2.10 COASTAL EROSION

Coastal erosion is defined as the gradual wearing away of the earth's surface by the natural forces of wind and water. The constant action of wind, waves, and ice flow has affected the coastline of Lake Erie[1]. Primarily, it is the waves and gravity that cause erosion. Waves undercut the land along the shore and gravity causes the land to slip into the water. As material from the bluff or bank slides into the lake, it too is eroded by waves. As this process continues, the shore moves farther landward[2]. Many natural factors affect erosion of the lakeshore, including shore and nearshore geology, shore relief, nearshore bathymetry, beaches, shoreline orientation, lake level fluctuations (long-term, annual, and storm surges), and climate changes (storm frequency, temperature, and precipitation)[3].

Lake Erie owes its fundamental existence to the presence of a basin or lowland that originated long before the Pleistocene Ice Age began 2 million years ago. This lowland was known as the valley of an east-flowing river, known as the Erigan River. This geology in the basin included Silurian and Devonian carbonates (limestone and dolomite) on the west and by Devonian shales on the east. Glacial ice was able to erode the less resistant shales (than the more resistant carbonate rocks) to a greater extent in the central basin and eastern basins. The first of the 4 major glacial advances during the Pleistocene obliterated this drainage system and deepened and enlarged the basin. Succeeding glaciations further deepened and enlarged it. Lake Erie, the southernmost of the Great Lakes, is also the shallowest because the ice was relatively thin (therefore lacking significant erosive power) when it reached so far south[4]. During the advancement of the glaciers, they eroded rock and soil and carried them with the flowing ice to the glacier edge where they were deposited as till released from melting ice. Laminated silt and clay were also deposited in proglacial lakes that formed along the margin of the glacier. These geologic materials are exposed in Lake Erie's bluffs and banks[5]. Upon final retreat of the glacier moving out of Ohio, the water started to discharge via the Niagara River. Glacial rebound raised the Niagara outlet and increased the water level in the Lake Erie basin. Due to a rapid glacial rebound in the upper Great Lakes, these lakes began to drain through the Lake Erie Basin [6]. There has been a continued slow rise following the rapid rise that has brought Lake Erie to its current mean level of 571 feet above sea level.

The geologic settings vary throughout the length of Ohio's coast. From the Ohio-Pennsylvania border to Huron, Ohio, moderate to high relief shore consists of bluffs and slopes composed of glaciolacustrine sands, silts, clay, till, and/or shale. From Huron around Sandusky Bay to Marblehead peninsula, the shore is

[1] Lake Erie Coastal Erosion Areas, included with 1998 CEA Designation packet
[2] Questions and Answers Regarding Ohio's Coastal Erosion Areas
[3] Updating Lake Erie Coastal Erosion Area Maps, Donald E. Guy, Jr., July 2005
[4] The History of Lake Erie by Michael C. Hansen
[5] Erosion of Coastal Bluffs in the Great Lakes, Mickelson, Edil, and Guy, USGS Professional Paper 1693
[6] The History of Lake Erie by Michael C. Hansen

a low-relief plain composed of glaciolacustrine sediments and till, with shale exposed west of Huron and limestone exposed around Marblehead peninsula. At Sandusky Bay, two barrier beach complexes extend across the bay mouth. Around Marblehead Peninsula and Catawba Island, low to moderate banks/bluffs are composed of rock and till. West of Catawba Island, the landscape consists of low-relief lake plain and coastal wetlands (remnants of the Black Swamp). Nearshore slopes are generally gentle and are composed of the same materials in bluff or bank. Beaches are typically narrow (<50 feet per 15 meters wide) to non-existent along much of the shore. Man-made features have affected the longshore transport of sand trapping sand on the updrift side at harbor jetties, power plant intakes, and long groins. Shore parallel structures have altered sand transport as well[7].

Climate affects overall physical setting in the nearshore, beach, and shore zones. Long-term and annual fluctuations in lake level are due to changes in the volume of the lake resulting from changes in precipitation in the Great Lakes Basin. Short-term fluctuations are due to wind-driven storm surges, changes in barometric pressure, or inertial surges of water (seiches) that occur after lake level has been set up by either of the two previous agents. The greatest storm surges occur when the wind blows parallel to the long axis of the lake. Under extreme conditions, lake level at the confined ends of the lake may rise or fall more than six feet from pre-storm levels. Passage of storm systems through the Great Lakes can cause lake levels at the ends of the lake to fluctuate 10 to 11 feet over a period of several days. The most important storm surges along the western part of the Central Basin and all of the Western Basin are those generated by northeast winds because these storm surges are accompanied by large storm waves[8].

The size of wind-generated waves depends upon wind speed and duration, open-water fetch distance, and water depth. The largest waves affecting the Ohio lakeshore are those generated by storm winds from the west through the northeast. Wave energy is highest from late fall through spring; however, lake level is at its lowest and shorefast ice typically forms a barrier between the waves and erodible shore material. Most wave erosion occurs during storms in early spring when the greatest amount of wave energy is expended on the shore. The largest waves to strike the shore are generated by onshore storms winds from the west to the northeast[9]. Wave erosion causes undercutting of the bluff or bank, mass wasting including block falls, rotational slumps, and debris flows, and lakebed downcutting of cohesive materials. Bedrock is not as easily eroded as the cohesive glacial sediments.

[7] Geologic Setting and Processes Along Lake Erie From Fairport Harbor to Marblehead, Ohio, D. Guy and L. Moore, 2006

[8] Geologic Setting and Processes Along Lake Erie From Fairport Harbor to Marblehead, Ohio, D. Guy and L. Moore, 2006

[9] Geologic Setting and Processes Along Lake Erie From Fairport Harbor to Marblehead, Ohio, D. Guy and L. Moore, 2006

Although erosion of the bluff is necessary to sustain beaches, excessive erosion of the Lake Erie shoreline can be considered a hazard exposure.

RISK ASSESSMENT

Location

Lake Erie comprises 262 miles of the northern coast of Ohio bordering Lucas, Ottawa, Sandusky (Sandusky Bay), Lorain, Cuyahoga, Lake, and Ashtabula Counties. Lake Erie, the 12th largest (area) lake in the world, it is about 210 miles long, 57 miles wide, and has a shoreline length of 871 miles (including the islands). With the exclusion of government-owned park and reserve areas, the coast is highly prized for commercial and residential development. In many cases, human activity has disrupted the natural function of beach formation and aquatic habitats. According to the Ohio Geological Survey, 95 percent of Ohio's Lake Erie shoreline is eroding.

LHMP Data

All of the LHMPs for the counties that border Lake Erie (Ashtabula, Cuyahoga, Erie, Lake, Lorain, Lucas, Ottawa, and Sandusky), except Sandusky County and Lucas County, indicate that coastal erosion is a recognized hazard and ranked them either fourth or fifth for their county. Almost all of the plans reference the same data (Figure 2.10.a) provided by the Ohio Geological Survey. Erie County's LHMP indicated that they had completed a structural inventory in the late 1990's; but those data were not available to them at the time of writing their plan.

According to the Ottawa County LHMP there are 367 parcels, 130 of which have residential structures, located within the CEA. Using the residential average values previously determined for two townships, the estimated loss that would result would be approximately $886,048 in Carroll Township and $787,941 in Put-in-Bay Township if the structures were destroyed.

Only the Lake County and the Cuyahoga County LHMP address the issue of mitigation. Lake County conducted a HAZUS review of their coastal areas and provided the HAZUS data along with their plan to Ohio EMA. Cuyahoga County spent a considerable amount of time looking at mitigation efforts to coastal erosion. They mention in their LHMP the "*Ohio Coastal Management Program"* through Ohio Department of Natural Resources as a means of mitigation. The Ohio General Assembly passed the Ohio Coastal Management Law in 1988. This law authorized ODNR to act as lead agency in developing and implementing a comprehensive Coastal Management Program (OCMP) that is to integrate the management of Ohio's Lake Erie coastal region in order to preserve, protect, develop, restore and enhance its resources. OCMP attempts to establish a balance between resource protection and development, and to provide guidance to coastal property owners as well as government agencies and commercial interests.

Past Occurrences

Unlike many of the other hazards affecting Ohio, Lake Erie is consistently undergoing coastal erosion. Although particular storms or development creates periods of increased occurrence, the shore is eroding slowly every day. To measure erosion, the net landward movement of the shore over a specific time is calculated. The position of characteristic shore features such as bluff lines can be determined from maps and aerial photographs. By analyzing the position of

Table 2.10.a

Ohio Lake Erie Erosion Statistics by County

Long and Short-term Recession Data by County
Long-term: 1877 to 1973 Short-term: 1973 to 1990

County	Long-term Distance (ft.)	Long-term Rate (ft/yr)	Short-term Distance (ft.)	Short-term Rate (ft./yr.)
Ashtabula	82	0.9	28	1.6
Lake	160	1.7	32	1.9
Cuyahoga	60	0.6	8	0.4
Lorain	80	0.8	12	0.7
Erie (lake)	103	1.6	42	2.5
Ottawa (lake)	208	2.0	27	1.6
Lucas	520	5.4	46	2.7
Erie (bay)	241	2.8	32	1.9
Ottawa (bay)	61	2.0	21	1.2

Source: Ohio Division of Geological Survey http://dnr/state.oh.us/geosurvey/

these features

(recession lines) through time, the amount of recession can be determined and rates of recession can be calculated. Long-term and short-term recession data have been developed for each county (see table 2.10.a).

During 1929-30, the mid-1940s, 1952, the fall of 1972, the spring of 1973, and 1985, storms and high lake levels caused property damage along the low-lying areas, such as low glacial till bluffs, low glaciolacustrine banks, and barrier beaches and eroded high glacial till or glaciolacustrine bluffs inducing mass wasting in Erie, Lake, Cuyahoga, and Ashtabula counties. The short-term and long-term rates indicate that the low-lying areas have been extremely affected.

Probability of Future Events

With shore structures increasing along the coastline, the shoreline becomes increasingly modified. Reports and studies suggest that wave erosion and mass wasting caused by Lake Erie will continue to erode the Ohio shore for the foreseeable future. Damage to the built environment is inevitable without intervention and will warrant the full understanding of coastal processes within each stretch to rehabilitate the shoreline.

VULNERABILITY ANALYSIS & LOSS ESTIMATION

Methodology

The Ohio Geological Survey is in the process of reassessing Ohio's vulnerability to coastal erosion. According to the Ohio Revised Code, costal erosion area designation must be conducted every 10 years and parcels at risk must be listed as Coastal Erosion Areas. The initial evaluation utilized 1973 and 1990 data and the results were published in 1998. Researchers utilize aerial photography to delineate exposure based on observed shoreline characteristics. The new evaluation will utilize aerial photographs from 1990 and 2004.

Once the preliminary designations of the coastal erosion areas are determined with extensive quality checking and ground proofing support, GIS layers are created and preliminary maps generated. Impacted property owners are contacted by mail of their inclusion and public meetings are held to provide an opportunity to see the risk assessment. Property owners may dispute the determination, if they believe that the shore features were not picked correctly and with proof that erosion did not occur. After all comments have been addressed, final maps are generated and final notifications are sent by mail to the coastal erosion area property owners.

Under normal circumstances the revised data from the coastal erosion areas would be aggregated by county and presented in tabular format. However, several factors must be considered before providing loss estimates. The factors of the decennial update that is in progress and preliminary results indicate significant changes in coastal erosion areas are expected from 1998 to 2008 must be weighed.

Results

After extensive conversation with state partners and extensive consideration, the decision was made not to report losses on outdated data. Based on reports from the Ohio Geological Survey, data from the current update will be available in final format in late 2008 or early 2009. It is anticipated that the number of Coastal erosion area designations will decline from the 1998 designation. This is partially due to a marked increase in shoreline protection measures installed over the past ten years.

STATE-OWNED / CRITICAL FACILITIES VULNERABILITY ANALYSIS & LOSS ESTIMATION

Coastal erosion has limited potential to affect all state-owned structures and critical facilities in the state and is confined mainly to Ohio Department of Natural Resources State Parks.

2.11 DROUGHT

Drought is a normal, recurrent feature of climate that originates from a deficiency of precipitation over an extended period of time, resulting in a water shortage for some activity, group, or environmental sector. Within the State of Ohio, drought is equally as possible to occur in one section of the state as it is in another. The effects of drought within the state vary though, based on land use (farming and cattle production as opposed to urban areas), economy (dependence on drought-impacted business (farming), geology (presence of an aquifer or ground structure that limits well production), and water source (public water supply, private well, cistern).

There are four primary types of drought: meteorological, hydrological, agricultural and socioeconomic. The State of Ohio is most often affected by agricultural and hydrological types of drought, and is often affected by both simultaneously. Below, these two types of drought are described in more detail.

Agricultural Droughts. Agricultural drought links characteristics of hydrological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and reduced ground water or reservoir levels. The amount of water available for agricultural use demand depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil. A good definition of agricultural drought accounts for the variable susceptibility of crops during different stages of crop development, from emergence to maturity. Deficient topsoil moisture at planting may hinder germination, leading to low plant populations per acre and a reduction of final yield.

