A Tornado Scenario for Barrie, Ontario

by:

David A. Etkin (corresponding author)
Adaptation and Impacts Research Group, Environment Canada
Institute for Environmental Studies, University of Toronto
33 Willcocks St., Toronto, Ontario, M5S 3E8
david.etkin@ec.gc.ca

Soren E. Brun
North Carolina Dep't. of Transport GIS Unit

Solomon Chrom
Faculty of Environmental Studies, York University

Pooja Dogra
Institute for Environment Studies, U. of T.

July 2002

ICLR Research

Paper Series – No. 20

(A contribution to the Canadian Natural Hazards Assessment Project)

INTRODUCTION

A natural disaster occurs when an environmental extreme triggers social vulnerabilities. The magnitude of the resulting impact is then a function of the intensity of the environmental extreme coupled with a society's perception and adaptation to the hazard (Blaike et al., 1994). An examination of risk should therefore be composed of two parts: one part relating to the probability of a natural hazard occurring, while the second relates to the magnitude of the resulting impact (which depends upon the vulnerability of the exposed infrastructure and population). Various studies such as Hague (1987), Paul (1995a,b), Etkin et al. (1995; 2001), Paruk and Blackwell (1994) and Newark (1983), have explored the probability of tornado occurrence in Canada; while other (Lawrynuik et al, 1985; Allen, 1986, Carter et al., 1989; Charlton,et al., 1998) have discussed the impacts of individual Canadian tornadoes. Globally, Canada ranks second, after the United States, in tornado risk.

The purpose of this paper is to focus on the second part of the problem - that is, the impact/vulnerability aspect. In order to accomplish this, this paper will briefly review historical tornado impacts, consider one tornado disaster in more detail (the May 31, 1985 Barrie Tornado), and consider a hypothetical scenario of how it might have been worse, had events transpired somewhat differently (ie. create a worse case scenario).

TORNADOES AS A NATURAL HAZARD IN CANADA

Newark (1983,1988) compiled the first national tornado data set for the period of 1918 to 1979 and provided a large-scale tornado occurrence and damage assessment. Etkin et al. (2001) extended the tornado database, mainly using the annual reports from the severe weather co-ordinators at the regional weather offices of the Meteorological Services of Canada, providing a frequency analysis for Canadian tornadic events based upon the 1980-1997 period.

In Canada tornadoes primarily occur between the months of May and September with peak numbers in July. Figure 1 (Etkin et al., 2001) displays the probability of reported tornado occurrence for Canada. The region of southwestern Ontario has the highest probability of reported tornado occurrence coupled with a very high population density, making it the region of greatest risk. Other areas with a high probability of tornado occurrence, where populations are large and tornado frequencies are significant include Edmonton, Alberta; Winnipeg, Manitoba, and extreme southern Quebec (Ottawa - Montreal area). An overview of Canadian historical tornadoes and tornado frequencies is discussed in Etkin et al. (2001).

In the future our risk from tornadoes may be different than it is now, as a result of climate change (IPCC, 2001). Most atmospheric scientists agree that the earth's climate will become warmer in the future as a result of increases in atmospheric CO_2 and other trace gases. As a result, extreme events will occur with different frequencies than the present climate. The frequency of some atmospheric extremes will be decreased accordingly (e.g. cold waves); while others (e.g. heat waves and droughts) seem likely to increase. Etkin (1995) analyzed the historical tornado record; comparing the frequency of tornado events before and after 1980. The data suggests that tornado frequency in western Canada increases with positive mean monthly temperature anomalies. The inference is that if Canada's climate warms, then a corresponding increase in tornado frequencies might be exhibited. Price and Rind (1993) found in a GCM model experiment that a doubling in atmospheric carbon dioxide with a 4.2^{o}C warming would result in a 72% increase in cloud-to-ground lightning strikes. Since lightning is a result of thunderstorm formation, this may logically be extended to suggest that more thunderstorms, possibly even more severe tornado producing thunderheads, may result from global warming. The recent report by the Intergovernmental Panel on Climate Change (IPCC, 2001) indicates that the frequency of tornadoes in the future cannot be assessed with any degree of confidence, however, due to the many uncertainties.

Table 1: The Fujita Tornado Scale

Rating		Maximum Wind Speed	Damage Description
F0	Gale tornado	64 - 116 km/hr	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.
F1	Moderate tornado	117 -180 km/hr	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F2	Significant tornado	181 -252 km/hr	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
F3	Severe tornado	253 -330 km/hr	Roof and some walls torn off well constructed houses; trains overturned; most trees in fores uprooted
F4	Devastating tornado	331 - 417 km/hr	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
F5	Incredible tornado	418 -509 km/hr	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel re-inforced concrete structures badly damaged.

