regeneration, and would alter the blowdown, which, I will argue in the next section, is both a valuable natural phenomenon, and a part of the wilderness. The injunction in the MacDonald decision that the forest preserve lands 'must always retain the character of a wilderness' and the language in the master plan stating that state must 'achieve and perpetuate a natural plant and animal community where man's influence is not apparent' in wilderness areas and protect the 'essentially wild character' of wild forests would appear to be inconsistent with the mechanical disturbance and ecological manipulation that a commercial salvage operation would involve.

Given all the above, is commercial salvage a useful risk abatement policy on state lands?

Again, I think not. It appears that it may be illegal and so impossible to do at all. If it turns out to be legal (and if this can be established before the timber spoils), it will be hard to do enough of it to - matter, and it may be ineffective to boot. And, whether effective or not, it is clearly inconsistent with ecological and protectionist goals, probably inappropriate in wild forests, and, without any qualification, potentially disastrous in wilderness areas.

Could small fuel reduction operations in high-use areas substantially reduce fire risks? Would the same objections apply to them as to a large-scale salvage?

I think that small scale fuel reduction operations near campsites and settlements can definitely reduce fire risks. Compared to large-scale salvage they have a number of obvious advantages. They can be limited to the areas where there is a known risk of fire, and where the consequences of a fire are potentially serious. In wilderness areas they can concentrate on slash reduction and leave the timber in place, and so be done without roads, heavy machinery, or extensive soil disturbance, thus avoiding the most objectionable features of large-scale commercial salvage.

What would a risk-controlled response to the fire danger involve?

By a risk-controlled approach I mean one that only institutes protection when the risk'-is actually there. Such an approach would take immediate action to reduce fuel in the immediate vicinity of structures and near campsites in areas where open fires are common. It would also institute a monitoring system to measure fire danger and fuel moisture and develop a quick response capability based on the premise that most blowdown fires would be fought by air. In periods when there was a substantial increase in fire danger, as measured by weather and the drying of the down timber, it would institute regular air surveillance and forbid fires or close high risk camping areas. In periods when fire danger was very high it would increase surveillance, close portions of the woods where there was not good emergency access, and keep fire crews and aircraft on alert.

Could a risk-controlled response cope with the increased fire hazard created by the blowdown?

I think that it could. It is essentially what the state has been using for some time, and a measure of its effectiveness is that there is no evidence that we get a major increase in number or extent of fires in periods when the fire danger is high.

The advantages of a risk-controlled response, compared to large-scale salvage, are that it:

Is clearly legal, and probably not very controversial.

Can be quickly instituted.

Emphasizes a mobile response rather than a fixed salvage plan, and so is consistent with the dispersed geography of the blowdown and the unpredictable occurrence of fires.

Doesn't commit the DEC to a large operation of questionable effectiveness.

Can be used in roadless areas, where much of the intense blowdown occurred.

Doesn't do ecological damage.

May have substantial one-time capital costs, but has low operational costs except when you have a period of major fire danger.

13. The Value of the Blowdown

It is conventional, and possibly quite misleading, for descriptions of powerful storms to emphasize their destructive aspects. On August 27th of this year the New York Times ran a picture of a one-acre blowdown on a small uninhabited island in Lows Lake under a caption saying 'Disasters', and spoke of 'nearly two million acres of damaged wilderness, some of it now extremely combustible.' Neither the extent nor the combustibility was true. A second article a month later was titled 'Tidy Up a Wilderness or Leave it in Tatters' and spoke of the ‘extraordinary extent of the devastation.’

The tendency to see the storm solely as a destructive agency is reflected in official reports. The DEC's draft assessment of the windstorm says that $200,000,000 of damage has been done to forest - resources. This includes $116,000,000 of damage on the forest preserve, where the timber cannot legally be sold and such an estimate is arguably meaningless. It goes on to describe $2,000,000 of damage to state facilities, gives a lengthy discussion of the fire and emergency management problems created by the storm, and says there is a 'severe degree of risk for those still intent on using the Five Ponds Wilderness Area.’