Hydrological Drought. Hydrological drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply – stream flow, reservoir and lake levels and ground water. The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Although all droughts originate with a deficiency of precipitation, hydrologists are more concerned with how this deficiency plays out through the hydrologic system.

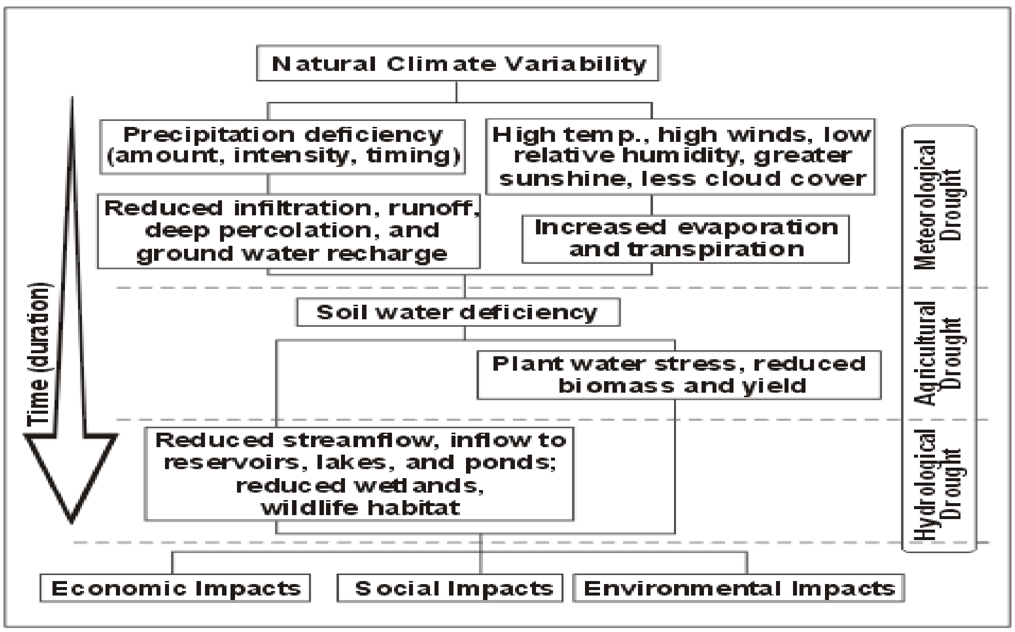
Hydrological droughts are usually out of phase with, or lag the occurrence of, meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as soil moisture, stream flow, and ground water and reservoir levels. As a result, these impacts are out of phase with impacts in other economic sectors. For example, a deficiency in reservoir levels may not affect hydroelectric power production or recreational uses for many months.

Water in hydrologic storage systems (e.g., reservoirs, rivers) is often used for multiple and competing purposes (e.g., flood control, irrigation, recreation, navigation, hydropower, wildlife habitat), further complicating the sequence and quantification of impacts. Competition for water in these storage systems escalates during drought and conflicts between water users increase significantly.

Although climate is a primary contributor to hydrological drought, there are other factors such as changes in land use, deforestation, land degradation, and the construction of dams which can all affect the hydrological characteristics of a basin. Because regions are interconnected by hydrologic systems, the impact of meteorological drought may extend well beyond the borders of the precipitation-deficient area.

The flow chart, below, illustrates the progression of drought, and the relationship between meteorological, agricultural, and hydrological drought. Economic, social and environmental impacts are shown at the bottom of the chart, independent of the time scale, indicating that such impacts can occur at any stage during a drought.

Figure 2.11.a
The Drought Cycle



Source: National Weather Service – Public Fact Sheet, August 2006
http://www.nws.noaa.gov/om/brochures/climate/Drought.pdf

National Drought Mitigation Center, http://www.drought.unl.edu/whatis/concept.htm

Measuring Drought

The Palmer Drought Severity Index (PDSI) is a soil moisture algorithm. The PDSI was d*eveloped by* W.C. Palmer in 1965. Many U.S. government agencies and states rely on the PDSI to trigger drought relief programs and responses. Most of the agency-based actions within the Ohio Emergency Operation Plan's Drought Incident Annex are triggered by the PDSI.

Figure 2.11.b
Palmer Drought Severity Index Classifications

4.0 or greater	Extremely Wet
3.0 to 3.99	Very Wet
2.0 to 2.99	Moderately Wet
1.0 to 1.99	Slightly Wet
0.5 to 0.99	Incipient Wet Spell
0.49 to -0.49	Near Normal
-0.5 to -0.99	Incipient Dry Spell
-1.0 to -1.99	Mild Drought
-2.0 to -2.99	Moderate Drought
-3.0 to -3.99	Severe Drought
-4.0 or less	Extreme Drought

Source: Palmer Drought Severity Index
http://www.math.montana.edu/~nmp/materials/ess/mountain_environments/intermediate/ystone/palmer_more.html

The PDSI is based on the supply-and-demand concept of the water balance equation, taking into account more than just the precipitation deficit at specific locations. The objective of the PDSI is to provide standardized measurements of moisture conditions, so that comparisons using the index can be made between locations and between time periods (usually months). The PDSI is calculated based on precipitation and temperature data, as well as the local Available Water Content of the soil. The Palmer Index is designed so that a -4.0 in South Carolina has the same meaning in terms of the moisture departure from a climatological normal as a -4.0 does in Ohio.

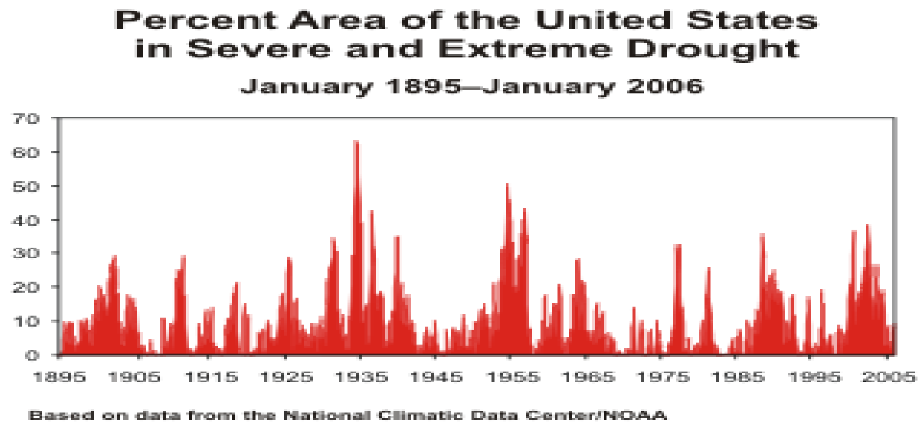
The Palmer Index is typically calculated on a monthly basis, and a long-term archive of the monthly PDSI values for every climate division in the United States exists with the National Climatic Data Center from 1895 through the present. Weekly Palmer Index values are calculated for climate divisions (the State of Ohio has ten climate divisions) during every growing season.

RISK ASSESSMENT

Location

The National Drought Mitigation Center (NDMC) has calculated values showing the spatial extent of drought based on historical Palmer Drought Severity Index (PDSI) data. The annual average of 18.1% was calculated by selecting the month of each year from 1895 to 1995 with the greatest spatial extent of severe or extreme drought and averaging the values.

Using PDSI data, the NDMC created data indicating the percent of time each climate division in the United States was in severe or extreme drought, from 1896–1994. The data show the spatial extent of drought for various time periods. The worst recent drought event occurred in July 1988, with 36% of the country in severe or extreme drought. The worst drought event ever recorded occurred in July 1934, with 65% of the United States experiencing severe to extreme drought.



Source: National Climatic Data Center, Understanding Your Risk and Impacts – A Comparison of Droughts, Floods, and Hurricanes in the United States. *http://www.drought.unl.edu/risk/us/compare.html*.

Figure 2.11.c

Past Occurrences

The table below lists the number of years that the United States has had severe or extreme drought in the 100 years from 1896 to 1995, based on the Palmer Drought Severity Index (PDSI). The data is divided and analyzed based on NOAA river basins. The chart shows that some part of the United States has experienced a severe or extreme drought in each year from 1896 to 1995, and that in 72 years, droughts covered more than 10% of the country.

Table 2.11.a
Number of Years with Severe or Extreme Drought between 1896 to 1995

% area of basin/region	>0%	>10%	>25%	>33%	>50%	>66%	>75%	>90%	100%
United States	100	72	27	13	1	0	0	0	0
Upper Mississippi	77	55	43	30	19	12	9	3	1
Mid-Atlantic	69	49	32	24	12	5	4	0	0
South Atlantic/Gulf	79	47	25	15	9	3	3	0	0
Ohio	67	51	34	28	16	12	9	4	3
Missouri	90	70	43	33	17	10	4	3	0
Pacific Northwest	86	61	42	33	23	14	9	1	0
California	53	45	40	30	14	9	5	3	3
Great Basin	71	65	43	37	19	6	3	1	1
Lower Colorado	56	54	35	28	16	11	10	4	3
Upper Colorado	50	50	42	34	27	25	16	9	8
Rio Grande	58	47	32	24	15	8	5	2	2
Texas Gulf Coast	49	48	38	26	22	13	10	9	7
Arkansas–White–Red	65	48	27	23	14	7	4	0	0

Lower Mississippi	56	38	19	15	4	1	0	0	0
Souris–Red–Rainy	66	57	38	29	19	10	8	5	2
Great Lakes	73	58	32	23	9	3	2	2	0
Tennessee	31	31	27	24	21	16	13	5	5
New England	56	44	27	13	8	5	4	0	0

Source: National Climatic Data Center, Understanding Your Risk and Impacts – A Comparison of Droughts, Floods, and Hurricanes in the United States. http://www.drought.unl.edu/risk/us/compare.html.

Probability of Future Events

The probability of future occurrences of drought in Ohio is difficult to predict; however, there are two factors that may influence future drought conditions: ENSO, and climate change.

El Nino and La Nina Southern Oscillation

A great deal of research has been conducted in recent years on the role of interacting systems, or teleconnections, in explaining regional and even global patterns of climatic variability. These patterns tend to recur periodically with enough frequency and with similar characteristics over a sufficient length of time that they offer opportunities to improve our ability for long-range climate prediction, particularly in the tropics.

Every 2 – 7 years off the western coast of South America, ocean currents and winds shift, bringing warm water westward, displacing the nutrient-rich cold water that normally wells up from deep in the ocean. The invasion of warm water disrupts both the marine food chain and the economies of coastal communities that are based on fishing and related industries. Because the phenomenon peaks around the Christmas season, the fishermen who first observed it named it El Niño (“the Christ Child”). In recent decades, scientists have recognized that El Niño is linked with other shifts in global weather patterns. The intensity and duration of an ENSO event is varied and hard to predict. Typically, it lasts anywhere from 14-to-22 months, but it can be much longer or shorter. El Niño often begins early in the year and peaks between the following November.

During an El Niño–Southern Oscillation (ENSO) event, the Southern Oscillation is reversed. Generally, when pressure is high over the Pacific Ocean, it tends to be low in the eastern Indian Ocean, and vice versa. It is measured by gauging sea-level pressure in the east (at Tahiti) and west (at Darwin, Australia) and calculating the difference. El Niño and Southern Oscillation often occur together, but also happen separately. High positive values of the SOI indicate a La Niña, or “cold event”. La Niña is the counterpart of El Niño and represents the other extreme of the ENSO cycle. La Niña years often (but not always) follow El Niño years. A table listing the El Niño and La Niña events since 1900 can be found on the next page.

Table 2.11.b
ENSO Phases Since 1900

		Negative PDO: 1900-1924, 1947-1976, 1999-2002	**Warm phase PDO: 1925-1946, 1977-1998, 2003-2005**
ENSO Phase	La Niña (cool)	1904, 1907, 1909, 1910, 1911, 1917, 1918, 1921, 1923, 1950, 1951, 1955, 1956, 1963, 1965, 1968, 1971, 1972, 1974, 1975, 1976, 1999, 2000, 2001	1925, 1932, 1934, 1938, 1939, 1943, 1944, 1945, 1984, 1985, 1986, 1989, 1996
	ENSO Neutral	1901, 1902, 1908, 1913, 1916, 1922, 1947, 1948, 1949, 1953, 1954, 1957, 1960, 1961, 1962, 1967, 2002	1927, 1928, 1929, 1933, 1935, 1936, 1937, 1946, 1979, 1981, 1982, 1990, 1991, 1993, 1994, 1997, 2004
	El Niño (warm)	1900, 1903, 1905, 1906, 1912, 1914, 1915, 1919, 1920, 1924, 1952, 1958, 1959, 1964, 1966, 1969, 1970, 1973	1926, 1930, 1931, 1940, 1941, 1942, 1977, 1978, 1980, 1983, 1987, 1988, 1992, 1995, 1998, 2003, 2005

Source: Climate Impacts Group, Joint Institute for the Study of the Atmosphere and the Ocean, University of Washington, http://www.cses.washington.edu/cig/pnwc/compensopdo.shtml.

Understanding the connections between ENSO (and La Niña) events and weather anomalies around the globe can help in forecasting droughts, floods, tropical storms and hurricanes. NOAA estimates that the economic impacts of the 1982–83 El Niño, perhaps the strongest event in recorded history (see map, below), conservatively exceeded $8 billion worldwide, from droughts, fires, flooding, and hurricanes. Between 1,000 and 2,000 deaths have been blamed on the event and the disasters that accompanied it. In addition, the extreme drought in the United States' Midwest during 1988 has been linked to the "cold event", or La Niña, of 1988 that followed the ENSO event of 1986–87.