CASE STUDY: THE BARRIE TORNADO OF MAY 31, 1985

Barrie and its surrounding areas report, on average, between 2 and 3 tornadoes per year per 10,000 km^2. The most severe historical event was rated an F4 and occurred on May 31, 1985. Tornadoes are rated (Table 1) by an intensity scale, ranging from F0 (weakest) to F5 (strongest). Canada has not yet experienced an F5 event that has been recorded, though there is no reason why it could not happen. The maximum vortex wind speeds associated with this event are assumed to be, based on the Fuji-scale, approximately 320 kmh^{-1} (ref) (though Allen, 1985, estimated a maximum near-ground wind speed at around 200 kmh^{-1} based on an engineering analysis of the damaged buildings). F4 tornadoes only represent 0.2% of tornado occurrences in Ontario, and 0.7% of US events.

Description of the Event

During Friday afternoon on May 31, 1985, at least seven distinct tornadoes were spawned from a strong cold front which moved through southern Ontario (See Figure 2). There were a total of twelve fatalities, and hundreds were injured or left homeless. Property losses for southern Ontario probably exceeded $100 million dollars .

The most damaging and destructive of these events was the single tornado which swept through the town of Barrie, Ontario. This was the fourth most damaging tornado in Canadian history. On this Friday afternoon, nicknamed "Black Friday", an F4 tornado touched down near the town of Hopeville. Before striking Barrie, this funnel moved along the countryside lifting off the ground twice before approaching the city of Barrie (though it is not clear whether there was one or three separate tornadoes). Between 4:15 and 5:00 pm, the tornado touched down for the third and final time just to the southwest of the Barrie city limits (Figure 2). Moving in a northeasterly direction, the storm first hit a pine forest plantation, where many 10 metre tall trees were broken off at the 2 metre level. The average damage width in this location was estimated at 600 metres (Lawrynuik et.al., 1985). The tornado, continuing to move east, crossed Crawford Rd. towards Patterson, completely obliterating an entire square block of older frame houses, killing three people (Newark, 1985; Ransom, 1986). Cars were thrown hundreds of metres into the bush. The tornado proceeded to an industrial park - at least sixteen factories were heavily damaged or destroyed. Many others, which were located just on the outskirts of the 350 to 450 metre wide path of destruction, were severely damaged. There was one fatality within the industrial complex. Factory roofs were blown completely off. In the isolated walls left standing, many small wooden splinters were found driven into brick mortar. Steel I-beams were twisted massively. It should be noted that casualties in the industrial section were minimized by a fortuitous power outage (caused by one of the other tornadoes), which prompted companies to dismiss their workers early. Thus, buildings in the area were largely unoccupied at the time the tornado hit.

The tornado next crossed Highway 400 moving just south of the Barrie racetrack, damaging several barns and the grandstand. Horses ran frantically to escape the destruction. Witnesses say they saw a horse lifted off the ground and gently replaced some distance away. The horse was subsequently nicknamed "Twister Resistor". Dents and small "bullet" holes caused by flying debris were found in most cars near Highway 400. A woman who was caught in her car in the tornadoes path later recalled that she was thrown to the floor while the vehicle was batted around by the tornado. She survived although her car was completely destroyed. Highway guard-rails were found several hundred metres away wrapped around trees and buildings. The sleeping compartment of a semi-truck, which may have originated somewhere near Highway 400, was found on the rooftop of a nearby house.

From there, the tornado tracked further eastward into the Hillsdale subdivision. The upper floors of an entire townhouse complex on Adelaide Street were destroyed; other sections were completely levelled. The tornado's 300 metre wide track moved from Debra Crescent to Marshall Street to Joanne Crescent causing extensive damage. Near Tower Crescent, the damage path narrowed to 50 metres, limiting the swath of destruction. On Briar Road, the homes sustained only minor damage, indicating that the tornado may have momentarily lifted off the ground. However, the next street east, Trillium Crescent, sustained heavy damage indicating that the tornado had strengthened. Four warehouses due east in an another industrial park near Highway 11 sustained massive damage. Heading towards the CNR tracks, the tornado crossed Yonge Street at Minets Point Road, cutting a 100 metre destructive path. Before hitting the Minet Point Marina on the shores of Kempenfelt Bay, the tornado skirted the northwest corner of the Tollendal Woods subdivision. The inflicted damage was less severe than in the Hillsdale area. As the tornado moved through these subdivisions, four more fatalities were reported. At the marina, thirty-five boats, including their concrete mooring anchors, were reported to have completely disappeared. Debris from the town of Barrie was discovered 5 km out into Lake Simcoe. Over the cool waters of Lake Simcoe, the tornado finally dissipated. No damage was reported on the opposite shore.