Even ecologists, who should know better, sometimes use the language of destruction: the DEC Draft Ecological Assessment, apparently apologizing for the mess that nature has made, reassures us that 'forest communities have been returning to damaged landscapes ever since the glaciers retreated.' It also says that 'the entire pre-storm area occupied by these occurrences is still categorized as old- growth forest', and that 'Five Ponds Wilderness Area is still a wilderness by definition! The presumption here seems to be that damage has occurred, but that we can word things so that the damage is not as bad as it might at first have seemed.

My objection to these views is not that they are wrong -- the storm did hurt people and damage trees and property -- but that they contain assumptions about how we should value wilderness areas. We are asked to appraise the value of wilderness forest in economic terms; to assume that obstacles and the lack of open marked trails are necessarily risks and disincentives for recreationists; and to consider that naturally created openings are damaged landscapes, and potentially less authentic, beautiful, and less wild than continuously forested landscapes. These assumptions, I maintain, are somewhere between severely biased and demonstrably wrong.

Interestingly, the DEC Storm Assessment itself contains much information that contradicts these assumptions. It says that since it is illegal to sell timber from the Forest Preserve there may not have been an economic loss; that ecological disturbances are agents of change but not disasters; that the wilderness character of Five Ponds has not been impaired; that the storm created scientific and educational opportunities; and that recreationists are using Five Ponds much as before, and actually coming to see the blowdown. But all of this information is treated as secondary or appendicular, and, not allowed to alter the ***Storm Assessment's*** basic premise that the storm is to be understood as a destructive agency that created losses and risks, and requires responses designed to reduce the losses and protect against the risks. This is reflected in the topics raised by the DEC Storm Working Group. They discussed damage and risks extensively, but never considered whether, if in fact the storm created scientific and educational opportunities, the state ought to try to take advantage of those opportunities.

In this section I will argue that the available information, doesn't simply mitigate the perceived destructiveness of the storm but contradicts it. I argue first that there has been in no sense a destruction of the forests; second that the blowdown is not only not detrimental to wilderness but is itself a spectacular part of the wilderness; third that the blowdown is an essentially unique scientific opportunity of great potential value; and fourth that, rather than damaging the Adirondack Park, the blowdown is a unique asset that has both added to the existing value of the park and confirmed the importance of managing it as a wilderness.

Has the blowdown damaged the forests?

To say that the blowdown had damaged the forests as a whole would imply that there was evidence that it had significantly interfered with ecosystem processes, or significantly reduced the number of species or their average abundance. Based on the discussions in Sections 9 and 10, I see no evidence for this.

In the central 100,000 acre area where the damage was most concentrated perhaps 16% of the land has moderate of severe blowdown (p. 25). The total percentage of canopy trees blow down is unknown. One estimate was 7%. Even if the dispersed single-tree mortality equaled the concentrated mortality, this suggests that no more than about 15% of the trees in the central triangle of Map 1 are down.

So far, only a few of the down trees have died. More will die in the next few years. Assume, as a rough estimate, that two-thirds of the down trees, and so about 10% of all the forest trees in the central triangle, die in the next year. Natural mortality of the canopy trees in mature forests typically runs somewhere about 1% per year. If the blowdown kills 10% of the trees over the next year, all it is really doing is compressing ten years of mortality into one year.

The blowdown will probably create small increases in diversity, a transient pulse of soil acidification, and a longer lasting pulse of carbon and nutrients cycled through the coarse woody debris compartment. It will replace old trees with younger trees, perhaps increase canopy diversity slightly, perhaps increase the abundance of spruce, yellow birch, and red maple. Its effects will be greatest in individual stands. Its long-term effects on the composition, average age, and average contents of nutrient pools, averaged over the whole forest, may be slight. One hundred years from now the overall state of the forest may be very little different than if the blowdown had not occurred.