It is possible that the direct impacts of climate change on water resources might be hidden beneath natural climate variability. With a warmer climate, droughts and floods could become more frequent, severe, and longer-lasting. The potential increase in these hazards is a great concern given the stresses being placed on water resources and the high costs resulting from recent hazards. The drought of the late 1980s showed what the impacts might be, if climate change leads to a change in the frequency and intensity of droughts across the United States. From 1987 to 1989, losses from drought in the United States totaled $39 billion. More frequent extreme events such as droughts and floods could end up being more cause for concern than the long-term change in temperature and precipitation averages.

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VULNERABILITY ANALYSIS & LOSS ESTIMATION

Drought risk is based on a combination of the frequency, severity, and spatial extent of drought and the degree to which a population or activity is vulnerable to the effects of drought. The degree of a region's vulnerability depends on the environmental and social characteristics of the region and is measured by their ability to anticipate, cope with, resist, and recover from drought.

Society's vulnerability to drought is determined by a wide range of factors, both physical and social, such as demographic trends and geographic characteristics. People and activities will be affected in different ways by different hazards.

There is a sequence of impacts associated with meteorological, agricultural, and hydrological droughts in Ohio. When drought begins, the agricultural sector is usually the first to be affected because of its heavy dependence on stored soil water, which can be rapidly depleted during extended dry periods. If precipitation deficiencies continue, then people dependent on other sources of water will begin to feel the effects of the shortage. Those who rely on surface water (reservoirs and lakes) and subsurface water (ground water) are usually the last to be affected. A short-term drought that persists for 3-to-6 months may have little impact on these sectors, depending on the characteristics of the hydrologic system and water use requirements.

When precipitation returns to normal and meteorological drought conditions have abated, the sequence is repeated for the recovery of surface and subsurface water supplies. Soil water reserves are replenished first, followed by stream flow, reservoirs and lakes, and ground water. Drought impacts may diminish rapidly in the agricultural sector because of its reliance on soil water, but linger for months or even years in other sectors dependent on stored surface or subsurface supplies. Ground water users, often the last to be affected by drought during its onset, may be last to experience a return to normal water levels. The length of the recovery period is a function of the intensity of the drought, its duration, and the quantity of precipitation received as the episode terminates.

Socioeconomic definitions of drought associate the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought. It differs from the other types of drought because its occurrence depends on the time and space processes of supply and demand to identify or classify droughts. The supply of many economic goods, such as water, forage, food grains, fish, and hydroelectric power, depends on weather. Socioeconomic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply.

FEMA estimated in 1995 that drought costs the United States $6–8 billion annually. Other studies have indicated that drought losses average $200 million to $1.24 billion annually in the Great Plains. This range is based on crop losses and other direct and indirect losses. According to NOAA's National Climatic Data Center, in 1999, a drought that affected twenty-eight Ohio counties caused $200 million in crop damages.

The Dust Bowl years of the 1930s and the drought of 1988–89 are both contenders for the worst drought on record in the United States. Economic losses are often hard to calculate and compare for a variety of reasons: lack of historical records and economic models, and past and present costs that are often based on different criteria. Today, many different types of losses are often included in an economic analysis, such as energy losses, ecosystem losses, and consumer purchasing losses, but they were not typically included in previous analyses and are difficult to assess in retrospect.

A 1975 study noted that the 1930s droughts were considered to be the most economically damaging droughts to affect the United States. It is estimated that total costs due to the 1988 drought, including losses in agriculture, energy, water, ecosystems, and other sectors of the economy, were roughly $39 billion, making it the most expensive natural disaster ever to affect the nation.

STATE-OWNED / CRITICAL FACILITIES VULNERABILITY ANALYSIS & LOSS ESTIMATION

Drought does not pose a specific threat to state-owned structures. The larger threat from drought would be based on the agricultural and drinking water demands with a limited supply.

2.12 SEVERE SUMMER STORMS

Severe summer storms traditionally precede an approaching cold air mass. In the northern hemisphere, the spin of the earth naturally produces weather patterns affecting North America, which travel from west to east across the continent. Key components to the formation of storms are a low pressure zone, high pressure zone and the jet stream.

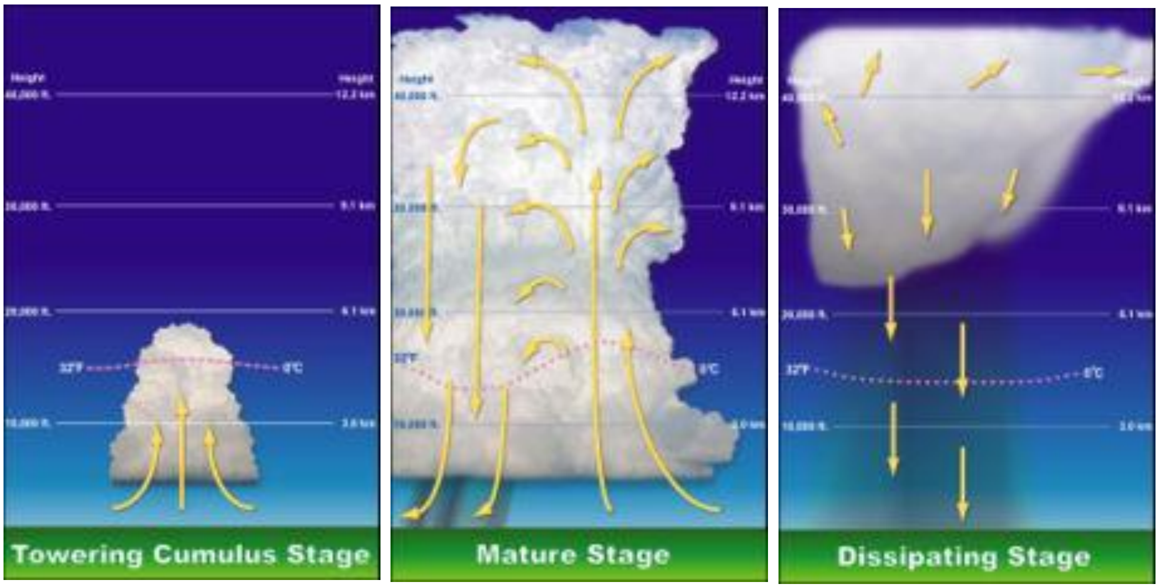
The troposphere is the lowest portion of Earth's atmosphere containing approximately 75% of the atmosphere's mass and almost all of its water vapor. Air at this level is acted upon by the earth surface (land and water) and the heating cycle associated with sunlight. Unlike other portions of the atmosphere which are largely homogenous, at the surface discrete areas or bubbles exist of differing temperature, water vapor content and pressure. Warm areas (low pressure) tend to rise, pressing on the borders of surrounding cool areas (high pressure). It is where the pressure zones interface that temperature changes cause water vapor in the air to condense creating precipitation. The warmer the overall temperature of the atmosphere and the greater the volume of water vapor present, the larger the associated perception event.

Jet streams are fast flowing, relatively narrow air currents found in the atmosphere around 11 kilometers (36,000 ft) above the surface of the Earth. They form at the boundaries of adjacent air masses with significant differences in temperature, such as of the polar region and the warmer air toward the equator. These air currents migrate north and south in a snakelike pattern changing their relative location as the planet's axis tilts with each passing year. These winds act on the high and low pressure zone moving them across the continent and shifting them north and south.

Thunderstorms develop when large differences exist between adjacent zones combined with significant water vapor. As warm air begins to lift, it eventually starts to cool and condensation takes place. When the moisture condenses, heat is released which further aids in the lifting process. If enough instability is present in the atmosphere, this process will continue long enough for cumulonimbus clouds to form, which supports lightning and thunder (see Diagram 2.12.a). As water droplets rise into the colder air, they can freeze. When the velocity of wind becomes great enough, the ice pellets are repeatedly lifted and dropped in the storm adding layers of ice with each cycle. Once the wind cannot support the weight of the ice pellet it falls the ground in the form of hail.

One key component to a thunderstorm is lightning, an atmospheric discharge of electricity. High speed videos (examined frame-by frame) show that most lightning strikes are made up of multiple individual strokes. A typical strike is made of 3 to 4 strokes. The sudden increase in pressure and temperature from lightning produces rapid expansion of the air surrounding and within a bolt of lightning. In turn, this expansion of air produces a sonic shock wave which produces the sound of thunder. Lightning, other storm components, often seeks a path though the tallest object available. Trees, utility line/poles, tall buildings and even humans can be sought as a pathway for the discharging electricity.

Summer storms are considered high wind events by the National Climactic Data Center when surface winds meet or exceed 50 knots or 57.6 miles per hour. It is possible for winds in strong storms to exceed 100 miles per hour, with gusts even stronger.



Source: Wikipedia http://en.wikipedia.org/wiki/Thunderstorm

Figure 2.12.a

Hurricane IKE Inland Effects in Ohio (September 2008 Windstorms)(FEMA DR-1805-OH)

The effects of Hurricane Ike in inland North America were unusually intense and included widespread damage across all or parts of eleven states, which included Ohio. The storm had rapidly become an extratropical cyclone and was enhanced by an adjacent frontal boundary and produced widespread winds with gusts to hurricane-force in several areas. The severe winds were reported across the Midwestern States, although little or no rain fell in many of those areas. They were as a result of a combination of factors, including the strength and size of Ike the location on the east side of the storm where the winds are usually stronger in a northward-moving system, its fast forward motion (approximately 40 miles per hour), and the warm air ahead of the storm. All of these factors most likely allowed the high winds aloft to reach the surface easier, resulting in areas reporting wind gusts nearing or topping hurricane force.

Ohio was hit extremely hard by the storm starting on September 14, 2008. The remnants of Ike caused a total of 2.6 million power outages in the state, including 370,000 outages in Columbus (Franklin County). Many of the citizens in Columbus were without power for 5 – 7 days, because many electric company workers were in Texas helping crews restore electricity to the millions who lost power from Hurricane Ike.

Wind gusts of over 75 miles per hour were recorded in Cincinnati (Hamilton County), Dayton (Montgomery County) and Columbus. Additionally, a State of Emergency was declared by Governor Strickland on September 15, 2008. On September 16th and 17th, the Governor took a tour of the heavily damaged areas, particularly in Cincinnati, Columbus and Dayton to survey the damage.

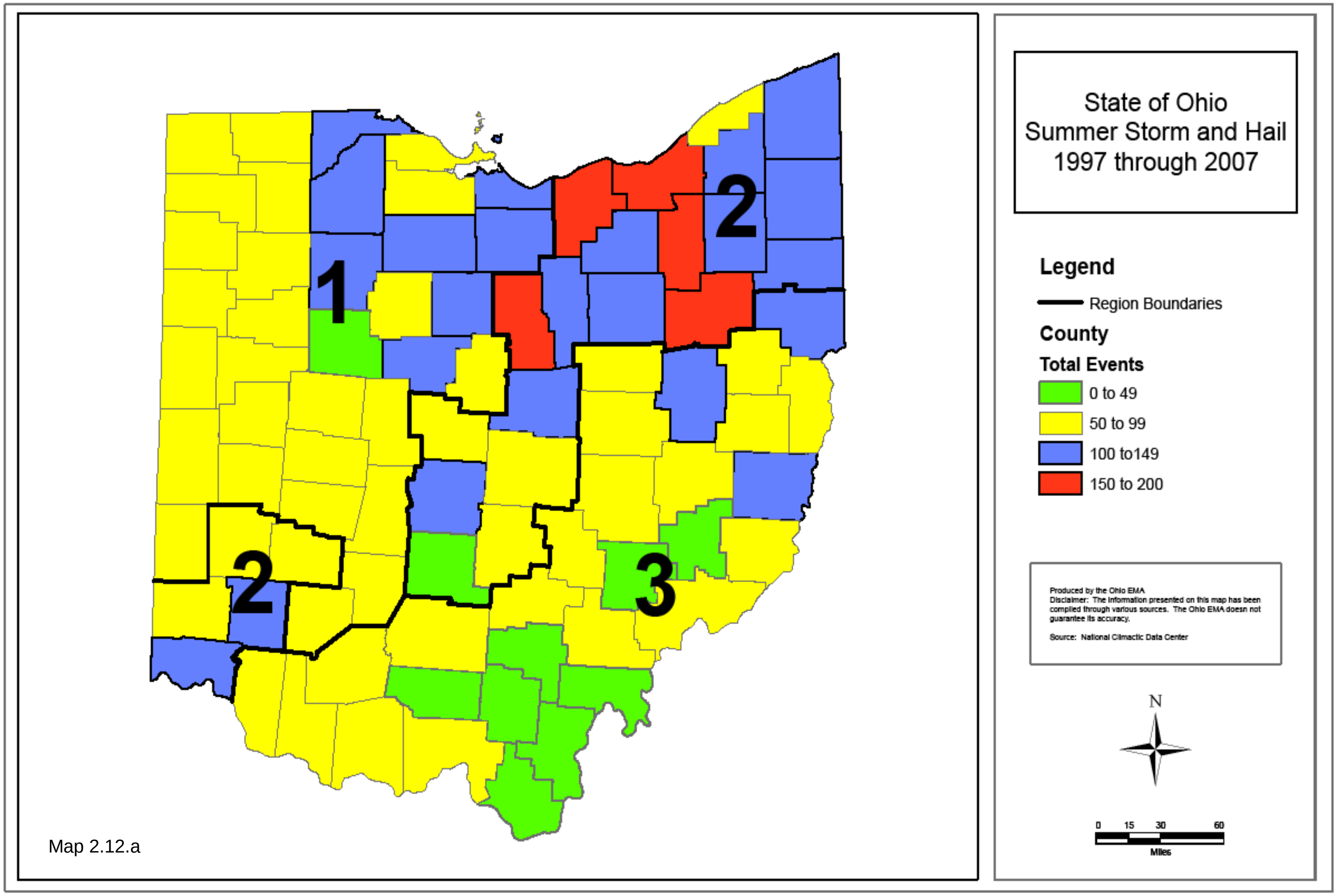
The Cincinnati metropolitan area was hit very hard, with approximately 2.1 million people losing power. A Duke Energy spokesperson said “We have never seen anything like this. Never. We’re talking about 90 percent of our customers without power." September 15th through 17th, most of the schools in Hamilton and Butler Counties had classes cancelled because of power outages. In the Dayton, Ohio area 300,000 of 515,000 Dayton Power & Light Company’s (DP&L) customers lost power following severe wind storms on the afternoon of September 14th, according to a company spokesperson. As of Thursday morning, September 18th, 90,000 DP&L customers remained without power. Also hit hard were central Ohio (over 350,000 customers losing power) and northeastern Ohio (over 310,000 customers losing power). A water emergency was also declared in Butler County as the water supply diminished due to the lack of power. A "Level 1 Emergency” was declared in the county to encourage people to remain at home. A curfew was implemented on September 17th in Carlisle (Warren County) due to increased looting as a result of the lengthy power outage.