In summary, there were eight fatalities in the city of Barrie, and 155 injuries requiring immediate medical attention. The eight fatalities were caused by severe head and chest injuries mostly resulting from flying debris (Morris and Armstrong, 1986). Injuries and fatalities in the industrial area probably would have been much worse, had the power outage not occurred. The entire path of destruction within the city limits was 5 km long and between 50 to 600 metres wide. Many houses on the outskirts of the tornado path sustained significant damage from both the severe winds and flying debris. The houses within the tornado path, which had not been completely destroyed, had their roofs or upper floors removed, windows shattered, or brick-walls blown apart. Some were even moved intact off their foundations. In total, 605 houses were extensively damaged, of which over one third were left completely uninhabitable (Morris and Armstrong, 1986). As many as 16 factories were completely demolished, and at least 400 people were temporarily put out of work. Most of the trees throughout the entire tornado track sustained heavy damage; many were either sheared-off or uprooted.

Infrastructure

The risk of death and injury is influenced by the susceptibility of buildings to tornado damage. Building codes, standards and quality of construction are therefore critical. In studies of this tornado, it was found that 7 of the 12 deaths occurred in houses inadequately anchored to their foundations (Allen, 1986). The floors on which people were standing became airborne, causing casualties on impact with the ground (Allen, 1986, p 18). This may be, in part, because the houses, which had been built in the 1940s and 1950s, were in the part of Innisfil Township annexed by Barrie in 1981 (Allen, 1986; Ray Buckle, personal communication), and were not subject to the national building code at the time of their construction. According to the city's director of planning and development, city building inspectors would not have inspected the homes after the annexation (Globe and Mail, Thomas Claridge, January 27, 1986).

Allen (1986) analyzed damage resulting from tornadoes in the Barrie/Orangeville, Ontario area, May, 1985, estimating a maximum wind speed of around 200 kmh^{-1}. Much of the damage resulted from a lack of anchorage to the foundation, in one case because washers were not put on the anchoring bolts. Several old brick houses collapsed as a result of roof lift-off (the roofs provide support to the brick walls, which collapse when the roof is gone). A large shopping plaza of block-wall and steel construction was severely damaged. The city's chief building inspector notes that anchorage is easy enough to monitor if it is caught during the early stage of home construction. The 1985 experience has certainly made people more aware of its importance; builders know houses have to be properly anchored, and they ensure that it is done (Ray Buckle, personal communication).

Inadequate anchorage is a cause for particular concern with respect to school portables. Portable classrooms are not anchored to foundations; in Barrie, visual inspection reveals them to be sitting on skirted blocks, an observation confirmed by Simcoe County educational authorities (David Barnes, Superintendent of Plant Services, Simcoe County Board of Education; Glenn Clarke, Controller of Plant, Simcoe County Roman Catholic Separate School Board, personal communications). There are no plans to anchor them more securely; emergency procedures under development (as of 1994) at the public board mandate evacuation to main school buildings in the event of an emergency (David Barnes, personal communication). In the event of a tornado emergency, this is a risky procedure, as it’s safe execution depends upon a timely weather warning, communication of the warning to the schools, and portables, and rapid and appropriate response by the students and teachers. In the past, many tornadoes occurred with little or no warning. Today, a Barrie type storm would have a 90% chance of having a watch out hours prior to the event, with about a 50% chance that it would be a tornado watch. With the current Doppler radar system, there is about an 80% chance that a severe thunderstorm warning would be issued a half-hour or so prior to it hitting Barrie, and about a 50% chance that a tornado warning would be issued (Mike Leduc & Isabel Ruddick, personal communication). Dissemination of warnings is still considered to be a limiting factor – it is not enough that they are issued. They must be heard and acted upon.

Similar concerns apply to mobile homes. In the 1987 Edmonton tornado, 15 of the 27 deaths occurred in a trailer park (Black Friday, Edmonton Sun / Jasper Printing Group, 1987). The City of Barrie may be trying to restrict or phase out trailer parks; the official plan adopted in 1986 does not recognize them as an acceptable form of housing (Official Plan, Land Use Policies, s. 4.2.2.15). As of March 2001, less than 1% of the population in Barrie lives in mobile homes, mainly on a seasonal basis (about 200 people) (Rick Monkman. personal communication).