Thus from a biological view it makes no sense to describe the blowdown as a disaster or say that the forests have been hurt. The blowdown has changed parts of the landscape, certainly has hurt individual trees, and in doing, so has, or will have once the trees rot, effaced some of the biological connection between current and past forests. But individual trees are always being hurt, and natural processes are always effacing history. I see no evidence that the forest as a whole has been diminished, or even that the ecosystem as a whole has been changed very much. There has been an increase in mortality; this will be compensated for by lower mortality (because the forest is younger) over the next few decades, and the hundred-year average will change very little.

Has the blowdown created devastation?

The primary meaning of devastate is to make barren or to create wastes (***vastes***). The blowdown has not done this. The August 27 ***New York Times*** article says that the park has 'endured devastation', but in the accompanying picture the down trees are still green and alive, and young trees are visible throughout. We know from our fieldwork - which included the island pictured by the ***Times*** – that this is generally true, and that all the blowdowns are filled with herbs, tree seedling and saplings. We also expect, based on studies of artificial openings, that the blowdowns will be much used by birds and animals. Thus the blowdowns are very much alive and active, in some ways perhaps more so than the surrounding forests, and can in no sense be considered wastes.

A second meaning of devastate is to make desolate, that is to destroy without consolation. Certainly some beautiful forests have been destroyed, and anyone who knew them before the blowdown will feel sadness and loss. But we would argue, from our three weeks traveling and working around the blowdowns, that there are in fact very strong consolations. One writer said in the log book at that High Falls shelter that he was saddened by all the trees down, but that he stayed for several days and it was still a beautiful place. We would agree. The blowdowns we were in were rugged, dramatic, visually complex, and engrossing. We found them, unexpectedly, to be both beautiful and imaginatively rich - places where you felt what Thoreau called the 'grimness and tenderness' of the northern forest. In retrospect I have come to think of them the way I do cliffs and landslides and rocky coasts - as powerful places where nature's seriousness and enduringness are evident. Almost everyone I have talked to who has spent time in the blowdown felt similarly, and has been, in one way or another, moved and educated by their experience. As most everyone was eager to go back, which is hardly the normal response to a devastated landscape.

Has the blowdown increased or decreased the wildness of the Five Ponds Area?

According to the state land use master plan, a wilderness area is one which has a 'primeval character' ‘appears to have been affected primarily by the forces of nature with the imprint of man's work substantially unnoticeable', 'has outstanding opportunities for solitude or primitive or unconfined type of recreation', and which may 'contain ecological, geological or other features of scientific, education, scenic, or historic value.'

I would contend that all the components that the master plan recognizes as essential to wilderness have in fact been enhanced rather than damaged by the blowdown. The blowdown is primeval -- a part of the pre-civilized world -- both by virtue of its size and the forces involved. By making parts of the country less accessible, it has increased the opportunities for solitude and primitive recreation. And it is obviously an ecological feature, and is of scientific and historic value for reasons to be explained below.

Has the blowdown increased or decreased the conservation value of the old-growth forests?

If the old-growth forests in the Five Ponds area are conceived of principally as a collection of large old trees, then the blowdown, by killing some of these trees, has decreased their value. But if they are conceived of as functionally and historically intact forests -- forests in which we can see all the natural forest-making processes at work -- then their value has been increased, because we can now go there' and see a process which previously we had to imagine or reconstruct.

To say this in another way: if you want to understand northern landforms you have to see glaciers. To do that you go to Alaska or Scandinavia or Greenland. Likewise, if you want to understand temperate old-growth forests you need to understand blowdowns. For the foreseeable future, the only place in North America, and perhaps on earth, where you can see a blowdown of thousands of acres in an old- growth forest will be in the Five Ponds Wilderness in the Adirondack Park.

If the blowdown is conceived of as a valuable part of the wilderness, what is required to protect it?