Agricultural damage was severe, with as much as 20% of the state's total corn crop lost as a result of wind. Some fields were nearly flattened by the hurricane-force wind gusts. Tens of thousands of people also lost power in northwest Ohio, where widespread damage was reported, especially in the Lima (Allen County) and Findlay (Hancock County) areas. Some of the most significant damage in these communities included a radio tower that collapsed and a church that was heavily damaged.

RISK ASSESSMENT

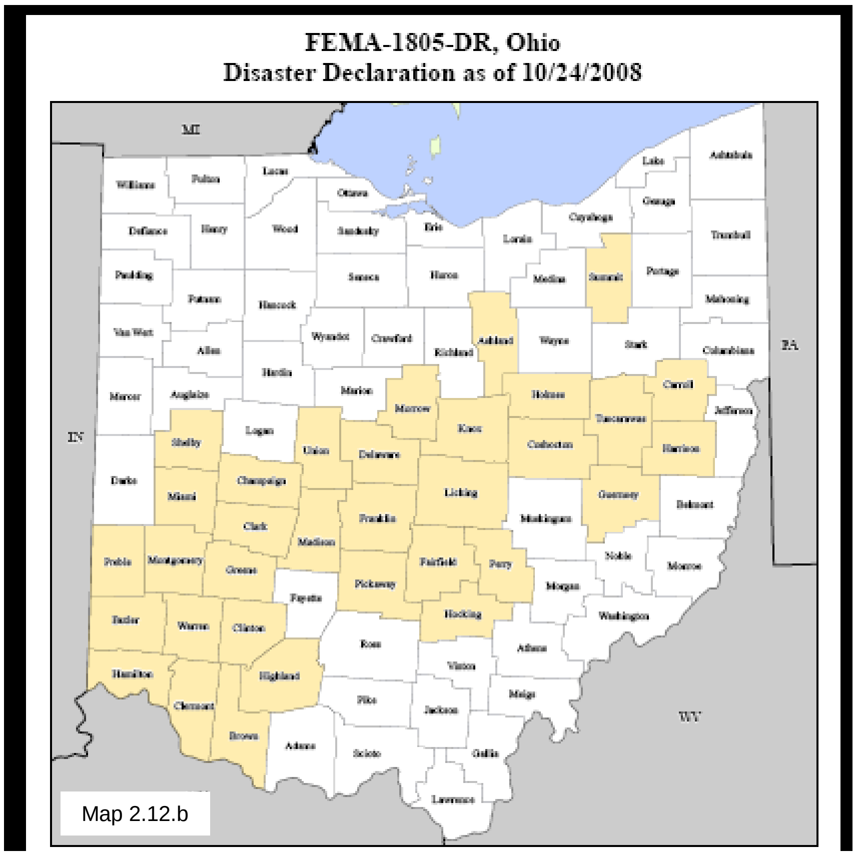
Location

Severe summer storms and associated high wind / hail events are common throughout Ohio and reported hundreds of times each year. Analysis of the number of reported occurrences from 1997 to 2007 by the NCDC shows a clear concentration in north-central and northeast Ohio (Map 2.12.a). The five counties with the highest number of reported occurrences (150 – 200 over ten years) are Richland, Lorain, Cuyahoga, Summit and Stark Counties (all in Region 2). Conversely, a concentrated area of low reported occurrences (0 – 49 over ten years) exists in south-central Ohio, with most in Region 3.


State of Ohio
Summer Storm and Hail
1997 through 2007
Legend
Region Boundaries
County
Total Events
0 to 49
50 to 99
100 to149
150 to 200
Produced by the Ohio EMA
Disclaimer: The information presented on this map has been compiled through various sources. The Ohio EMA doesn not guarantee its accuracy.
Source: National Climactic Data Center
N
0 15 30 60
Miles
1
2
2
3

Map 2.12.a

Over one half of the counties in Ohio have between 50 and 99 reported summer storm events over the course of 10 years. These counties are predominantly in the western and central portions of the state. Based on the dispersion pattern generated, it can be reasonably concluded the number of summer storm events in Ohio is influenced by the proximity to Lake Erie.



Map 2.12.b

<u>Statewide High Winds – September 2008 (FEMA DR-1805-OH).</u>

Usually, tropical storms and hurricanes directly affecting other states result in extended rainfall in Ohio. NOAA Operational Significant Event Imagery shows that the windstorms of 2008 were a legacy from Hurricane IKE, which arced clockwise from the Gulf of Mexico to the western basin of Lake Erie and the Saint Lawrence Seaway. Ohio was affected from Hamilton County in southwest Ohio to the northeastern counties of Ashland, Carroll and Summit. Unlike other secondary effects of a diminishing hurricane, high winds in excess of 65 miles per hour were primarily the cause of damage for many counties, causing power outages across these portions of the state. It was reported that winds equal to a Category 1 hurricane (winds up to 74 miles per hour) caused at least $1.255 billion in insured losses.

Past Occurrences

In 2003 the largest recorded event caused $145,000,000 in hail damage to the central Ohio counties of Franklin and Delaware. The area impacted is urbanized with a large number of high valued residences. The largest single-county event recorded occurred in 2006 with $100,000,000 in estimated property damage in Licking County. Hail stones 1.75 inches in diameter damaged many homes and vehicles during a 15-minute period. In a similar event the Montgomery County, the City of Huber Heights experienced $70,000.000 in damages in 2001. Of the varied forces involved in summer storms, hail has been the most destructive.

High wind events are more destructive from the perspective of transportation and utilities. Although the dollar value of the most destructive wind event is reported at $750,000 (Erie County), power outages and disabled telephone lines that accompany the inaccessibility of emergency services creates potentially life threatening situations.

<u>Hurricanes and tropical storms.</u>

Not much detail can be found without extensive research about hurricanes and tropical storms significantly affecting Ohio. However, in September 2003, the effects of Hurricane ISABEL dropped light to moderate precipitation on the eastern half of Ohio with isolated areas reporting over 3 inches of rainfall. Tropical Storm BRET created 1 to 3 inches of rainfall in the extreme southwest and southeast counties of the state. Again, only isolated areas received 3 inches of rain.

Probability of Future Events

The historical period used for severe summer storm analysis began with April 30, 1997 and closed April 30, 2007 based on statistics tabulated by the NCDC. During this period over 5,000 events are documented with over 15,000 documented since 1950. Based on available documented occurrences, severe summer storms are the most prevalent natural hazard events in Ohio.

From January 1997 to August 2007 Ohio has received 19 presidential declarations. Of the declared events, 16 specifically cite severe storms as part of the description. Additionally, the only year Ohio did not receive a federal declaration for a severe storm was 1999. Based on historical trends, Ohio can reasonably expect at least one storm every two years large enough to trigger a federal declaration, as well as numerous smaller events.

<u>Hurricanes and tropical storms.</u>

In the 208 years that Ohio has been a State, there has been only one hurricane or tropical storm resulting in a Presidential Declaration. Therefore, 1 event in 208 years is equivalent to 0.005% or one half of one percent of hurricane or tropical storm affecting Ohio, which is an extremely low probability of this type of event occurring in the future.

LHMP Data

Jefferson County. The county's February 2007 Multi-Hazard Mitigation Plan states that thunderstorms are not exceptionally large in extent, but they are intense with the potential to deposit large amounts of rain in a short period of time over a small area. Combined with high winds, hail and lightning, these storms can cause as much damage as many tornados. During the late spring and all summer, these storms can be expected to occur on a regular basis with varying degrees of severity. Overall, the experience of Jefferson County has been sufficient to classify thunderstorms as being high frequency, but moderate severity natural hazard. The structures most at risk of thunderstorm damage are those in exposed locations on hilltops, tall structures with large exposed surfaces and all types of manufactured housing. Education and awareness, along with land use regulations to control location and required anchoring of manufactured housing, would seem to be the best method to mitigate all but the most severe storm effects.

Lawrence County. The November 2003 Hazard Mitigation Plan cites that because severe storms are random in nature, their Core Group chose to look at historic events to determine susceptibility. According to the National Climatic Data Center (NDCD), there have been 60 thunderstorm and high wind events recorded in Lawrence County from 1950 to 2003, with damages totaling approximately $1.5 million. Because the severe storm category also includes hailstorms, these must also be assessed in terms of historical occurrence. There were 29 hailstorms recorded for Lawrence County from 1950 to 2003, totaling $386,000 in damages.

Trumbull County. The HIRA from the October 2005 Trumbull County Hazard Mitigation Plan references 189 severe thunderstorm events between 1950 and 2003. The assessment also cites a Presidential Disaster Declaration was issued for the county in August 1992 due to significant damage. The assessment also states that a notable large storm in August 1994 moved across the county, blocking many roads with debris. Potential structural losses are estimated at $9,867,300, with content losses estimated at $1,217,200, and structural use/functional losses estimated at $1,643,020. Total potential losses from severe thunderstorms in the county are estimated to be $12,727,520.

VULNERABILITY ANALYSIS AND LOSS ESTIMATION

Methodology

During data development for the thunderstorm/high wind and hail hazard, it quickly became apparent the two must be addressed separately. Hail events, as stated earlier, are far more costly and have a much greater financial impact in urbanized areas. Events of the same magnitude can create $10,000,000 worth of damage in an urban setting, or as little $50,000 in forested or agricultural area. Of the 88 counties in Ohio, 22 percent reported no hail loss while 2 counties reported $100,000,000 or more.

The extreme range of the data for hail would skew any useful thunderstorm/high wind analysis. As a result, the vulnerability and loss estimate by county for summer storms considers only thunderstorms/high wind events while hail is addressed at the state level.

The 10-year summer storm losses (1997 to 2007) for each county provided the basis for estimating potential vulnerability and losses. To yield the per capita 10-year damage total for each county, the total damage for the decade was divided by the 2001 population. That figure divided by ten, resulted in the annual per capita damage figure for severe summer storms in each county (in raw dollar unadjusted for inflation). This is the figure that appears in the column on the right.

Statewide High Winds – September 2008 (FEMA DR-1805-OH).

Following this event, the Ohio Insurance Institute (OII) conducted a windstorm loss survey in which 24 property and casualty companies participated. This represented:

- 68% of Ohio's personal auto insurance market
- 72% of the homeowners' market
- 33% of the state's commercial lines market based on 2007 Ohio premium volume

Results of the survey were reported on September 11, 2009.

Results

With an annual summer storm loss figure of $1.67 per capita, based on the population of 11,381,725, Ohio can expect an annual statewide summer storm loss of approximately $19,007,481 any given year. The 10-year loss includes all residential, commercial, governmental structures, as well as infrastructure and public facilities for each county. Table 2.12.a shows severe summer weather per capita loss.

