10.0 SEVERE WEATHER

10.1 Overview

Winter storms affecting Multnomah County are generally characterized by a combination of heavy rains and high winds throughout the county, sometimes with snowfall, especially at higher elevations. Heavy rains can result in localized or widespread flooding, as well as debris slides and landslides. High winds commonly result in tree falls which primarily affect the electric power system, but which may also affect roads, buildings and vehicles. Winter storms may also result in significant ice accumulations, which primarily affect the electric power system and transportation. This chapter deals primarily with the rain, wind, snow and ice effects of winter storms. Larger scale flooding is addressed in Chapter 9.

For completeness, we also briefly address other severe weather events, including severe thunderstorms, hail, lightning strikes and tornadoes in Section 10.5. However, the frequency, severity, and impacts of such severe weather events are generally minor for Multnomah County, compared to winter storm effects.

Winter storms can affect the area directly, with damage within Multnomah County, or indirectly, with damage outside the area but affecting transportation to/from the area and/or utility services (especially electric power). Historically, Multnomah County has often been subject to both direct and indirect impacts of winter storms. The winter storms that affect Multnomah County are typically not local events affecting only small geographic areas. Rather, the winter storms are typically large cyclonic low pressure systems moving from the Pacific Ocean and that thus usually affect large areas of Oregon and/or the whole Pacific Northwest.

Historical winter storm data compiled by the Portland Office of the National Weather Service include the following major winter storm events in western Oregon:

1. January 9, 2009
2. December 14-15, 2008
3. December 1-3, 2007
4. December 14, 2006
5. February 7, 2002
6. February 6, 1996
7. December 12, 1995
8. November 13-15, 1981
9. March 25-26, 1971
10. October 2, 1967
11. March 27, 1963
12. October 12, 1962
13. November 3, 1958
14. December 21-23, 1955
15. December 4, 1951
16. November 10-11, 1951
17. April 21-22, 1931
18. January 20, 1921.

The specific severity and impacts of the major historical winter storm events listed above varied significantly with geographic location within Oregon. However, in terms of sustained wind speeds and damage levels, the 1962 Columbus Day windstorm stands out as the most severe such event for western Oregon.

The highest sustained wind speed recorded at the Portland Airport was 88 mph during the 1962 Columbus Day windstorm. The peak gust recorded during this storm was 104 mph before the wind equipment was damaged; thus the actual peak gust was likely higher than 104 mph.

10.2 Rain Hazard Data

Severe winter storms in Multnomah County often include heavy rainfall. The potential impact of heavy rainfall depends on both the total inches of rain and the intensity of rainfall (inches per hour or inches per day). In the context of potential flooding, "rainfall" also includes the rainfall equivalent from snow melt. Flash floods, which are produced by episodes of intense heavy rains (usually 6 hours or less) or dam failures, are rare in western Oregon but do represent a potential meteorological hazard.

Large drainage basins, such as that for the Columbia River typically have response times of a week or more: the total rainfall amounts (plus snow melt) over periods of a week or more are what determines the peak level of flooding along large rivers. Small, local drainage basins have very short response times and levels of peak flooding may be governed by rainfall totals over a period of an hour to a few hours.

Multnomah County annual precipitation data are summarized in Table 10.1 below. These data are for the Portland airport site.

Table 10.1
Multnomah County Rainfall Data

Location	Average Annual Precipitation (inches)	Lowest Annual Precipitation (inches)	Highest Annual Precipitation (inches)	Period of Record
Portland Airport	36.84	22.48 (1985)	63.20 (1996)	1941-2010

Western Regional Climate Center website: www.wrcc.dri.edu

Average annual precipitation amounts are moderately high in Multnomah County, about 37 inches per year. As shown above, there are also substantial variations in annual rainfall from year to year. However, precipitation varies significantly within Multnomah County, with much higher precipitation at higher elevations, especially on the slopes of Mount Hood. For example, average annual precipitation at Government Camp (Clackamas County) is over 87 inches; similar values occur elsewhere at similar elevations.