First and foremost, the recognition that it is a living natural feature, and hence a legally protected part of the wilderness, exactly the way the forests that preceded it were. This means that it is a participant in a host of ecological processes, and if you disrupt it you disrupt those processes. In December 1950, a month after the Great Blow, Attorney General Goldstein said that 'to permit these dead trees to decay and rot away would accomplish no purpose contemplated by the framers of the constitution.' Whether or not he was correct about the founders, he was wrong about either death or decay. The blowdowns are in fact filled with living trees, which are liable to be damaged by attempts to salvage the dead ones. And we now know many purposes, ecological and human, that are served by leaving trees alone to sprout or rot.

Second, a recognition that local clearing of the blowdown for the purposes of fire control or opening trails is an alteration of the wilderness. The cutting will kill living trees and likely damage saplings, just as if we were cutting standing trees. It may be justifiable and indeed valuable to clear parts of the blowdown, but it still decreases naturalness and alters natural cycles, and so should be done as little as possible, and in as non-invasive a way as possible. For example, I would recommend leaving the trunks and large branches when clearing firebreaks near campgrounds. They are not liable to catch fire from sparks, and they are now a part of the natural landscape, just like boulders or living trees. We are perhaps justified in removing them when they are a direct threat to our safety, but not, I would assert, for our convenience or because we want to tidy things up.

Is the blowdown of scientific interest?

It is of great interest. Our standard model of disturbance asserts that major windstorms have occurred in many temperate forests, and have had lasting effects on canopy age distributions and composition. But blowdowns are rare and usually small, opportunities to verify this on the landscape scale have been all but non-existent. Thus far all the blowdowns that have been studied in old-growth have been at most a few hundred to a thousand acres. This is the first chance that ecologists will have had in 45 years to study a blowdown involving tens of thousands of acres, a substantial amount of which is in old growth.

What can be learned from the blowdown?

First, things about blowdowns. We would like to know what really happened in the storm, and if there' was a logic to which trees toppled and which didn't, or about where the storm hit and where it didn't. We also need to find out if blowdowns really increase plant diversity, and if so by how much. Will the openings provide food for deer, create foci from which beetles and fungi will spread into adjacent woods, acidify streams, or create new habitat for amphibians? And how fast will they grow back to forests, and how different will the post-blowdown forests be from the pre-blowdown ones?

Second, potentially important things about forest regeneration. Currently a number of commercial timberlands are experiencing problems in getting desirable hardwoods to regenerate. We don't know whether these problems are built into Adirondack forests in general, or if they reflect something about the history and circumstances of the commercial forests. The blowdown is valuable here because it is essentially a giant experiment in forest regeneration, carefully controlled so there has been no mechanical disturbance to confound the results, and elegantly replicated in forests of a number of different ages and ownerships and histories. Ibis gives us as good a chance to learn about natural gap regeneration as we will ever have.

Third, things about fire hazard and fire management. The question of how great the fire risks are depends on how dry the down branches and timber become. There are models that attempt to predict this from temperature and humidity, but these have never been calibrated in the Adirondacks, or, so far as I know, with the mixture of living and dead material that you will have in the blowdown. By actually measuring the dryness of different size fuels in blowdowns of different intensity at different times, we could greatly increase our knowledge of what the risks of fire really were. And, with luck, we could determine whether the models worked.

Are some of the things that can be learned of general importance for conservation biology?

Yes they are. One that seems to me of potentially great importance, both in the U.S. and abroad, is the possibility of developing a functional concept of old-growth. Currently old-growth is usually defined by its historical features -- big trees and no logging history. Under this definition, old-growth forests are relics, and cease to be old-growth if they get logged or if the trees die. Thus we have an un- increasable quantity of old-growth. Disturbances, by killing old trees, can only diminish that quantity.

But this way of defining old-growth, although in common use, is in fact an unnatural way of looking at forests. All old-growth forests were young once and all have recovered from disturbances in the past. Antiquity and historical continuity are sufficient, but not necessary, for a forest to be old-growth.

An alternative approach would say that when certain functional standards are met that a forest becomes, effectively, an old-growth forest. Under such a definition, the quantity of old-growth could increase: a forest with a human disturbance history at some point becomes biologically indistinguishable from a forest that has had only natural disturbances, and so should then be considered of equal status and value.