One of the observations from the tornado damage was that masonry ties were not always used. Brick facades on houses are usually not load-bearing structural components; they simply cover the concrete masonry blocks and other parts of the framework. Responsible builders are supposed to use masonry ties to secure brick facades to the blocks. The building inspector describes this as very difficult to police; bricklayers have to be monitored during construction, which is very time-consuming (Ray Buckle, personal communication).

Retrofitting following damage has been popular in California following earthquakes, but not common among tornado-damaged buildings; these are often simply rebuilt the same way, with no design improvement. Reluctance seems tied to the assumption that people and buildings are unlikely to get hit again and the fact that insurance policies generally only pay for rebuilding to pre-event standards. Also, insurance and public disaster aid usually mitigate financial losses. Moreover, building owners have no incentive, in the form of reduced insurance premiums, to invest in more than the minimum wind resistivity required by building codes.

Injuries

Carter et al. (1989) analyzed risk factors related to deaths and injuries in the Barrie tornado. There were 12 deaths, 48 serious injuries and 233 minor injuries (4%, 16% and 80% respectively). The deaths resulted from head and chest trauma. Eleven of the 12 deaths occurred before the injured could reach the local hospital. Ten of the 12 deaths resulted from becoming airborne, the remaining two by being crushed. Head and neck injuries accounted for about 49% of the seriously injured, with fractures and concussion/brain injuries the most common diagnoses. Most of these injuries resulted from being struck (60%) while 25% became airborne. The head and neck injuries were also the most common in the minor injury group, followed by the arm and the back-spine area. Most of these injuries resulted from being struck by moving objects, often flying glass.

Readiness [1]

The city of Barrie has an emergency plan, which it updates yearly. It is also in a unique position in that responsible officials have had two opportunities to evaluate the plan's effectiveness on a

[1] *This section based primarily upon interviews carried out June-Aug., 1994*

very practical basis: the 1982 Medonte train derailment and the 1985 tornado. Under this plan, direction rests with an emergency control group which at the time of the tornado included the mayor, the fire and police chiefs, the city administrator, and the superintendent of public works.

Is the city more or less vulnerable in the year 2000 than it was in 1985? Based upon interviews carried out in 1994, the fire chief and deputy fire chief seem to feel that vulnerability has increased rather than decreased (Jack McAllister & Jim Lemieux, personal communication). They attribute this to a combination of population growth, attitudes and availability of resources. In 1985, the city had fairly recent memories of the Medonte experience, which the fire officials describe as having "helped us find some of the gaps." They had also been able to learn from the 1979 Mississauga evacuation; the lessons from those events were invaluable in terms of preparation for the 1985 tornado. However, the lack of any major disasters since then seems to have allowed emergency preparedness to slide down the public agenda.

One of the lessons from Medonte, they recall, was the need for a centralized command. Fortunately, the city had obtained a mobile command post the year before the tornado. Barrie was also fortunate, the deputy chief notes, in that the nearby Canadian Forces Base at Borden was able to provide manpower and equipment to assist with emergency response; not every community will have that advantage.

Local educational authorities were consulted regarding the status of their emergency planning; in 1994, neither the public nor the separate school board had anything in the way of a standard plan applicable to all the schools in its jurisdiction. Some schools have developed emergency plans and procedures geared to their particular situations, which others may use as guides. Both boards indicated that they were in the process of developing basic procedural guidelines which individual schools will be able to adapt to meet their own needs. (Sources: David Quinlan, Senior Health & Safety Officer, Simcoe County Board of Education, and Natalia Neves, Health & Safety Officer, Catholic Education Centre.) Brief follow-up interviews carried out in the spring of 2001 showed little knowledge on the part of schools or school boards regarding the precise nature of emergency plans with respect to tornadoes (Pooja Rooja, personal communication, 2001).

The question of resources, in fact, is one of the most important themes emerging from conversations with Barrie fire officials. The chief and deputy chief noted that while the city's population and physical plant have increased since the 1985 tornado, resources devoted to the fire department had not increased proportionally. In practical terms, this means that the fire department, which takes the lead role in emergency response according to the city emergency plan, would have difficulty in providing the level of service expected of it, compared to 1985. In this regard, they suggest that the city's vulnerability has increased.

The other point stressed by the fire officials is the importance of standardization. Ideally, they say, there should be one short document for each municipality which sets out who is responsible for what and coordinates the efforts of various agencies and levels of government. Individual departments would be free to develop their own detailed procedural manuals based on these master plans, but the format and organization of the master plans should be consistent across the province; inconsistency creates needless complication when one municipality is called upon to assist another. To an extent, this is reflected in local educational authorities' desire to standardize emergency procedures as well.