Table 2.12.a

Estimate of Potential Losses to Summer Storms by Region											
Region 1				Region 2				Region 3			
County	2001 Pop.	10-Year Cumulative Summer Storm Losses	Per-Capita Annual Summer Storm Losses	County	2001 Pop.	10-Year Cumulative Summer Storm Losses	Per-Capita Annual Summer Storm Losses	County	2001 Pop.	10-Year Cumulative Summer Storm Losses	Per-Capita Annual Summer Storm Losses
Allen	108,522	$2,307,000	$2.13	Ashland	52,786	$2,476,000	$4.69	Adams	27,225	$768,000	$2.82
Auglaize	46,453	$231,000	$0.50	Ashtabula	102,729	$2,331,000	$2.27	Athens	62,792	$324,000	$0.52
Champaign	39,210	$333,000	$0.85	Butler	335,992	$418,000	$0.12	Belmont	69,605	$539,000	$0.77
Clark	143,969	$380,000	$0.26	Cuyahoga	1,384,252	$5,735,000	$0.41	Brown	43,425	$453,000	$1.04
Clinton	41,277	$1,614,000	$3.91	Delaware	118,215	$367,000	$0.31	Carroll	29,011	$406,000	$1.40
Crawford	46,695	$2,386,000	$5.11	Fairfield	125,109	$479,000	$0.38	Clermont	180,970	$1,181,000	$0.65
Darke	53,178	$482,000	$0.91	Franklin	1,081,784	$915,000	$0.08	Columbiana	111,684	$790,000	$0.71
Defiance	39,195	$218,000	$0.56	Geauga	92,294	$1,735,000	$1.88	Coshocton	36,803	$289,000	$0.79
Erie	79,321	$3,637,000	$4.59	Greene	148,530	$377,000	$0.25	Gallia	30,929	$149,000	$0.48
Fayette	28,387	$291,000	$1.03	Hamilton	838,134	$1,240,000	$0.15	Guernsey	40,899	$849,000	$2.08
Fulton	42,334	$355,000	$0.84	Knox	55,250	$2,663,000	$4.82	Harrison	15,813	$370,000	$2.34
Hancock	71,745	$1,250,000	$1.74	Lake	227,324	$1,827,000	$0.80	Highland	40,875	$300,000	$0.73
Hardin	31,945	$287,000	$0.90	Licking	149,080	$476,000	$0.32	Hocking	28,241	$265,000	$0.94
Henry	29,090	$99,000	$0.34	Lorain	285,798	$4,698,000	$1.64	Holmes	39,539	$2,174,000	$5.50
Huron	59,775	$3,235,000	$5.41	Mahoning	254,810	$1,467,000	$0.58	Jackson	32,743	$567,000	$1.73
Logan	46,115	$241,000	$0.52	Medina	154,718	$2,864,000	$1.85	Jefferson	72,705	$645,000	$0.89
Lucas	454,029	$1,969,000	$0.43	Montgomery	553,579	$671,000	$0.12	Lawrence	62,017	$202,000	$0.33
Madison	40,158	$224,000	$0.56	Pickaway	52,840	$396,000	$0.75	Meigs	22,920	$85,000	$0.37
Marion	65,639	$1,474,000	$2.25	Portage	153,056	$4,405,000	$2.88	Monroe	15,141	$212,000	$1.40
Mercer	40,886	$287,000	$0.70	Richland	128,549	$2,741,000	$2.13	Morgan	14,961	$48,000	$0.32
Miami	99,329	$308,000	$0.31	Stark	378,098	$6,215,000	$1.64	Muskingum	84,783	$461,000	$0.54
Morrow	32,319	$920,000	$2.85	Summitt	542,899	$3,734,000	$0.69	Noble	14,052	$214,000	$1.52
Ottawa	41,036	$5,708,000	$13.91	Trumbull	223,513	$2,432,000	$1.09	Perry	34,212	$254,000	$0.74
Paulding	20,163	$397,000	$1.97	Warren	168,229	$5,035,000	$2.99	Pike	27,982	$137,000	$0.49
Preble	42,344	$310,000	$0.73	Wayne	112,274	$2,759,000	$2.46	Ross	73,437	$424,000	$0.58
Putnam	34,741	$1,138,000	$3.28	**TOTAL**	**7,564,327**	**$53,649,000**	**$0.71**	Scioto	78,428	$271,000	$0.35
Sandusky	61,653	$5,538,000	$8.98					Tuscarawas	91,521	$838,000	$0.92
Seneca	58,314	$2,079,000	$3.57					Vinton	12,953	$68,000	$0.52
Shelby	48,233	$523,000	$1.08					Washington	62,798	$1,321,000	$2.10
Union	40,909	$328,000	$0.80					**TOTAL**	**1,458,464**	**$14,604,000**	**$1.00**
Van Wert	29,432	$503,000	$1.71								
Williams	39,200	$167,000	$0.43								
Wood	121,680	$9,263,000	$7.61								
Wyandot	22,956	$966,000	$4.21								
TOTAL	**2,200,232**	**$49,448,000**	**$2.25**								

The total 10-year cumulative summer storm loss for Region 1 is $49,448,000, and an annual per-capita loss of $2.25, which is the highest in the state. Within the Region, Ottawa and Sandusky Counties have historically had the highest 10-year loss each exceeding $5,000,000 affecting approximately 102,689 people. Henry County historically had the lowest 10-year loss at $99,000 affecting 29,090 people.

Region 2 has the highest 10-year cumulative summer storm loss in the state at a total of $53,649,000. However, this is the most populous Region in the state, and exhibits the lowest annual per-capita loss of $0.71. Within the Region, Geauga County has historically had the highest 10-year per-capita loss of $1.88 (Table 2.12.a). Franklin County has historically had the lowest 10-year per-capita loss at $0.08, but has the second highest population in the state.

Region 3 has a 10-year cumulative summer storm loss of $14,604,000, which has affected a population of approximately 1,458,464 persons (annual per-capita of $1.00). Holmes County has had experienced the highest 10-year loss at a total of $2,174,000 affecting approximately 39,539 persons (Table 2.12.a). Morgan County has had the least 10-year loss to summer storms at $48,000, which affected approximately 14,963 persons (Table 2.12.a).

Hail events cannot be assessed by county; however, historical trends indicate Ohio will experience hail storms generating $25,000,000 or more of damages once in a two year period. Predominantly rural areas range from no reported losses in 19 counties to a high of $975,000 in Gallia County. The highly sporadic nature of hail events makes county-to-county comparisons misleading. With 2,491 hail events and $463,571,600 in damages over the analysis period, the mean event would cost $186,062. However, the usefulness of such a statistic is highly debatable, as it is provided for illustration only.

Property damage is not the only loss associated with summer storms and hail. Over the analysis period 13 deaths and 98 injuries were attributed to these events. Of the injuries reported, 20 are attributed to a single event in Franklin County which involved a campground.

<u>Statewide High Winds – September 2008 (FEMA DR-1805-OH).</u>

The OII survey concluded Ohio's insured losses totaled $1.255 billion and government costs for protection and clean-up were $38.6 million. Insurance companies reported a record-high number of claims filed across the state. At least 270,000 were filed in Ohio, including 220,000 homeowners, 30,000 commercial and 20,000 auto insurance claims.

STATE-OWNED / CRITICAL FACILITIES VULNERABILITY ANALYSIS & LOSS ESTIMATION

Since summer storms are non-spatial hazards and have the potential to affect all state-owned structures and critical facilities in the state, this section defaults to the overall discussion of state-owned structures and critical facilities identified in Section 2.1, Table 2.1.a, and Appendix C.

Statewide High Winds – September 2008 (FEMA DR-1805-OH).

An Ohio Department of Jobs and Family Services structure was damaged at the Fifth Avenue facility in Columbus (Franklin County). Additionally, due to power and telecommunication issues, some facilities had trouble coordinating through traditional means. The Ohio Department of Transportation reported 46 state roads and hundreds of local roads were impacted by debris. Power outages and physical damage to traffic signal systems also were caused by the storm. At the storm's peak, 490 state-controlled traffic systems were non-functional with tens of thousands locally-controlled systems without power.

2.13 INVASIVE SPECIES

According to the ODNR, Division of Wildlife, of the approximately 3,000 species of plants known to occur in Ohio, about 75 percent are native or have occurred in Ohio before the time of substantial European settlement, which was about 1750. The other 25 percent is not native to Ohio, having been introduced from other states or countries.

Most of these species never stray far from where they are introduced (gardens, urban areas, agricultural fields), yet some become very invasive and displace native plants in woodlands, wetlands, prairies, and other natural areas. Non-native plants have been introduced for erosion control, horticulture, forage crops, medicinal use, and wildlife foods as well as by accident. The top 10 species invading Ohio are:

1. Bush Honeysuckle
2. Autumn Olive
3. Buckthorn
4. Common Reed
5. Garlic Mustard
6. Japanese Honeysuckle
7. Japanese Knotweed
8. Multiflora Rose
9. Purple Loosestrife
10. Reed Canary Grass

Without natural predators or controls, invasive, non-native plants are able to spread quickly and force out native plants. In Ohio, several non-native plants are invading woodlands and displacing native spring wildflowers. Other non-native plants are impacting our wetlands by creating monocultures. Native plant diversity is important for wildlife habitat, as many animals depend on a variety of native plants for food and cover.

According to the Aquatic Nuisance Species Task Force, which is a nationwide cooperative effort between many federal departments, the species listed below are a few of the many aquatic nuisance species that are potentially harmful to North American environments in which they are not native. (* not currently in Ohio)

1. Zebra Mussel
2. Ruffe
3. Chinese Mitten Crab
4. European Green Crab
5. Brown Tree Snake*
6. Eurasian Water Milfoil
7. New Zealand Mudsnail
8. Asian Swamp Eel*
9. Lionfish*
10. Round Goby
11. Sea Lamprey
12. Snakehead
13. Nutria*
14. Hydrilla
15. Applesnail
16. Water Hyacinth
17. Rusty Crayfish
18. Giant Salvinia

Lastly, according to the ODNR, Division of Forestry one of the most invasive insect species in Ohio is the Emerald Ash Borer. This Asian pest is part of a group of insects known as metallic wood-boring beetles. Emerald Ash Borer affects all species of native ash found in Ohio. Because North American ash trees did not coexist in association with this pest, they have little or no resistance to its attack. This ash tree-killing insect from Asia was unintentionally introduced to southeastern Michigan several years ago. In February of 2003, it was first found feeding on ash trees in northwest Ohio.

Emerald Ash Borer larvae feed on the living portion of the tree, directly beneath the bark. This eating habit restricts the tree's ability to move essential water and nutrients throughout the plant. In three to five years, even the healthiest tree is unable to survive an attack.

RISK ASSESSMENT

Location

The area invaded by each plant species varies based on its preferred environment. Those with the fewest limitations have spread to nearly every county in Ohio. Following is a description of each plant from the ODNR, Division of Natural Areas and Preserves along with a map of known impacted counties from The Nature Conservancy.

Bush Honeysuckle
Lonicera Morrowii Displayed

Found in 47 out of Ohio's 88 counties. Its range is shown here in yellow.

Autumn Olive

Found in 34 out of Ohio's 88 counties. Its range is shown here in yellow.

Source: The Nature Conservancy

Bush Honeysuckles consist of a number of upright shrubs which can grow 6-15 feet in height. Each has dark green, egg-shaped leaves. The tubular flowers are white on the Amur and the Morrow (changing to yellow with age), and pink on the Tatarian. Berries range from red to orange, occasionally yellow, and are eaten and dispersed by birds.

Habitat: The bush honeysuckles inhabit abandoned fields, roadsides, woodlands, and edges of marshes. Morrow is currently a problem in northern Ohio; Amur is found mostly in southwestern Ohio; and Tatarian is widespread in Ohio.

Management: The best control method is to cut and treat stumps with systemic herbicide. Sprouts from cut stems may be treated with a foliar application of systemic herbicide. Young shrubs are easy to pull or dig up. Be aware there is a native bush honeysuckle in Ohio (Diervilla lonicera).

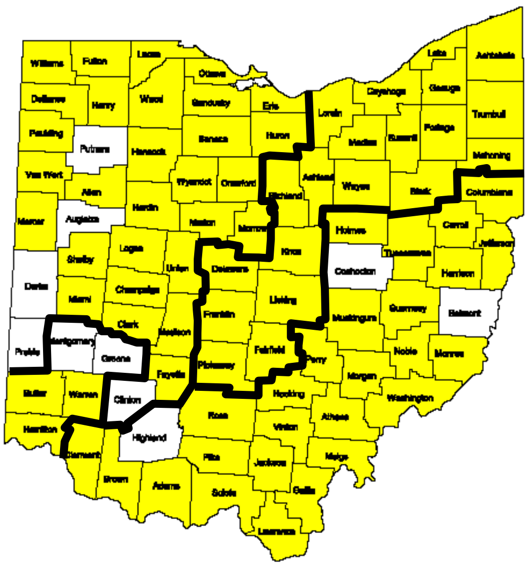
Autumn-Olive is a fast-growing shrub or small tree reaching up to 20 feet tall. Its leaves are small and oval, dark green on the upper surface and silvery below. Small coppery dots occur on stems and leaves. This shrub has light yellow, aromatic flowers and produces large quantities of small, round red fruits that are readily eaten and spread by birds.

Habitat: Autumn-olive can survive in very poor soils because of its nitrogen-fixing root nodules. It grows in disturbed areas, roadsides, pastures, and fields throughout Ohio.

Management: Stems may be cut and treated with systemic herbicide. Resprouting will occur, so follow-up control is necessary. A combination of hand-pulling, digging and herbicide treatments is usually necessary.