If a functional concept of old-growth could be developed, it would change the way we see and value forest lands. Our current view essentially says that old-growth is priceless, everything else is ordinary second-growth, and the conservation value of a landscape is dominated by the (usually small) amounts of old-growth in it. But if, say, forests with a 100-year or 150-year post-logging history are functionally old-growth, then we immediately have an enlarged, and, I would hold, more biological, sense of what certain landscapes are worth and what conservation can achieve. In particular, recovering forests like those in the New York Forest Preserve would be seen as replenishing the global supply of old-growth on a large scale, rather than just containing a few relic stands.

At present we don't know enough about how forests work to frame a functional concept of old- growth. And this is where the blowdown comes in. Disturbance is a very good test of how things work. The blowdown is a very large disturbance experiment, replicated across undisturbed, once- disturbed, and recently disturbed landscapes. With luck we might be able to use this experiment to test, on the landscape scale, the way that forests with different histories function. For example we can measure regeneration, diversity fluctuations, responses of animal populations, plant immigration rates, ecosystem chemistry, etc. Thus the blowdown could help to enlarge our concept of what a forest is and how it works, and determine how close our managed and recovering forests are or aren't to natural forests.

Are some of the questions that might be studied in the blowdown of significance outside the temperate zone?

Possibly. If we can use the blowdown as an experimental tool to study the disturbance-recovery cycle in different landscapes we may get information that bears on some very general problems in conservation biology. We could, for example, learn something about whether big forests work differently than small ones; about how long chemical and composition perturbations last after disturbances; or whether some kinds of logging in some landscapes are geochemically and biologically benign. Obviously the blowdown can't provide answers to all of these, but I believe it .could contribute important pieces to the answers.

Why is it scientifically fortunate that the blowdown occurred in the Adirondack park?

For two reasons. First because the Adirondacks contain the largest old-growth landscape in the U.S. east of the Mississippi river, and one of the largest, possibly the largest, in a temperate deciduous forest anywhere in the world. 7banks to the July 15th storm, we now have tens of thousands of acres of blowdown embedded in hundreds of thousands of acres of intact forests. A wilderness study area of this size has never been available in any other study of a blowdown. Its presence could be critically important because the interesting questions are landscape-scale questions, and simply cannot be answered, with any generality, in a smaller area.

Second, because the Adirondacks juxtapose a wilderness landscape with a commercial forest landscape, and both occur within the blowdown area. One of the basic questions, and one which is of wide importance given the increasing commercial use of forests world-wide, is how the post- blowdown processes -- invasion, wildlife use, regeneration - differ depending on how the land has been used, and on how the blowdown is treated. From this point of view, both unsalvaged and salvaged blowdowns in commercial forests are of great scientific interest.

How special an opportunity is this?

I think extremely special, perhaps unique. No other place in the northeast US juxtaposes large Patches of these contrasting landscapes. No other has a large, recent blowdown, and given the rarity of large blowdowns, no other may have one for a long time. Essentially, if you want to know about temperate zone wind disturbance, and if your questions are on a landscape scale, there is currently a unique opportunity in the Adirondacks, and there may not be a similar opportunity, anywhere in the world, for a long time.

Notes

1. The radar was not set to measure winds over 77 mph.

2. The atmospheric instability and shear associated with derechos and downbursts are measured by a variety of indices: Lifted Index, CAPE, WINDEX, SHOWALTER, etc. Most of these are computed only for post-storm analysis, and are not part of standard forecasting routine. These indices require vertical temperature and velocity profiles, and these are only available at large airports where regular radiosonde soundings are taken. In areas like the Adirondacks, which lack radiosonde observations, they cannot be applied.

3. dbz = decibels of radio-frequency energy. 65 decibels is a gain in power of about 1800 times.

4. Doppler radar can determine the component of the wind speed along the radar beam (for regions where there is some precipitation to create a radar echo), but has a lower horizon determined by the height of the transmitter and the minimum scan angle. While the storm was over the Adirondacks, the forecasters could not measure the winds much below 3000 feet.