The rainfall data shown in Table 10.1 give general overview of the potential for winter storm flooding in Multnomah County, but whether or not flooding occurs at specific sites depends heavily on specific local rainfall totals during individual storms and local drainage conditions. For example, 2" of rain in one area may

cause no damage at all, while 2" of rain in a nearby area may cause road washouts and flooding of buildings.

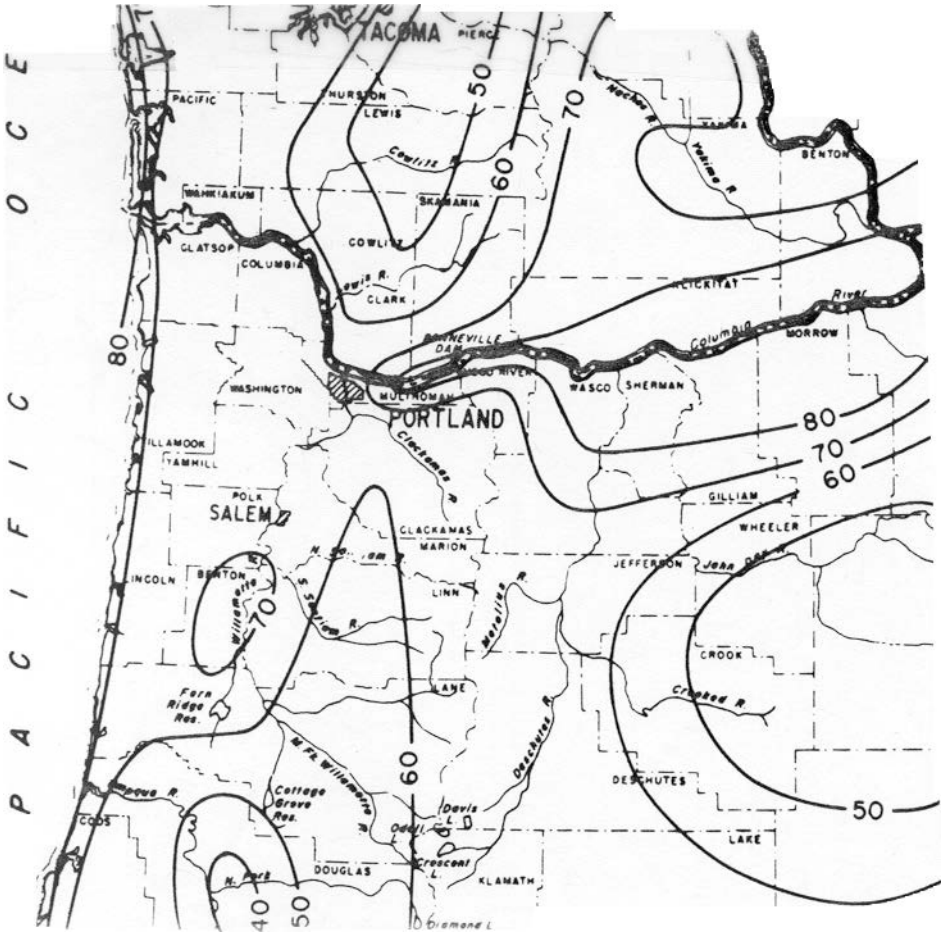
For Multnomah County, identification of specific sites subject to localized flooding during winter storms is based on historical occurrences of repetitive flooding events during past winter storm events. Most of these sites affect roads, rather than buildings. Flood data, including both overbank flooding from rivers and streams as well as localized flooding from stormwater drainage are addressed in Chapter 9.

10.3 Wind Hazard Data

Wind speeds associated with winter storms vary depending on meteorological conditions, but also vary spatially depending on local topography. For Multnomah County, high winds occur most commonly in eastern Multnomah County, along the Columbia River gorge and on Mount Hood.

The regional pattern wind hazards is shown by the contours in Figure 10.1, which show contours of wind speed (in kilometers per hour) for western Oregon (Wantz and Sinclair, Distribution of Extreme Wind Speeds in the Bonneville Power Administration Service Area, Journal of Applied Meteorology, Volume 20, 1400-1411, 1981). These data are for the standard meteorological data height of 10 meters (about 39 feet) above ground level. These data are for sustained wind speeds. Peak gusts are commonly 30% or so higher than the sustained wind speeds. These wind-speed data are fairly old, but still representative of overall wind storm conditions in Oregon and in Multnomah County.