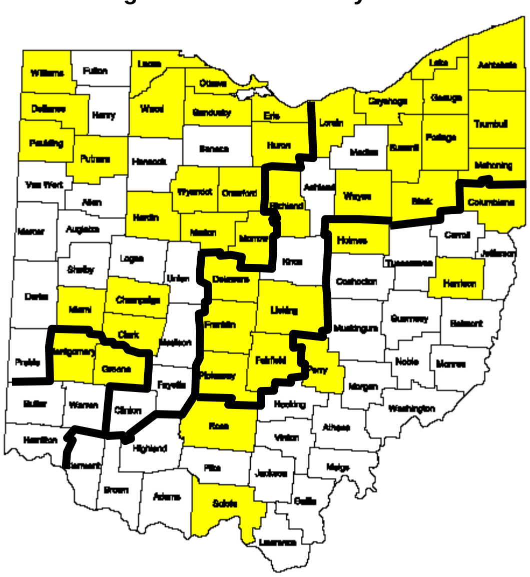
Buckthorn
Rhamnus Frangula Displayed

Found in 30 out of Ohio's 88 counties. Its range is shown here in yellow.



Common Reed

Found in 43 out of Ohio's 88 counties. Its range is shown here in yellow.



Source: The Nature Conservancy

Buckthorns are tall shrubs or small trees that grow up to 20 feet tall. The smooth, gray to brown bark is distinctively spotted. Glossy buckthorn has shiny leaves with smooth edges. It has solitary red to purple berry-like fruits. Common buckthorn has black fruits and dull green smooth leaves. Both species are abundant seed producers.

Habitat: Glossy buckthorn usually occurs in wetlands, such as fens or bogs, but it is also found in forests, fencerows, edges, prairies, and old fields. Common buckthorn occurs in a range of upland habitats, such as forests, woodland edges, fencerows, prairies, and old fields. Both species are most prevalent in central and northern Ohio.

Management: Cutting and treating stumps with systemic herbicide is the best method of control. Buckthorns are very difficult to control due to vigorous resprouting and a large seedbank.

The Common Reed, or Phragmites, is a grass that reaches up to 15 feet in height. The leaves are smooth, stiff and wide with coarse hollow stems. The big, plume-like flower head is grayish-purple when in fruit. Common reed spreads mostly vegetatively forming huge colonies by sprouting new shoots through underground stems (rhizomes).

Habitat: Common reed grows in open wetland habitats and ditches primarily in northern Ohio. It occurs in still water areas of marshes, lake shores, riverbanks, and disturbed or polluted soils, often creating pure stands.

Some populations are not invasive and may be native, however there is no reliable method to tell the two apart.

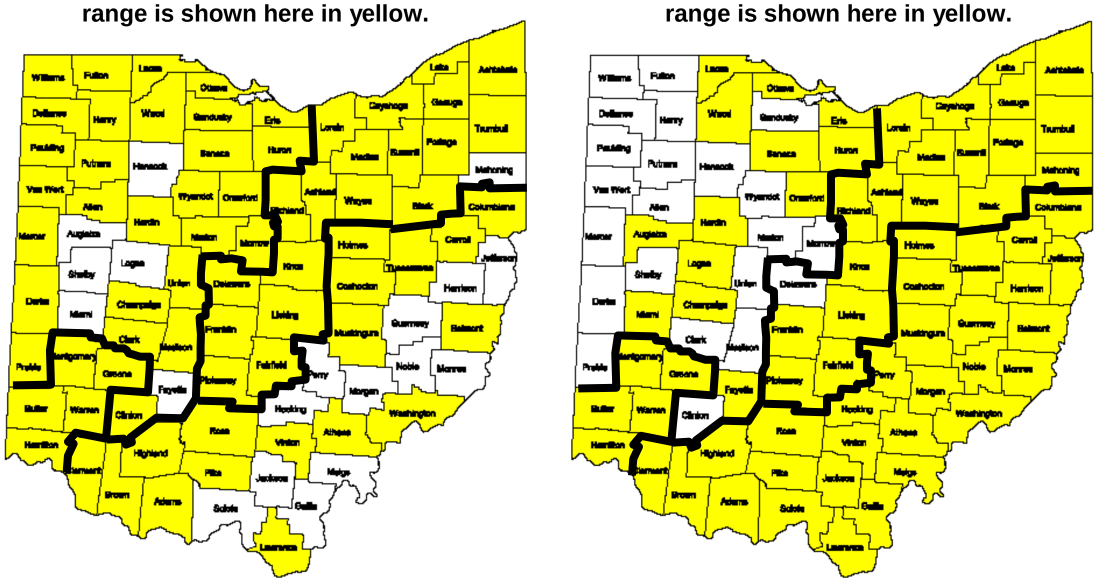
Management: Long-term management is necessary for control of this persistent plant. Cutting and/or treating stems with systemic herbicides is generally the most effective, grass-specific herbicides are recommended in areas where native plants occur.

Garlic Mustard

Found in 69 out of Ohio's 88 counties. Its range is shown here in yellow.

Japanese Honeysuckle

Found in 66 out of Ohio's 88 counties. Its range is shown here in yellow.



Source: The Nature Conservancy

Garlic Mustard is a biennial herb. It begins as a rosette of leaves in the first year, overwinters as a green rosette of leaves, flowers and fruits in the second year, and then dies. First-year rosettes consist of kidney-shaped, garlic-smelling leaves; the second-year plant grows a stem up to four feet tall with triangular, sharply-toothed leaves. The small, four-petaled flowers are white and grow in clusters at the top of the stem. Garlic mustard produces large quantities of seeds which can remain viable for seven years or more.

Habitat: This woodland plant prefers some shade but is occasionally found in full sun. It invades upland and floodplain forests, savannas, yards, streams, trails, and roadsides throughout Ohio.

Management: Repeated prescribed burns in oak forests may be effective. Light infestations of garlic mustard can be hand pulled before or at flowering time. Plants should be removed from the site after pulling, as the seeds may continue to mature. Systemic herbicides can be applied to the rosettes in early spring or late fall.

Japanese Honeysuckle is a woody semi-evergreen vine with opposite, oval leaves. The flowers grow in pairs, are white to yellow, and very fragrant. Fruits, also in pairs, are purple to black berries. This vine climbs and drapes over native vegetation, forming dense patches.

Habitat: Japanese Honeysuckle thrives in disturbed habitats, such as roadsides, trails, fencerows, abandoned fields, and forest edges primarily in southern Ohio. Disturbances such as logging, road building, floods, and windstorms create an opportunity for this vine to invade native plant communities.

Management: Burning in combination with systemic herbicide application may be an effective control method. Herbicides can be applied to the leaves when native plants are dormant. Be aware there are native climbing honeysuckles in Ohio, such as Lonicera Dioica.

Japanese Knotweed is a shrub-like herb that grows up to 10 feet tall. Stems are smooth and the pointed leaves vary from broadly oval to almost triangular. Flowers are greenish-white and very small. The seeds are dispersed by wind. Once established, the plants spread by a system of underground stems reaching 60 feet.

Habitat: Japanese Knotweed can grow in a wide variety of habitats. It is found in open areas, such as roadsides, streambanks, and woodland edges, primarily in eastern Ohio. It spreads quickly and forms dense thickets.

Management: Knotweed is very difficult to control. Leaves may be sprayed or stems cut and treated with systemic herbicide.

Reed Canary Grass reaches 2-5 feet tall. The hairless stems gradually taper to flat and rough leaf blades 3-10 inches long. The flowers occur in dense clusters and are green to purple, changing to beige and becoming more open over time. The plant spreads aggressively both by seed and by forming a thick system of underground stems (rhizomes).

Habitat: This grass occurs in wetlands, such as marshes, wet prairies, meadows, fens, stream banks, and seasonally wet areas throughout Ohio. Reed Canary Grass has been planted widely for forage and erosion control. Native strains possibly occur, however introduced strains are thought to be more invasive. There is no reliable method to tell the two strains apart.

Management: A combination of burning or mowing with systemic herbicides is the best method of control; grass-specific herbicides applied with wick applicators are recommended in areas where native plants occur.

Multiflora Rose is a dense spreading shrub with widely arching canes and stiff, curved thorns. This shrub grows up to 15 feet tall with alternate, compound leaves of seven to nine oval leaflets. Multiflora Rose has numerous white flowers that produce clusters of small, red fruits. The fruits (called hips) are eaten by birds and mammals which help disperse the seeds. An individual plant can produce up to 500,000 seeds per year!

Multiflora Rose

Found in 78 out of Ohio's 88 counties. Its range is shown here in yellow.

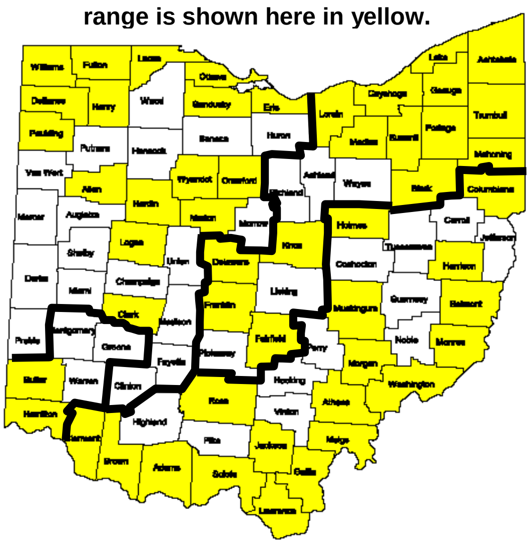
Source: The Nature Conservancy

Habitat: Multiflora rose was formerly planted as a "living fence" to control livestock, stabilize soil and create barriers for roadways. It has also been planted as a wildlife cover and food source. This rose occurs in a wide range of habitats throughout Ohio but prefers sunny areas with well-drained soils.

Management: A long-term management program of mowing or cutting and treating stems with systemic herbicide several times during the growing season is recommended. Digging or hand-pulling small shrubs may also be effective.

Purple Loosestrife

Found in 51 out of Ohio's 88 counties. Its range is shown here in yellow.



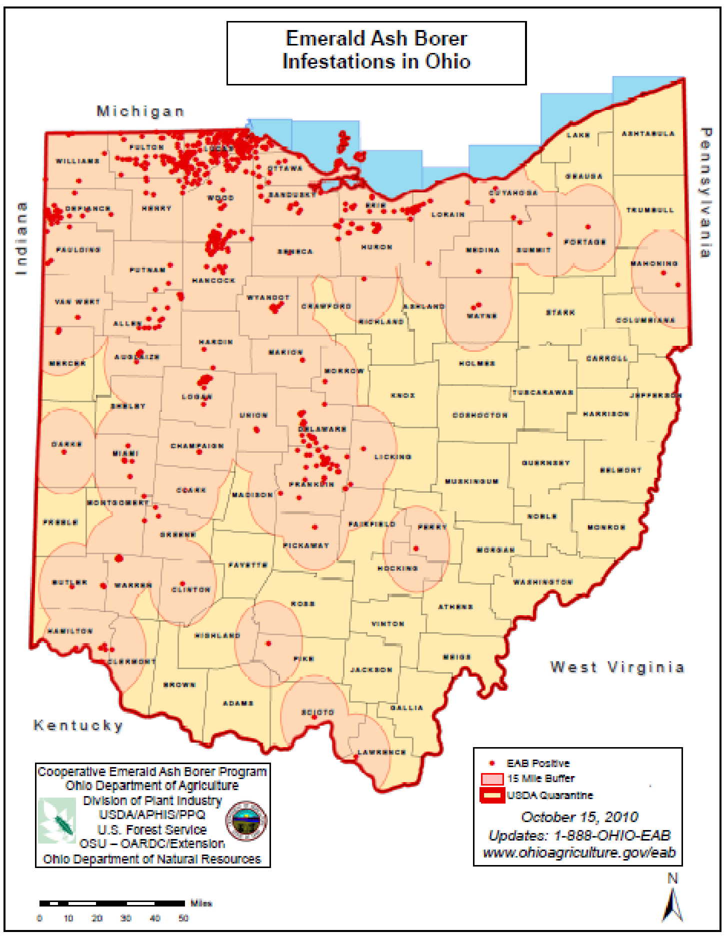
Source: The Nature Conservancy

Purple Loostrife grows 3-7 feet tall and has a dense bushy growth of 1-50 stems. Long spikes of flowers are purple to magenta; linear-shaped leaves grow opposite along the square stems. Purple Loosestrife spreads aggressively by underground stems (rhizomes) and can produce as many as a million seeds per plant. Supposedly sterile strains of L. virgatum will outcross with this plant and produce seeds.

Habitat: Purple Loosestrife grows in a variety of wetland habitats including marshes, river banks, ditches, wet meadows, and edges of water bodies, primarily in northern Ohio. Loosestrife can invade both natural and disturbed wetlands, replacing native vegetation with nearly pure stands of Loosestrife.

Management: Small stands of Purple Loosestrife can be controlled by hand-pulling, digging, or applying systemic herbicides to the foliage. Herbicides may be used to control large populations. Biological controls using insects are being researched in Ohio and other states and may be helpful in reducing infestations.