Other Community Characteristics
Although there is some disagreement between professionals and politicians on some issues, virtually everyone interviewed spoke approvingly of the way people pulled together to help each other in 1985. The study encountered no reason to believe this has changed; if the city still enjoys that capacity for solidarity, it must be considered a factor mitigating vulnerability.

Historical and scientific accounts of the event were supplemented by a questionnaire published (June, 1994) in the Barrie Examiner, the city's daily newspaper. The questionnaire was designed to elicit subjective accounts and personal recollections from Barrie residents regarding their experiences of the event. The survey generated only 8 responses, from people directly affected, and indicated two divorces as a result of the tornado. None of the respondents indicated that they had advance warning of the tornado, though a severe weather warning had been issued by Environment Canada at 3:54 p.m., well in advance of the tornado touchdown at Barrie.

In the aftermath of the 1985 tornado, many residents and homeowners were faced with the prospect of extensive repairs to damaged property. Insurance payouts, charitable donations, and public disaster relief from various sources made substantial resources available for this purpose; the city's chief building inspector notes that the compensation and reconstruction process left many people better off than they had been before the tornado. This is echoed by one of the survey respondents, who observed the installation of numerous new hot tubs in the Allandale neighbourhood (Lea La Chapelle, survey respondent).

A WORST CASE SCENARIO...

In order to assess the City of Barrie's vulnerability in the event of another tornado, the track of the 1985 tornado was transposed in space and time. It was superimposed over a more densely populated residential area of the city (See Figure 2), and assumed to occur at a time of maximum exposure. The comparison assumes a storm of comparable magnitude. The projected track, while mostly avoiding industrial targets, passes over schools, homes, a shopping mall, highway 400, and a senior centre, and possibly represents a worst case scenario from a 'risk-to-life' perspective. Statistics indicate that tornadoes in Ontario usually occur in the mid to late afternoon (Newark, 1983; Etkin et al., 1995). In order to maximize the threat to the population, this scenario assumes that a tornado would strike on a weekday early in the afternoon - hence, schools and office buildings would still be occupied.

The Ontario Weather Centre is assumed to have issued a severe weather watch and warning, as a result of the day's severe weather potential. In the 1985 event, only 1% of affected people heard the warning that had been issued by Environment Canada (Carter et al., 1989). This is similar to the Aylmer tornado of August 4, 1994, where only 3% of those affected heard a warning (White et al., 1995). White estimated that 74% of the residents had no knowledge of appropriate response to a tornado. Since the tornado is assumed to move at a speed of about 60 km/h, with a track length of about 5 km, the event would last around 5 minutes. It is quite possible therefore that Barrie residents would only be aware of the tornado as it approached them. This assumption is supported by the 1985 survey, in which respondents were unaware of the approaching storm, although a warning had in fact been issued.

Given that the location and amount of damage within any tornado track is extremely erratic, it is not possible to quantify the exact number of structures or lives which would be affected. Approximately 1000 to 1500 homes, 7 schools with 83 portable classrooms, a senior citizens centre, a shopping mall and 8 km of a major highway lie within the proposed tornado path. Depending on wind speeds and type of construction, they would sustain varying degrees of damage. In the 1985 event, four of eight unanchored portable classrooms in the tornado path became airborne and disappeared. Approximately 1/3 of the 605 homes sitting in the path of the 1985 event were left completely uninhabitable. These statistics translate into 41 or more portables becoming airborne and 300-500 homes destroyed, in this hypothetical scenario. Since the mall is located at the tornado touch down point, it would likely sustain heavy damage. One could expect considerable damage to vehicles on highway 400. The resultant congestion and wreckage would hamper rescue efforts. The 1985 event caused an estimated $100 million damage. The 1987 Edmonton tornado (also an F4) caused $250 million damage. This scenario could easily cause a much greater monetary loss.

In the 1985 event, fatalities were roughly 1 person per 50 damaged homes. If one-third of the homes-at-risk were damaged (300-500), this translates into 6 to 10 deaths. Deaths could be much higher at the schools as a result of the large numbers of portables. Assuming an average of 20 students per portable, over 1600 students would be at risk. If one-half of the portables became airborne, as occurred in the 1985 event, then over 800 students would be at very high risk. The emergency response plan of evacuating the students into the school is unlikely to be successful in this scenario, as it requires a timely weather warning, efficient communication of the warning to all of the classrooms, appropriate decision-making by the teachers and sufficient time for evacuation. Some injuries and fatalities, as well, could well occur in the senior citizens center, the shopping mall and on the highway.