Figure 10.1
Wind Speed Contours for 2-Year Recurrence Interval
(km/hour)

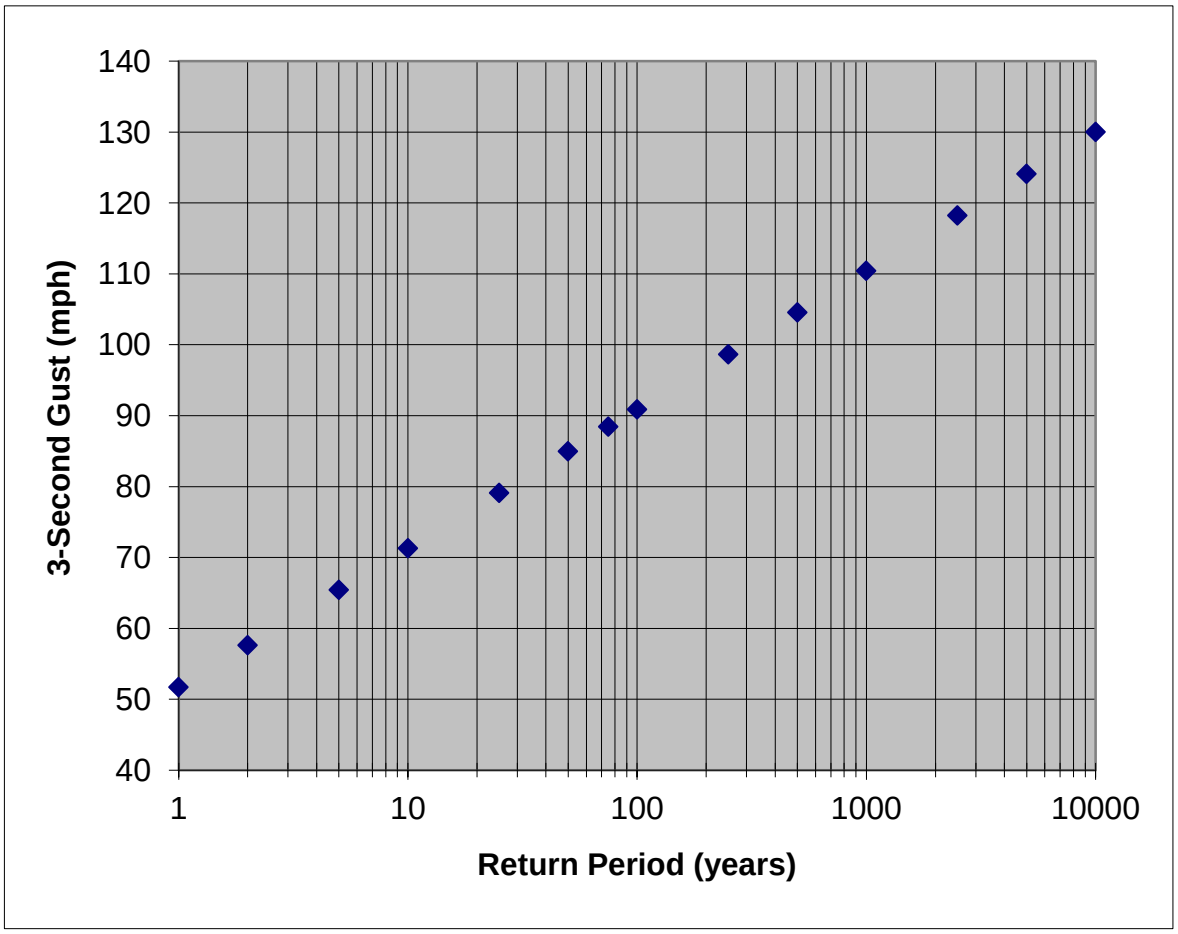


The level of wind hazard in much of Multnomah County is higher than many locations in western Oregon, other than the immediate coast, because of the unusually high winds common in the Columbia Gorge.