5. Estimates of the area blown down can be converted into estimates of frequency by assuming that the spatial distribution and average frequency of storms has been uniform over relatively long periods, and that the number of years during which a surveyor would recognize a blowdown is roughly constant for different places and different storms. Under these assumptions, a survey showing 2% blowdown in a study area where blowdowns are visible for 30 years would be taken to predict that the average frequency of blowdowns at one particular point is one in 30/0.02= 1500 years. 'Return times' for windstorms, calculated in this way, are commonly cited in the literature, and sometimes treated as if they were historical facts. For example, the statement in the DEC Ecological Assessment that the Adirondacks have a higher frequency of windstorms than the surrounding regions, is based on published statements that average return times are 400 years for the Adirondacks, 1700 years for Wisconsin, and 4000 years for western New York. Unfortunately these numbers are subject to a number of serious statistical uncertainties. Climate history shows that the frequency of storms varies greatly and that their historical distribution is episodic, not uniform. The early surveyors' definitions of wind damage, and hence the time that such damage would remain visible after a storm, are not known and cannot be assumed to be the same in different states. And finally, the relatively short lengths of time that blowdowns remain visible mean that a given survey samples only a short period of history and a few storms and so the sampling error is correspondingly great (see next note 6).

6. If major windstorms are relatively infrequent, it is quite possible that a given group of surveys samples only one or two storms. Suppose, as a worst case, that the 5% blowdown observed in the Totten and Crossfield Purchase by the early surveyors was the result of a single storm and that in the Adirondacks a blowdown remains visible for about 20 years. In this case the best estimate of the return time of storms is 400 years, but there is still a 1/20 chance -- the normal margin used in calculating confidence intervals -- that the return time could be as long as 4000 years. Given these uncertainties, I prefer to work with the percentage of the land blown down, which is a directly observed quantity, rather than the estimated historical frequency, which I conceive to be so uncertain as to be useless.

7. This cell was imaged by the radar at Rome, but not by the radar at Beme.8. Map 6 was prepared from a copy of the map in McMartin (1994).

9. The wild rice, which occurs in the Oswegatchie Plains, is an open ground species that is probably fire dependent. The Plains have not burned in a long time and have mostly grown back to tall shrubs and young trees. The wild rice is currently limited to small populations along the trails, and may eventually go extinct there if the area doesn't bum again.

10. In a slow moving storm the outflow winds from the downburst radiate in all directions. In a fast moving storm the storm velocity is added to their individual radial velocities. They still have radial velocities, but these are small with respect to their total velocity, and so the outflow winds are more parallel overall.

11. If the logs decay more slowly, say in 60 years, the percentage increase will be correspondingly less, but the period of release longer.

12. For example, water moving through rotting logs becomes more alkaline; in test watersheds which have been cut and in which logs are left in place, after the short-term nitrification pulse ceases, the logged watersheds becomes slightly more alkaline than reference watersheds. And the organic anion content, which be associated with acidification driven by organic acids, has not increased in many acidifying lakes.

13. A non-trivial legal issue is hidden within the phrase forest preserve. Currently, state lands within the Adirondack Park fall into two categories: forest preserve lands (2.4 million acres), which are clearly subject to Article XIV of the state constitution, and non-forest preserve lands (36,000 acres). The latter are considered, apparently without legal foundation, to be exempt from Article XIV. See Glennon (58).

14. Even if there had been a major change in ecosystem or composition, this would not automatically translate into damage. In so far as we can read the records of northern forest history it appears that major changes and disturbances are relatively common, and that, in all but the most drastic changes associated with glacial advances, the forests simply reorganize and survive.

References

I give general references for each section, specific references only where there are several general references on each topic. Numbers refer to entries in the bibliography. Where an individual is cited without a number the information was obtained orally.