Isabel Ruddick (personal communication) noted that with respect to these types of warnings that "Our biggest problem is dissemination. Users do not use our Watches/Warnings appropriately. They are not disseminated properly. We usually have them out, especially during these most severe cases. We now have a web site that is continuously updated with the latest watch/warning/statement. If schools are interested in safety, then they will have to come up with a system to monitor these warnings, and have an emergency response plan in place…much like a fire drill. In fact some schools in Dufferin County (Shelburne) actually have Tornado drills every Spring."

It must be emphasized that this extremely unlikely scenario was chosen to illustrate the rarest of cases, where all circumstances align to create a major disaster. Only one known tornado has produced deaths of an order suggested here, the F5 tri-state tornado of March 18, 1925. Though no F5 tornado has been reported in Canada there is no known reason why one could not occur. A worst case scenario developed along the lines described above, for an F5, would be far worse as a result of the stronger winds and larger path width and lengths. One would have to assume, for example, that all mobile homes in the path of an F5 would become airborne, and completely destroyed. In Barrie there are a total of 153 portables, and it is conceivable that an F5 event could affect more portables than the 83 portables in the F4 worst case scenario. The degree to which this is a worst case scenario can be illustrated by comparing it to the 10 worst US tornado disasters shown in Table 2.

Table 2: Ten Worst US Tornado Disasters (http://www.tornadoproject.com/)

Rank	State(s)	Date	Dead	Injured	F-Scale	Town(s)
1	MO-IL-IN	March 18, 1925	695	2027	F5	Murphysboro,Gorham, DeSoto
2	LA-MS	May 7, 1840	317	109	F?	Nachez
3	MO-IL	May 27, 1896	255	1000	F4	St. Louis, East St. Louis
4	MS	April 5, 1936	216	700	F5	Tupelo
5	GA	April 6, 1936	203	1600	F4	Gainesville
6	TX-OK-KS	April 9, 1947	181	970	F5	Glazier, Higgins, Woodward
7	LA-MS	April 24, 1908	143	770	F4	Amite, Pine, Purvis
8	WI	June 12, 1899	117	200	F5	New Richmond
9	MI	June 8, 1953	115	844	F5	Flint
10	TX	May 11, 1953	114	597	F5	Waco

CONCLUSIONS

Although severely destructive tornadoes are uncommon in Canada, they can have a devastating effect upon both lives and property when they do occur. They belong to the type of hazards categorized as low probability - high consequence. Response to and anticipation of such events tend to be cyclical in nature. In the days and weeks immediately following such disasters, planning and discussion tend to be high on the public agenda; as the events recede in time, they tend to lose priority and are supplanted by other community needs. Like most policy issues, the status of emergency planning tends to be most influenced by recent events.

The vulnerability of any community to tornado damage is a function of many factors, primarily the resistance of structures to extreme winds but also of physical layout, population, emergency planning and response capability. The presence of particularly vulnerable structures, such as mobile homes and portable classrooms (especially if they are not anchored) contributes greatly to the likelihood of injury or death, and played an essential part in defining a worst case scenario. Also very important is the public perception of their risk, when they do hear watches warnings (i.e. do they take them seriously, or are they apathetic), and their knowledge of how to respond. When a disaster has not happened in a long time, people tend to become complacent, with the ultimate effect of exacerbating future disasters. Through good planning, we can save lives and ease the human misery that accompanies many of nature’s extremes.

REFERENCES

Allen, D.E., (1984), Tornado damage at Blue Sea Lake and Nicabong, Quebec, July 1984. Building Research Note No. 222, National Research Council Canada, 12pp.

Allen, D.E., (1986), Tornado damage in the Barrie / Orangeville area, Ontario, May 1985. Building Research Note No. 240, National Research Council Canada, 23 pp.

Carter, A.O., Millson, M.E. and Allen, D.E., (1989), Epidemiological study of deaths and injuries due to tornadoes, Amercian Journal of Epidemiology, vol. 130, no. 6, 1209-1218.

Charlton, R.B., B.M. Kachman, L. Wojtiw, 1998: The Edmonton Tornado and Hailstorm: A Decade of Research, CMOS, Bulletin, v. 26, 1-56.

Blaikie, P., Cannon, T., Davis, I. and Wisner, B., 1994. At Risk, Natural Hazards, People's Vulnerability, and Disasters. Routledge Press, London, 284 pp.