Design wind speeds for new construction are determined per the maps in ASCE 7-10, Minimum Design Loads for Buildings and Other Structures, as referenced in the building code. The standard wind design load is for an 85 mph 3 second gust. Higher wind design loads apply in special wind regions, but there are no such special wind regions within Multnomah County. There is a special wind hazard area in the Columbia Gorge Area, just east of Multnomah County.

The wind hazard curves for Multnomah County, based on the consensus ASCE 7-10 probability relationships for standard wind design locations is shown below in Figure 10.2

Figure 10.2
Wind Hazard Curves for Multnomah County



In Multnomah County, the 10-year and 100-year return periods are approximately 71 mph and 91 mph, respectively. These winds speeds are three-second gusts which are typically about 30% higher than sustained wind speeds. Thus, for example, a three-second gust of 91 mph corresponds to a sustained wind speed of about 70 mph. Higher elevations, such as on Mount Hood, have higher levels of wind hazards, but there is relatively little development in such areas.

For new construction, the Multnomah County relies on the applicable building code wind speed design requirements, as established by Portland and Gresham.

10.4 Snow and Ice Hazard Data

Winter storms can also involve ice and snow in Multnomah County. The most likely impact of snow and ice events on Multnomah County are road closures limiting access/egress to/from some areas, especially roads to higher elevations. Winter storms with heavy wet snow or high winds and ice storms may also result in power outages from downed transmission lines and/or poles.

Average annual snowfalls in Multnomah County are generally low as shown below in Table 10.2.

Table 10.2
Snowfall Data for Multnomah County

Location	Average Annual Snowfall (inches)	Lowest Annual Snowfall (inches)	Highest Annual Snowfall (inches)	Period of Record
Portland Airport	2.80	0.00 (many years)	34.0 (1968-1969)	1941-2010

Western Regional Climate Center website: www.wrcc.dri.edu

Average snowfall in Multnomah County, at the Portland Airport is low, only about 3 inches, with many years in which no snowfall has been recorded. However, the maximum annual snowfall was 34 inches in 1968-69. During the period of record, there have been ten years with snowfall above 10 inches.

Snowfalls vary markedly within Multnomah County, especially with altitude. Higher elevations receive much higher snowfalls than areas at lower elevations. For example, the mean annual snowfall at Government Camp (Clackamas County) is 270 inches per year. Locations in Multnomah County on the slopes of Mount Hood receive similar amounts of snow.

The most recent major snow storm event affecting Multnomah County occurred in December 2008. This storm event, which began on December 14th dumped more than a foot of snow and ice on the area. The major effects were road closures, with Interstate 84 closed through the Columbia River Gorge for two days. There were many road closures on hilly streets and localized power outages.

In addition to snow events, Multnomah County is also subject to ice storm and freezing rain events. The National Climatic Data Center (NCDC) database inexplicably shows zero significant snow, ice storm or freezing rain events for Multnomah County between 1950 and 2011, even though major such events have occurred. For example, the database shows 78 snow/ice events for Columbia County.