Of the 18 aquatic invasive species noted at the national level there are three the Ohio Department of Natural Resources specifically notes: the Round Goby, Eurasian Ruffe and Zebra Mussel. The Round Goby and Eurasian Ruffe are species of fish which have proven in all Great Lakes region to rapidly increase in numbers and some have seen a decrease in native fish populations. Exact counts and range of impacted waters are difficult to determine. Often sport fishermen are the first to confirm their presence. The Zebra Mussel is a mollusk found throughout Lake Erie and in a few inland lakes that will attach to any unprotected surface which may include native clams. All three species pose the greatest threat to Lake Erie with the potential of moving inland. The counties immediately impacted are Lucas, Ottawa, Sandusky, Erie, Lorain, Cuyahoga, Lake and Ashtabula.



The Emerald Ash Borer is currently found in 50 of Ohio's 88 counties, six neighboring states and the province of Ontario. From its initial detecting in Northwest Ohio the insect has spread south to the Ohio River in the south and Pennsylvania in the East. One of the greatest problems increasing the spread of the insects is the transport of infected firewood. Quarantine areas have been established making the transport of firewood across county lines illegal. As of September 8, 2010, all 88 counties in the state comprise Ohio's quarantine area.

Past Occurrences

Invasive species of plants, fish and insects have been arriving in Ohio since the establishment of European settlers in the 1750s. With each improvement in the scale and speed of human transportation, the potential for unintended introduction of invasive species has increased. Organisms which could not survive the month-long journey from Europe or Africa to America can make the journey in a matter of hours today. Several examples of species introduction pathways follow:

The Round Goby species was introduced from Eurasia into the St. Clair River and vicinity on the Michigan-Ontario border where several collections were made in 1990 on both the U.S. and the Canadian side. Speculation exists the Goby was transported from its native Caspian Sea by way of ballast tanks on ocean going vessels. Today the Goby is found in all the Great Lakes and is making inroads in all contiguous state watersheds.

The Multiflora Rose was introduced to the U.S. from Japan in 1886 as an under-stock for ornamental roses. Birds are responsible for spreading the seeds, which remain viable for a number of years. In the 1930s, the Soil Conservation Services advocated the use of Multiflora Rose for erosion projects and as a way to confine livestock. Hedges of Multiflora Rose have also been used as a crash barrier and to reduce headlight glare in highway medians.

The Emerald Ash Borer was introduced into North America sometime in the 1990's. The insect is believed to have been introduced into the U.S. in wood packing material from China. It was first reported killing ash trees in the Detroit and Windsor areas in 2002. Only species of ash are hosts for the beetle, which usually kill infested trees within a couple of years. Since then, infestations have been found throughout Lower Michigan, Ohio, northern Indiana, the Chicago area, Maryland and recently in Pennsylvania.

Considering the thousands of plant, dozens of aquatic and unknown number of insect species introduced into Ohio over the past 250 years samples of the most often cited transfer media are provided here. Exotic species can arrive by a nearly endless number of vectors making a complete listing impossible.

Probability of Future Events

Since the beginning of European colonization non-native species have been arriving in Ohio. With the increase in global trade and travel the probability of new and unexpected species arriving in Ohio will continue to grow. Legislation is in place around the world in an attempt to control the migration of unwanted species between ecosystems. The ODNR is currently battling the entrance of wild boars from Kentucky and West Virginia. In addition, there are several species of carp currently migrating up the Mississippi watershed from the Gulf Coast. Although not currently reported in any Ohio waterways, the probability of future infestations is near certain.

It is certain that new wanted and unwanted species will arrive in Ohio. The importance of controlling the integrity of existing ecosystems will require ongoing state, national and international efforts to avoid unwanted infestations.

VULNERABILITY ANALYSIS & LOSS ESTIMATION

Methodology

Impacts of invasive species tend to have commercial operational impacts, as opposed to many built environment impacts of the other hazards covered. Due to this unique situation, rather than a matrix of counties and losses the loss estimates will be presented using historical response costs to predict future losses in unadjusted dollars.

Results

From the perspective of invasive plant species the Multiflora Rose is one of most expensive to combat in Ohio. Each individual plant's ability to produce 500,000 seeds a year allows this invasive species to spread over large area with incredible speed. Agricultural groups are facing the highest exposure and expense in the form of infiltration of crop lands and eradication programs. According to agricultural experts associated with The Ohio State University, Ohioans are estimated to spend millions of dollars combating the Multiflora Rose. Precise dollar figures are not available due to the majority of response activities being performed by non-governmental entities.

Four known methods of responding to the species exist. First, the removal of the plant as a whole, including the roots, can be cost effective in small applications. Second, repeated defoliation or mowing down the plants will eventually kill almost any plant. Third, the use of herbicides can be effective if applied at specific stages of the plant's growth. All of the above management techniques can be expensive and labor intensive. The last method is the use of Rose Rosette Disease, a mite-vectored virus, which is giving rise to a hope for a lower cost control agent.

Turning to invasive aquatic species, the Zebra Mussel is one of the most expensive to control. The mussels naturally collect on any solid surface and create significant problems for drinking water processing facilities and utilities. All in-water structures are impacted including, but not limited to, piers, breakwalls, vessel hulls and vessel engines cooled with external water. Estimates for controlling infestations run between $2 and $10 million per year depending on how many sources are aggregated. Should the Zebra Mussel effectively invade the river systems of Ohio, it is suggested the annual control costs could raise 10-fold.

Invasive insect species are both the direct source of damage to trees and a vector for other parasites. In the last century the north American population of Elm trees was decimated by a fungus which arrived on infected trees shipped to an Ohio furniture company. One of the primary transport methods is though beetles which the fungus uses as a host to move from tree to tree. The beetle's ability to fly exponentially increased the number of trees impacted. Trees located in non-urban areas posed financial impact only to loggers; however, the Elm was a popular urban tree and the cost to remove them ran into the millions over the years.

The Emerald Ash Borer, which is currently impacting the North American Ash tree, has already cost millions of dollars in attempts to identify and isolate infected trees. In Ohio alone there are an estimated 5 billion Ash trees at risk. Although many research centers are searching for an effective means of combating the insect, the only method currently available is the use of insecticides which have to be applied annually. The un-captured cost to treat Ash trees in Ohio will likely reach into the millions, as urban areas combat the insect.

STATE-OWNED / CRITICAL FACILITIES VULNERABILITY ANALYSIS & LOSS ESTIMATION

Unlike many of Ohio's other hazards, invasive species have very limited impact on state-owned facilities. The most prominent impact to state facilities relates to the maintenance of marinas in Zebra Mussel impacted areas.

Since invasive species are not fixed hazards and have the potential to affect all state-owned structures and critical facilities in the state this section defaults to the overall discussion of state-owned structures and critical facilities identified in section 2.1., Table 2.1.a, and Appendix C.

2.14 LAND SUBSIDENCE

Subsidence is motion of the Earth's surface as it shifts downward relative to a benchmark (often sea-level) of the surrounding terrain. There are a number of causes for this effect. In Ohio the two primary causes are abandoned underground mines (AUMs) and karst.

Underground mining of coal began in the early 1800's and continues to current day. In the 1900's underground salt, limestone and gypsum mining began. Most mining is accomplished by direct human action utilizing heavy machinery to remove the material; however, with salt there are cases where pressurized water is used to wash-out the deposit (solution mining). All of these mines create voids under the Earth's surface. Several key factors determining the potential for these voids to collapse include depth, mining technique used, types of rock and or soils and development on the ground surface.

Abandoned underground coal mines in Ohio have the added environmental impact of discharging acidic water. It is common for coal mines to become charged with water. The collected water interacts with the remaining coal deposit and other materials becoming acidic. If acidic mine water is discharged into creeks or streams it can alter the chemical composition of the water habitat. Cases exist where changes in water acidity have caused sensitive aquatic life considerable harm.

Karst topography in Ohio is a landscape shaped by the dissolution of a soluble limestone or dolomite layers of bedrock. As surface water percolates down to the water table, it slowly dissolves away the limestone or dolomite creating voids under the Earth's surface. In cases where a visible depression is present, surface water may flow directly to the water table. Depending on the depth of the void, there may be no observable ground surface deformation. Deep voids may exist at or below the water table and, as a result, the rock is replaced by water. Long-term changes in the water table could destabilize deep voids resulting in surface deformation as observed in southern Missouri and northern Arkansas. Shallow voids are often underground caves or caverns, which lack any replacement support. With time, the roof of these voids may collapse and result in ground failure.

Once a hole or fissure appears in a karst area, surface water can travel directly to the aquifer bypassing the natural filtration and cleaning processes. The result has been contamination of aquifers from farm chemicals, animal waste, along with oil and gasoline from roadway runoff. Cases exist where aquifer contamination resulted in making the water unfit for human consumption. Also, karst topography can result in unusual flooding when water tables are high. Such flooding issues are difficult to address.

The last form of land subsidence in Ohio is associated with soils, which dramatically expand when wet and contract when dry. Structures built on these soils can experience significant shifting as the ground saturates and dries.

Currently there are no commercial insurance carriers which offer mine subsidence coverage in Ohio. In response to gaps in commercial insurance availability, the Ohio FAIR Plan underwriting association was established in 1968 to provide a variety of essential insurance products for eligible properties unable to obtain insurance through the voluntary market. The Ohio Mine Subsidence Insurance Underwriting Association provides eligible Ohio counties with mine subsidence insurance (see Map 2.14.a). Under the program 26 primarily Appalachian counties (Region 3) are required to carry mine subsidence insurance at a cost of one dollar annually. Additionally, eight counties in Region 2 and three counties in Region 1 are eligible to obtain insurance at the owner's discretion at a cost of five dollars annually. The remaining 51 counties are not eligible for mine subsidence insurance.

HAZARD PROFILE

Location

Beginning in the 1700s and continuing to today there has been considerable coal mining in the Appalachian region of Ohio. In addition to coal, several salt, clay and gypsum mines opened in counties close to Lake Erie. Finally in central and southwestern Ohio there are several isolated mines (see Map 2.14.a).

The majority of abandoned mines are located in, or directly adjacent to, Region 3, and most of these were coal mines. Coal mine depths can range from less than 100 feet below the surface to 1,000 feet or more. There are a number of methods which can be employed to remove a coal deposit, whether accomplished by hand/pick or machines. As the coal vein is removed, oftentimes pillars of coal are left at intervals to support the mine roof. In some cases as the mine vein is depleted and miners withdraw, the pillars were removed. In these situations the depth of the mine becomes important. Deeper mines, with solid layers of rock (*i.e.*, strata) above the void and limited soil at the surface, are less likely to fail than those closer to the surface. The ODNR, Division of Geological Survey and the Ohio Department of Transportation (ODOT) have developed profiles of voids, support strata composition and surface soils for a limited number mines to assist in understanding the potential for subsidence events. Analysis requires experts trained in geology and significant time, which limits the number of sites assessed.

Other minerals mined include gypsum, clay and limestone, primarily in Ottawa, Preble and Butler Counties. Finally, very limited exposure to abandoned mines exists in Hamilton, Lucas, Erie, Delaware and Licking Counties, where the mineral being extracted was not available.

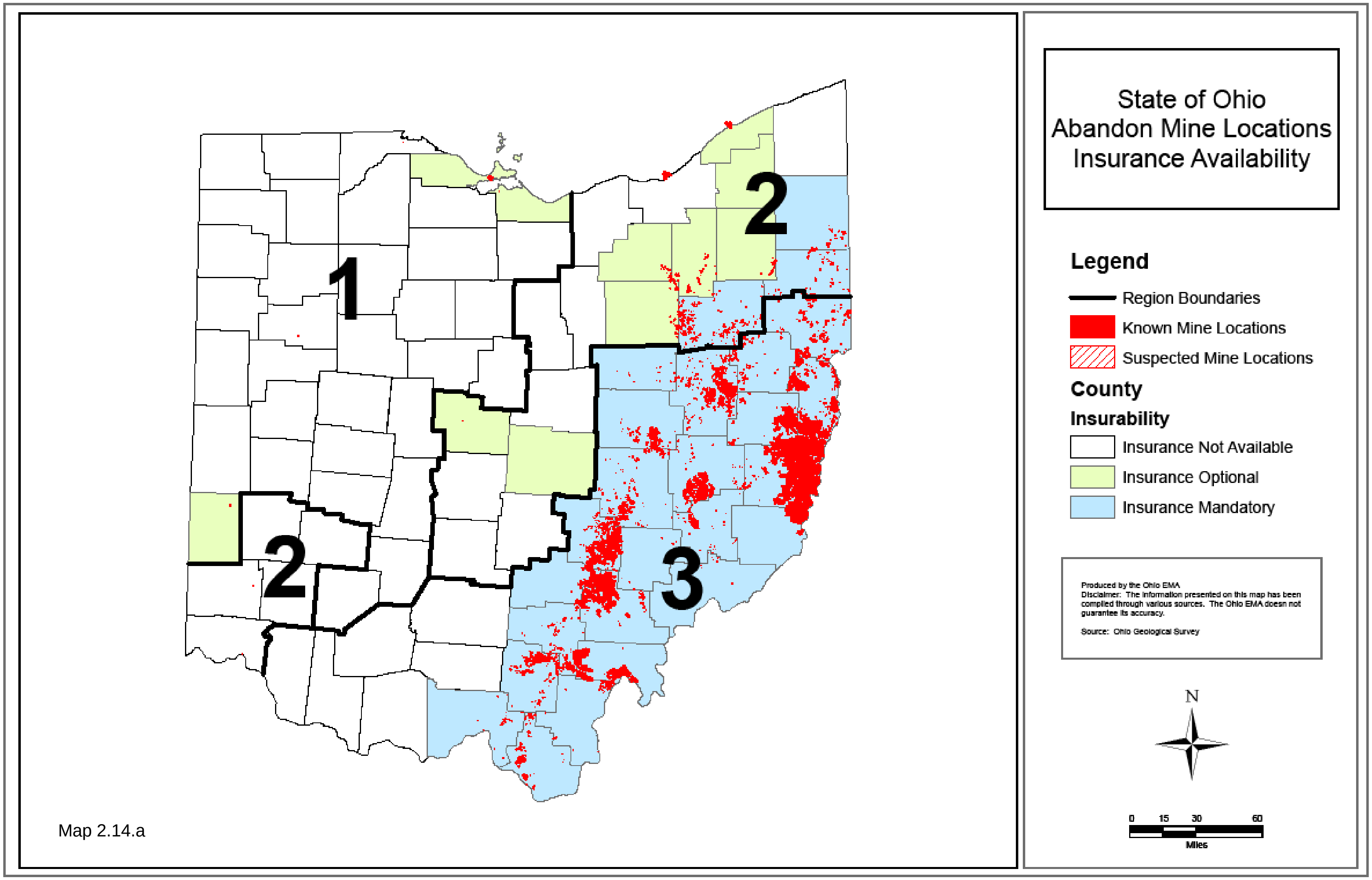
Karst features are associated with the western third of Ohio, excluding the far northwestern counties of Williams, Fulton and Defiance (see Map 2.14.b). Nearly all of Region 1 and the far western sections of Regions 2 and 3 are impacted by karst geology. The limestone, shale and dolomite layers were deposited between 408 and 505 million years ago as the floor of an ancient sea. Later, the continental plate would rise above the existing sea level creating dry land and vast salt deposits. These sedimentary rock layers are naturally porous and dissolve into the water which passes though them.