Etkin, D.A., (1995), Beyond the year 2000, more tornadoes in western Canada? Implications from the historical record. Natural Hazards, vol. 12, 19-27.

Etkin, D, S.E. Brun, A. Shabbar, and P. Joe, 2001. Tornado Climatology of Canada Revisited: Tornado Activity During Different Phases of ENSO Int'l. J. of Climatology, 21(8), 915-938

Hague, K.D., 1987. A Comparative Study of Tornadoes and Other Destructive Windstorms in Alberta and Saskatchewan. . Proceedings of a Symposium, Edmonton, Alta, Sept. 9-11, in The Impact of Climate Variability and Change on the Canadian Prairies B.L. Magill and F. Geddes editors. Pgs. 351-377.

IPCC, 2001. Climate Change 2001 : The Scientific Basis : Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate by J. T. Houghton (Editor).

Lawrynuik, W.D., Greer B.D., Leduc, M.J., and Jacobsen, O., (1985), The May Thirty-First Tornado Outbreak in Southern Ontario. Ontario Region Technical Notes, ORTN-85-3, Ontario Weather Centre, Atmospheric Environmental Service, Downsview, Ontario.

Morris, B.A.P. and Armstrong, T.M., (1986), Medical response to a natural disaster: the Barrie tornado. Canadian Medical Association Journal, vol. 134, 767-769.

Newark, M.J., (1983), Tornadoes in Canada for the period 1950-1079. Report No. CLI-2-83, Atmospheric Environment Services, Downsview, Ontario, 87pp.

Newark, M.J., (1988), The tornado hazard in Canada. In El-Sabh and Murty (eds.): Natural and Man-made Hazards, D. Reidel Publishing Co., 743-748.

Paruk, B.J. and Blackwell, S.R., (1994), A severe thunderstorm climatology for Alberta, National Weather Digest, vol. 119, no. 1, 27-33.

Paul, A.H., 1995a. The Saskatchewan Tornado Project. University of Regina, Dep't of Geography internal report. 48 pp.

Paul, A.H., 1995b. Strong Tornadoes in Saskatchewan and North Dakota. Annual Meeting of Great Plains Rocky Mountain Division, Association of American Geographers, Rapid City, S. Dakota, Oct. 5-7. 14pp.

White, K., C. McKie, and J. Laverdiere., 1995. Human Response to Warning: The August 4th, 1994 Alymer, Quebec Tornado., Report for the City of Aylmer, EPC, EC and Regional Municipality of Ottawa-Carleton, 23pp.

Personal Communications (February 2002):
Mike Leduc & Isabel Ruddick, Severe Weather Co-ordinator, Ontario Weather Centre

Personal Communications (March 2001):
Rick Monkman. Deputy Chief, Fire Department Interview, City of Barrie

Personal Communications (June, July, and August 1994):
Allen, Dave. National Research Council, Institute for Research in Building and Construction
Barnes, David. Superintendent of Plant Services, Simcoe County Board of Education.
Buckle, Ray. Manager of Inspections, Building Division, City of Barrie.
Clarke, Glenn. Controller of Plant, Simcoe County Roman Catholic Separate School Board.
Collier, W. Elaine. Assistant Vice-President, Subscriber Services, Insurerers Advisory Organization Inc.
Coulter, Sandy. Pollution Control Officer, City of Barrie.
Griffiths, Maureen. Head, Community Preparedness, Emergency Planning Ontario, Ministry of the Solicitor General and Correctional Services.
Lemieux, Jim. Deputy Chief, Fire Department, City of Barrie.
Maurice, Brenda. Assistant to the Clerk, County of Simcoe Administration Centre.
McAllister, Jack. Chief, Fire Department, City of Barrie.
Neves, Natalia. Health and Safety Officer, Simcoe County Roman Catholic Separate School Board.
Quinlan, David. Senior Health and Safety Officer, Simcoe Country Board of Education.
Scott, Alec G. Area Supervisor, Barrie District Office, Central Region, Ontario Ministry of Environment and Energy.
Slomka, Larry J. Assistant Director of Public Health Inspection, Simce County District Health Unit.
Speirs-White, Gail. Intermediate Policy Planner, City of Barrie.
Trach, Brent. Environmental Officer, Regional Inspection Unit, Central Region, Ontario Ministry of Environment and Energy.
Tuckett, Nancy. Economic Development Officer, City of Barrie.