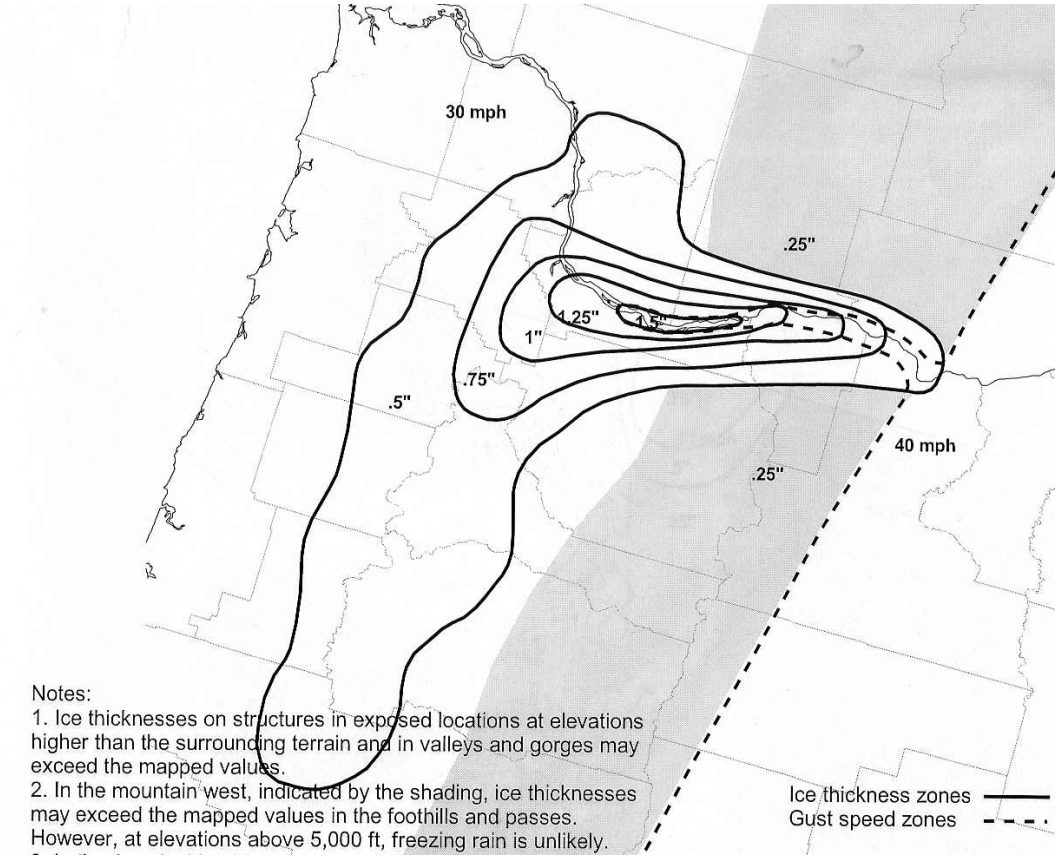
Website addresses for NCDC and the state and county storm event database are:

- www.ncdc.noaa.gov and
- http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms, respectively.

Nevertheless, the level of hazard for snow/ice storms is relatively high for Multnomah County, especially for ice storms. As illustrated by the ice thickness contour map below, Figure 10.3, the risk of ice storms in western Oregon is highest along the Columbia River, especially along the Columbia Gorge portion. This area has the highest level of ice storm hazard in the entire United States.

Probabilistic ice storm data showing ice thicknesses with return periods from 50 years to 400 years are given in a recent American Lifelines Alliance report: Extreme Ice Thicknesses from Freezing Rain (2004). The 50-year return period ice thickness map (Figure 10.3 below) shows about 1.5" of ice for Multnomah County. Typical 100-year and 400-year ice thicknesses for Multnomah County are about 1.75" and about 2.5", respectively.

Figure 10.3
50-Year Ice Thickness from Freezing Rain



For Multnomah County, ice thicknesses in 50-year or more severe events are high enough (about 1.5") to cause widespread substantial damage, especially to trees and utility lines. Using typical ice thickness scaling relationships, ice thicknesses for 25-year and 10-year ice storms in Multnomah County would be about 1.2" and about 0.75" inches, respectively. Such events are also severe enough to result in significant damage to trees and utility lines.

Ice storms along the Columbia Gorge may also affect Multnomah County indirectly, potentially resulting in loss of electric power, because much of Multnomah County's power is transmitted from Bonneville Power Authority sites along the Columbia River. Closures of Interstate 84 outside of Multnomah County may also affect transportation to/from the county

The most significant recent ice storm event occurred between December 26th and 29th in 1996, with up to 4 or 5 inches of ice in the Columbia Gorge. Interstate 84 was closed for 4 days. There were hundreds of downed trees and power lines, with widespread power outages in the greater Portland area, including Multnomah County.

Ice storms have affected Multnomah County throughout its history. Figure 10.3 shows downtown Troutdale after the ice storm of November 18, 1921.