Section 1

Meteorology from archived doppler images of the storm at National Weather Service, Albany. Derecho: (75). Damage estimates: (4). Historical fires: (7). Timber salvage: (7,16,18-23). Quotes relating to 1950 storm: (16). Wilderness areas: (8). Ecological evaluation by the DEC: (4,92).

Section 2

Currently there seem to be the following primary sources of data concerning the blowdown:

Maps and GIS files showing areas of moderate and severe damage, prepared by the DEC from color airphotos taken in late July and early August.
Landsat TM images of the blowdown area from August 1994 and 1995, at the park Agency in Ray Brook.
A 'difference image' prepared from the Landsat images at St. Lawrence University.
Field data on damage, trail and shelter condition, and fuel loading gathered by DEC personnel this summer and fall. Parts of this are archived, parts anecdotal.
About 300 low altitude oblique air photos of the Oswegatchie Basin taken by J. Jenkins in July (pre-blowdown), August, and October 1995.
Descriptive data from about 15 blowdown sites in the Oswegatchie Basin and quantitative data from four sites, gathered by the author and assistants in July and October.
Quantitative data gathered by Michael Bridgen and his students at the SUNY ESF campus at Wanakena.
Damage estimates by various private timber companies.

Section 5

Definition and physics of derechos: (64,74,82,83,86-89). Occurrence and synoptic meteorology of derechos: (63,66,74,76-78). Examples of derechos: (63,66,67,75). Forecasting derechos: (81,85). Downbursts: (67-71,84,90). Mesoscale convective complexes: (80). Doppler radar images: (72).

Information on July 14 synoptic situation and subsequent storm behavior from John Cannon and archived doppler images of the storm at National Weather Service, Albany. For storm descriptions see Box 3.

Section 6

DEC estimates from (93). Other estimates from sources noted in text. Meteorology as above.

Section 7

Most of the information observations by the author and his students, August and October, 1995. Maps of 1950 blowdown and 1903-8 fires from (7).

Section 8

Most of the information observations by the author and his students, August and October, 1995.

Section 9

Fire models: (52). Early fire history: (4, 93), plus Charles Cogbill and Barbara McMartin. New England fires history: (49), plus Vt. data compiled by the author. Quantitative data on recent NYS and Region 6 fires compiled by the author from archives of DEC Fire and Safety Office, Albany. Fuel load based models: appendix to (4). Quotes relating to 1950 storm: (16, 22). Large historical fires in northeast: (12). Large smoldering fires in 1908: anecdotal information gathered by Joe Kennedy from residents of Piercefield.

Section 10

Standard model of forest disturbance: (33, 34, 37, 40, 42). References to windstorm studies, see Box 6. Chemistry of simulated blowdown at Harvard Forest: (94). Diversity increases: Harvard Forest data from Sarah Cooper-Ellis; Flambeau data from (99). Regeneration data from (99,114,104,117,118).

Section 11

Model for CWD dynamics from (119-121), plus discussions with Charles Cogbill and Kerry Woods. CWD nutrient fluxes based on numbers from 121, plus discussions with Kathleen Weathers. Acid base balance from (25,29,30) plus communications from various workers collected and circulated by Karen Roy. Alternate acid-base models: (26-29), plus some statistical work by J. Jenkins.

Section 12

Legality of responses: (57-59), appendix to (4). Attorney General's opinion: (16). Master plan: (6,8). Pulpwood markets: conversations with Dave Smith, Ken Super, Joe Hanley, John Flynn and others. DEC responses, current state of trails: (4) conversations with Dave Smith and Joe Kennedy. Cold River blowdown Fire: (46). Risk-controlled strategy: appendix to (4). Wilderness ethics (118).

Section 13

New York Times: quotes from the Time Magazine, 27 August 1995; and 25 September 1995. Estimates of damage: (4). Quotes from ecologists: (92). DEC storm assessment (4). Killed one tree in six: based on our maximum estimate of 18% damage in the central damage swath. Canopy mortality in old-growth: estimate is from Kerry Woods. Thoreau 'grimness and tenderness': from the conclusion of the Kataadin section of the Maine Woods. State Master Plan: (8).

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