APPENDIX 1

1. **Regina "Cyclone", Saskatchewan; June 30, 1912.** Twenty-eight dead and hundreds injured. Damage of $4 million.
2. **Edmonton, Alberta; July 31, 1987.** Twenty-seven dead and 300 injured. Thousands homeless. Damage of $300 million.
3. **Windsor to Tecumseh, Ontario; June 17, 1946**. Seventeen dead and hundreds injured. Damage conservatively estimated at $1.5 million.
4. **Hopeville to Barrie, Ontario; May 31, 1985**. Twelve dead and 155 injured. More than 1000 buildings damaged. Damage of $100 million.
5. **Pine Lake, Alberta, July 14, 2000.** Eleven dead and 132 injured
6. **Lancaster Township, Ontario to St-Zotique to Valleyfield, Quebec; Aug. 16, 1888**. Nine (possibly 11) dead and 14 injured. Extensive property damage.
7. **Windsor, Ontario; Apr. 3, 1974**. Nine dead and 30 injured. Damage of $500 thousand.
8. **Sudbury, Ontario; August 20, 1970**. Six dead, 200 injured. Damage of $10 million or more.
9. **St. Rose (Montreal) Quebec; June 14, 1892**. Six dead and 26 injured.
10. **Buctouche, New Brunswick; August 6, 1879**. Five to seven dead and 10 injured. Damage of $100 thousand and 25 families homeless.
11. **Portage La Prairie, Manitoba; June 22, 1922**. Five dead and scores injured. Damage of $2 million.

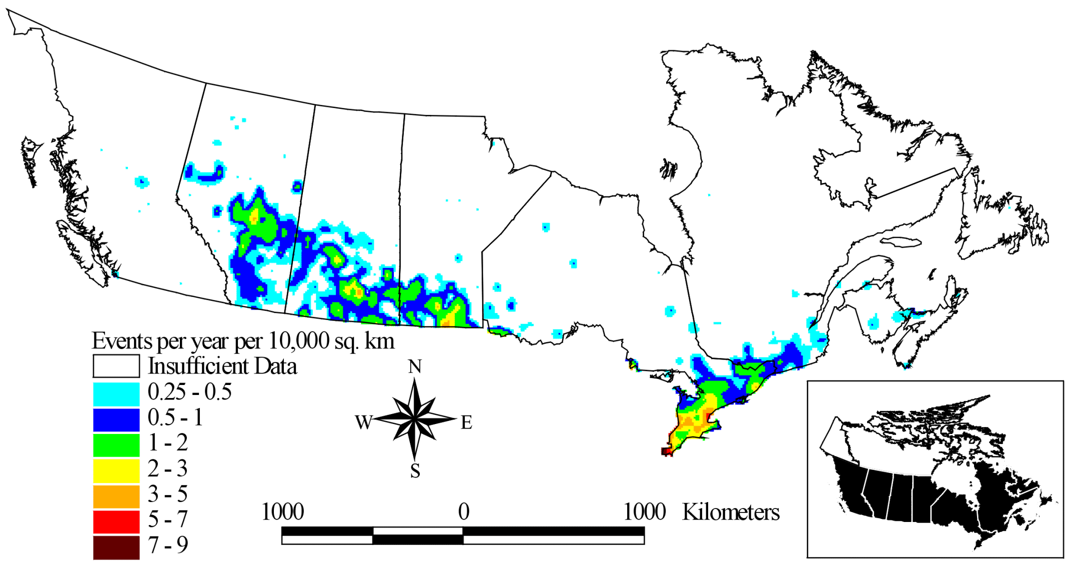

Figure 1: Frequency of observed tornadoes in Canada, from 1980 to 1997.

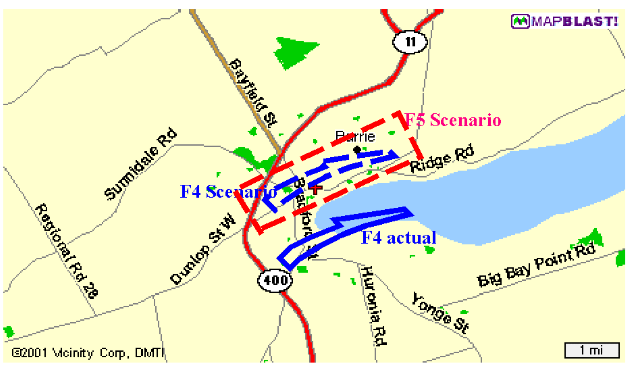

Figure 2. Comparison of the damage path of the actual F4 tornado that hit Barrie on May 31, 1985 (F4 actual), with a more destructive path (F4 scenario) and a larger event (F5 scenario)