Figure 10.3
Downtown Troutdale – Ice Storm of November 18, 1921

10.5 Other Severe Weather Events

The National Oceanic and Atmospheric Administration (NOAA), which includes the National Weather Service, also includes the National Climatic Data Center (NCDC). The NOAA and NCDC websites have a vast amount of historical information on severe weather events throughout the United States. These databases can also be searched by State and County to obtain more localized information. Website addresses are: www.noaa.gov and www.ncdc.noaa.gov, for NOAA and NCDC, respectively. The state and county storm event database can be found at: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms. Unless otherwise referenced, all of the storm event data below for Multnomah County are from the state and county storm event database referenced above.

Severe Thunderstorms and Hail Events

The NCDC database lists 10 thunderstorm events in Multnomah County from 1950 to 2010. Only two of these events included a damage amount which totaled only $7,000.

Thus, the thunderstorm events in Multnomah County are typically too minor to be recorded as significant storm events. Nevertheless, thunderstorm events in Multnomah County may occasionally cause locally high winds with tree falls which may affect roads, utility lines, and buildings.

The NCDC database lists seven hail events for Multnomah County from 1950 to 2011. Two of these events included damage amounts which were total only $10,000. However, all of the listed events occurred from 1991 to 2010; thus, the database is likely incomplete for earlier years. Hail damage is generally very localized to areas affected by strong thunderstorm cells which produce large diameter hail. Six of the seven listed hail events had hail diameters of 0.5” to 1.5” which is large enough to cause some damage.

Hail events may occur in Multnomah County, generally during summer months. However, hail damage is generally minor and few practical mitigation alternatives are applicable to hail, other than taking shelter and moving vehicles to garages when possible.

Lightning

Nationwide, lightning is a significant weather related killer. NOAA data show that lightning causes about 90 deaths per year, with at least 230 injuries (NOAA Technical Memorandum NWS SR-193, 1997). Lightning injuries appear to be systematically underreported and thus the actual injury total is most likely significantly higher. For Oregon, however, casualties from lightning are very low, with totals of only 7 deaths and 19 injuries reported over a 35 year period (NOAA).

The NCDC data base lists seven severe lightning events for Multnomah County. Three of these events included reported damages:

- Gresham June 6, 1995 - $115,000 in damage.
- Gresham June 19, 2005 - $50,000 in damage.
- Fairview July 3, 2008 - $2,000 in damage.

Thus, the level of risk posed by lightning strikes in Multnomah County, while not zero, is low. Public education about safe practices during electrical storms is the only available mitigation measure to reduce casualties from lightning. Lightning strike damage to buildings or infrastructure is generally relatively minor and few practical mitigation alternatives are applicable to lightning, other than installing lightning arrestors on critical facilities where lightning strikes might damage critical electronic equipment, such as IT or communications equipment.

Tornadoes

Tornadoes also do occur occasionally in Oregon. However, Oregon is not among the 39 states with any reported tornado deaths since 1950. NOAA's National Climatic Data Center's website lists a total of 101 recorded tornadoes in Oregon. These events are characterized on the Fujita Scale which ranges from F0 to F5, with F5 being the most severe. Of these, nearly all are small F0 or F1 tornadoes, with only three F2 and one F3 tornadoes. Cumulatively, these records indicate only 5 injuries and about $31 million in damages. The majority of the reported damages occurred in the 1968 Wallowa tornado (F3, $25 million), the 1975 Tillamook tornado (F2, $2.5 million) and the 2010 Aumsville tornado (F2, $1.2 million).

The most recent significant tornado in Oregon at Aumsville in 2010 was characterized as an EF2 on the Enhanced Fujita Scale, which has replaced the Fujita Scale with revisions to the estimated wind speeds for each class of tornado. This tornado had a total path length of about 5 miles, although the tornado was apparently off the ground for about the middle third of this path length. The average width was about 150 yards. Damage was reported to about 50 structures, mostly in the downtown area with more than 30 large trees uprooted or snapped in two.

An important caveat on historical reports of tornadoes, especially older events and those for small tornadoes, is that some events previously reported as tornadoes are now more accurately understood as downbursts or microbursts associated with thunderstorms and not actually tornadoes.

Climate and weather conditions in Oregon overall, and specifically in Multnomah County, make the occurrence of major tornadoes unlikely, but not impossible as demonstrated by the 1972 tornado event. The most practical mitigation actions

for tornadoes are public warnings and taking shelter to minimize the potential for deaths and injuries.

A compilation of historical tornadoes in Oregon by the National Weather Service includes four tornadoes and one cyclonic storm in Multnomah County. These tornadoes are summarized in Table 10.3 below.

Table 10.3
Historical Tornadoes in Multnomah County

Date	Location	Notes
November 12, 1991	near Troutdale	Small tornado damaged fencing with minor damage to one building
April 9, 1991	near Gresham	Very small weak tornado touched down with very slight damage.
August 16, 1978	near Gresham	Small tornado touched ground briefly with some damage to buildings and crops.
April 5, 1972	Portland area	F3 tornado, the most violent tornado in Oregon's recorded history. About $250K damages in Oregon. About $5,000,000 damages, 6 deaths, and 300 injuries in Vancouver WA.
March 19, 1904	East Portland	"cyclonic storm" damaged the Lewis and Clark Fairgrounds, several shacks and a large warehouse.

Source: http://www.wrh.noaa.gov/pqr/paststorms/tornado.php

Although relatively rare in Oregon, the 2010 Aumsville tornado and the 1972 tornado which caused relatively minor damage in Multnomah County but approximately $6 million in damage in Vancouver Washington demonstrate that the risk from tornadoes is not zero.

10.6 Winter Storm Risk Assessments

Winter storm flooding, snow, ice and wind events may affect both infrastructure and buildings. Localized flooding from winter storms very commonly affects the transportation system, especially roads. Severe winter storms may result in numerous road closures due either to washouts or due to depth of water on road surfaces. Such localized flooding also affects buildings located in the flooded areas.

Wind impacts from winter storms arise primarily from tree falls, which may affect vehicles and buildings, to some extent, but whose primary impact is often on utility lines, especially electric power lines. Widespread wind damages may result in widespread downing of trees or tree limbs with resulting widespread downage of utility lines. Such tree-fall induced power outages affect primarily the local electric distribution system, because transmission system cables are generally less prone to tree fall damage because of design and better tree-trimming maintenance. In severe wind storms, direct wind damage or wind driven debris impacts on

buildings cause building damages, especially for more vulnerable types of construction such as mobile homes.

Snow and/or ice events typically disrupt transportation, with more severe events also damaging above-ground utilities. Utility outages may be widespread and of long duration in major events, as occurred in the December 1996 ice storm event.

The location and severity of winter storm impacts depend very strongly on specific local conditions. Therefore, it is difficult to make regional risk assessment or loss estimates from mapping the hazards and overlaying the inventory: such a risk assessment would require very detailed data which are generally not available.

An alternative approach is to document the severity and locations of winter storm flood wind, snow and ice damage from the pattern of historical events. Fortunately, however, Multnomah County has suffered only relatively minor impacts from winter storms in recent years.

The probable impacts of winter storms on Multnomah County are summarized qualitatively below in Table 10.4.

Table 10.4
Probable Impacts of Winter Storms on Multnomah County[1]

Inventory	Probable Impacts
Portion of Multnomah County Affected	Severe winter storms may affect all of Multnomah County, although the severity if impacts typically varies significantly with location within the county.
Buildings	Isolated damage from tree falls, wind, heavy snow loads, landslides and localized flooding.
Streets and Roads Within Multnomah County	Road closures due to snow or ice, tree falls, landslides or flooding.
Highways to/from Multnomah County	Road closures may also affect major highways to/from Multnomah County, especially Interstate 84 through the Columbia Gorge.
Airports	Severe weather may result in temporary closures of PDX and smaller airports in Multnomah County.
Electric Power	Loss of electric power may be localized or widespread due to effects of wind, snow, ice and tree falls on local distribution lines or very widespread if transmission lines fail.
Other Utilities	Generally minor impacts on other utilities from winter storms, except for possible effects of loss of electric power; however, telephone and other telecommunications systems with above ground lines may also experience outages.
Casualties	Potential for casualties (deaths and injuries) from tree falls or contact with downed power lines or from traffic accidents.

[1] These winter storm impacts include localized flooding, the effects of wind, snow, and ice and landslides or debris flows.

For more quantitative risk assessment of localized flooding, snow, ice, wind and landslide damages arising from winter storms, the best approach is to systematically gather data on sites of repetitive damages. By documenting and mapping such sites using GIS, the sites of repetitive damage events, along with documentation of the type and cost of damages and losses, the most seriously impacted sites can be clearly identified. Then, such identified repetitive loss sites with significant damages would be likely candidates for future mitigation actions.

10.7 Mitigation of Winter Storm Impacts

Potential mitigation projects for winter storms may address any of the aspects of such storms, including floods, winds, and snow/ice.

For winter storm flooding, the mitigation measures discussed in Chapter 9 (Floods) for local storm water drainage flooding are the mitigation measures for the localized flood aspects of winter storms. Common mitigation projects include: upgrading storm water drainage systems, construction of detention basins, and structure-specific mitigation measures (acquisition, elevation, flood-proofing) for flood-prone buildings.

For roads subject to frequent winter storm flooding, possible mitigation actions include elevation of the road surface and improved local drainage. For utilities subject to frequent winter storm flooding, possible mitigation actions include improved local drainage, elevation or relocation of the vulnerable utility elements to non-flood prone areas nearby.

For wind, snow and ice effects of winter storms, the most common and most effective mitigation action is to increase tree trimming effects, because a high percentage of wind damage to utilities, buildings, vehicles, and people arises from tree falls. However, economic, political and esthetic realities place limits on tree trimming as a mitigation action.

Effective tree trimming mitigation programs often focus on limited areas where tree falls have a high potential to result in major damages and economic losses. High priority areas include examples such as the following:

1) Transmission lines providing electric power to the area,
2) Major trunk lines providing the backbone of the electric power distribution system within the area
3) Distribution lines for electric power to critical facilities in the area,
4) Specific circumstances where falling of large trees poses an obvious threat to damage buildings and/or people or close major transportation arteries.

Mitigation measures for snow and ice are limited, although tree trimming efforts, discussed above, also reduce the impact of snow and ice on trees, roads, and utility lines. For the most part, dealing with snow and ice storms are primarily issues of emergency planning, along with response and recovery actions.

Similarly, few mitigation measures appear practical for Multnomah County for other types of severe weather, including severe thunderstorms, hail, lightning, and tornadoes. For such weather events, public education about safe practices and emergency planning, response and recovery appear to be the most useful pragmatic actions.

The following table contains winter storm mitigation action items from the master Action Item table in Chapter 4.

Table 10.5
Severe Weather Mitigation Action Items

Hazard	Action Item	Coordinating Organizations	Timeline	Plan Goals Addressed				
				Life Safety	Protect Property and Infrastructure	Emergency Management Capabilities	Public Awareness and Education	Environmental Stewardship
Severe Weather Mitigation Action Items								
Short-Term #1	Ensure that all critical facilities in Multnomah County have backup power and/or coordination of operations plans in place to withstand loss of grid power.	Facilities	5 Years	X	X	X		
Short-Term #2	Conduct tree trimming activities on county roads where County Transportation has jurisdictional responsibility.	Transportation	Ongoing	X	X			X
Short-Term #3	Develop a strategy that encourages property owners to trim trees that could impact life safety and damage property.	Multnomah County Emergency Management	1-2 Years	X	X		X	X
Short-Term #4	Work with stakeholder groups to identify common criteria for defining extreme heat and cold events for the sake of determining proper mitigation, protection or preparedness strategies.	Multnomah County Emergency Management	1 Year	X		X	X	X
Long-Term #1	Encourage utilities to upgrade lines and poles to improve wind/ice loading, undergrounding critical lines, and adding interconnect switches to allow alternative feed paths and disconnect switches to minimize outage areas.	Multnomah County Emergency Management	5 Years	X	X	X	X	