The current landscape in the karst region of Ohio was created by glaciers as they advanced from the north reaching to the Ohio River roughly 14,000 years ago. When the last glacier receded it left behind a layer of unconsolidated material in a wide range of depths. The shallower the loose material layer, the greater the chance of water penetrating to the underlying bedrock, resulting in a void or ground deformation occurring. This is represented by the probable karst areas on the map which group into two significant clusters. In the south, the greatest impacted counties include Brown, Adams and Highland. In the north, the greatest impacted counties include Seneca, Huron, Erie, Sandusky and Ottawa.

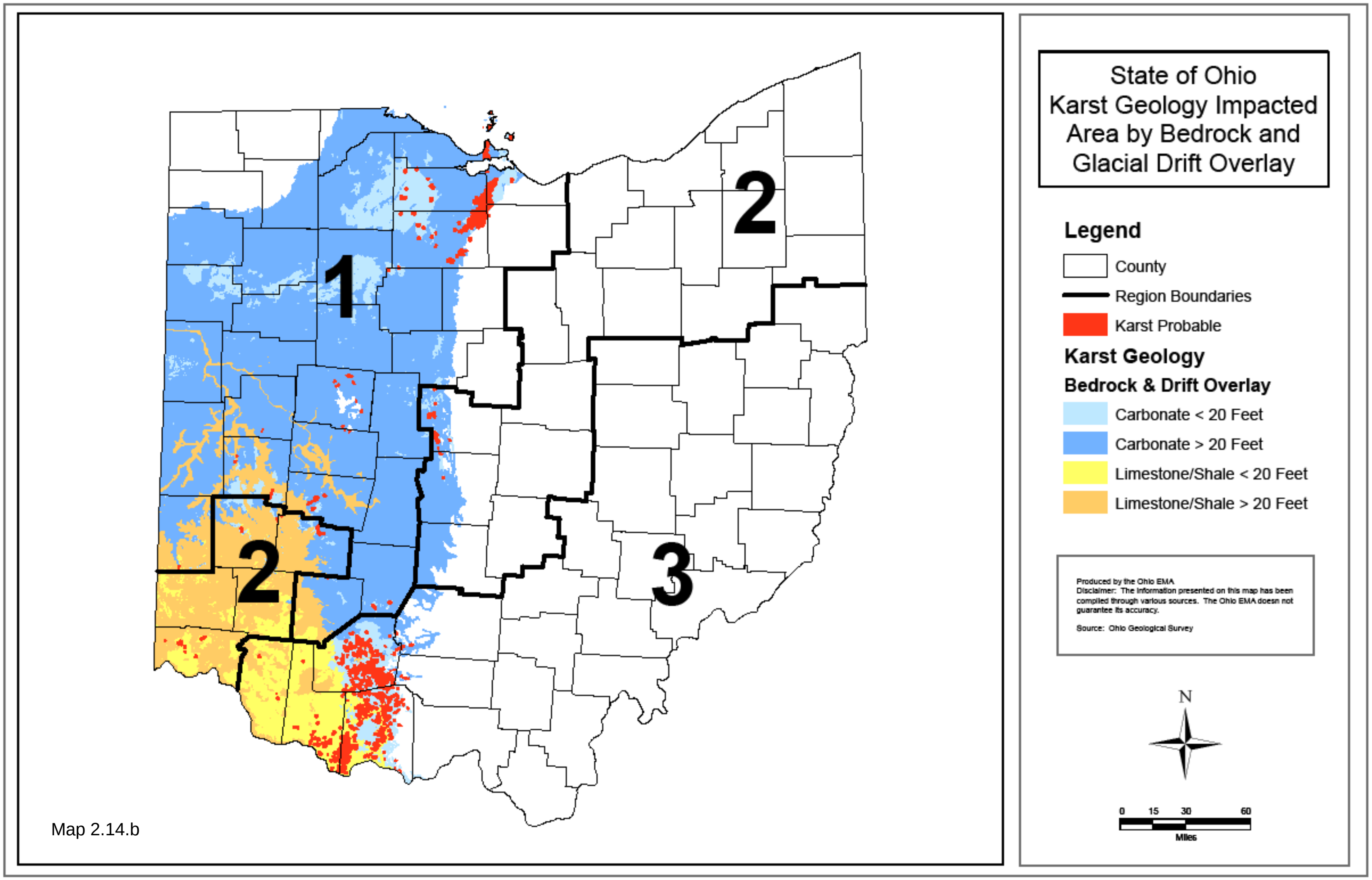
Areas which are reclaimed strip mines and other type of soils poorly suited for development are often mapped by local communities and the Ohio Department of Natural Resources. Ohio's built environment exposure to this type of hazard is very limited.

LHMP Data

The City of Bellevue is located within the Bellevue-Castalia Karst Plain and resides within four counties; Erie, Huron, Sandusky, and Seneca. Of these counties, only Sandusky County's LHMP indicated that land subsidence was a hazard risk. They recognized that land subsidence, in the form of sinkholes, has a potential to occur; but also notes that there have been no incidents of land subsidence that has resulted in the damage of structures, personal injury, or loss of life. An area of concern for Sandusky County, in regards to land subsidence, is a Class I dam that is located in the southeastern portion of the county.


State of Ohio
Abandon Mine Locations
Insurance Availability
1
2
2
3
Legend
Region Boundaries
Known Mine Locations
Suspected Mine Locations
County
Insurability
Insurance Not Available
Insurance Optional
Insurance Mandatory
Produced by the Ohio EMA
Disclaimer: The information presented on this map has been compiled through various sources. The Ohio EMA doesn not guarantee its accuracy.
Source: Ohio Geological Survey
N
0 15 30 60
Miles

Map 2.14.a


State of Ohio
Karst Geology Impacted
Area by Bedrock and
Glacial Drift Overlay
Legend
County
Region Boundaries
Karst Probable
Karst Geology
Bedrock & Drift Overlay
Carbonate < 20 Feet
Carbonate > 20 Feet
Limestone/Shale < 20 Feet
Limestone/Shale > 20 Feet
Produced by the Ohio EMA
Disclaimer: The information presented on this map has been compiled through various sources. The Ohio EMA doesn not guarantee its accuracy.
Source: Ohio Geological Survey
N
0 15 30 60
Miles
1
2
2
3

Map 2.14.b

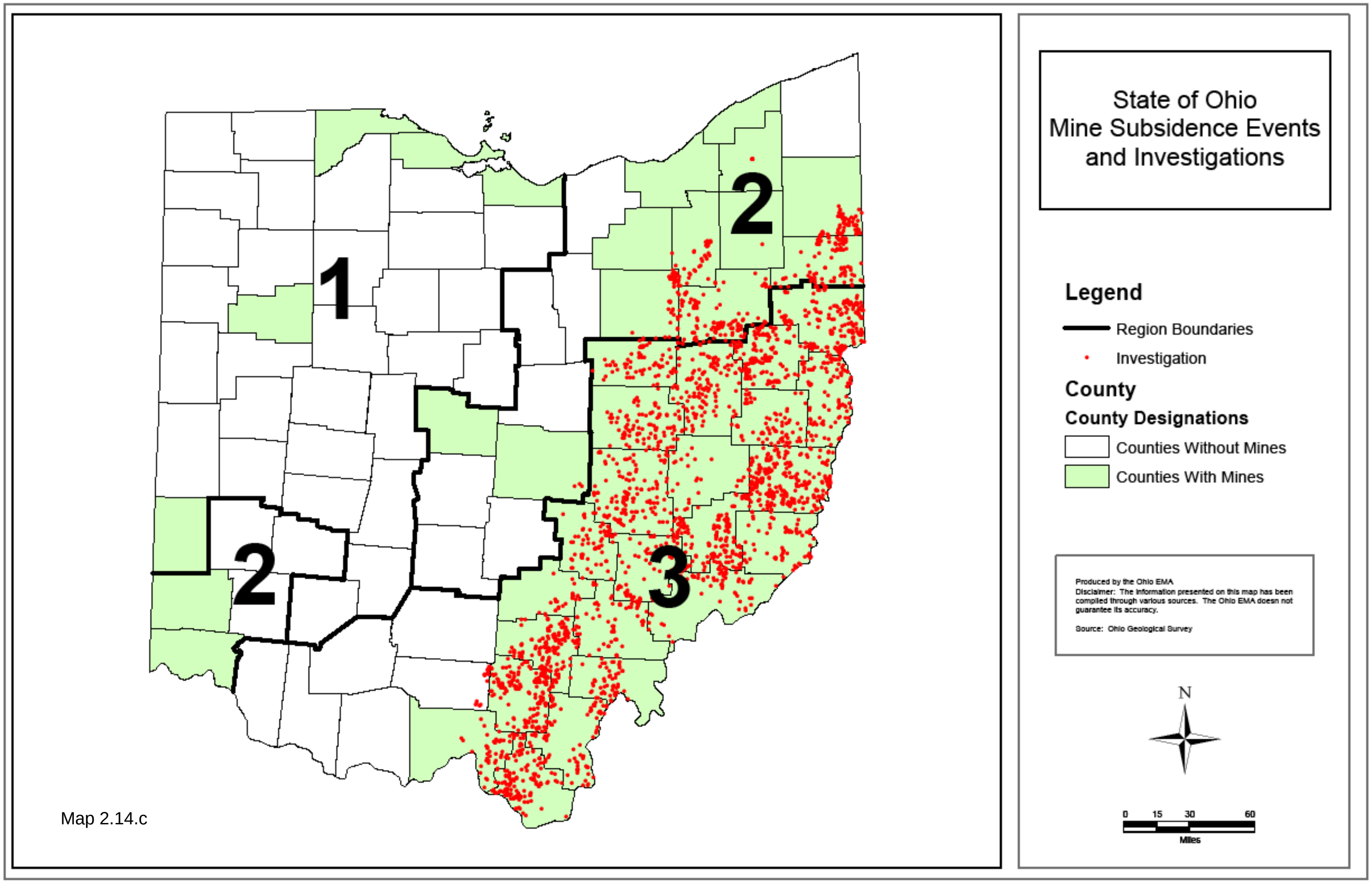
However, Sandusky County, at this time, considers land subsidence and dam failure as having a low mitigation potential and have no current mitigation activities or plans for them.

Past Occurrences

Abandoned underground mines in Ohio are monitored by the Ohio Department of Natural Resources, Division of Mineral Resources Management, which is primarily federally funded. Within the division, two programs exist to address mine subsidence: one for emergencies and a second for non-emergencies. Inspectors institute an investigation for every reported occurrence. The inspector uses several criteria to classify the emergency status of the event by determining first if it is mine related, second if there is an imminent and substantial threat to the public or the environment and finally if the onset was sudden and not part of a prolonged event. The emergency program gives priority to events which are directly affecting a structure (within 300 feet) or transportation route. Each year between 50 and 60 investigations are completed generating 25 to 30 projects. Of those investigations, approximately five or six represent damage to a structure (see Map 2.14.c). When an event is classified as an emergency, federal concurrence is requested followed by a streamlined engineering evaluation and hiring of a contractor. The time between the event and response is often within one week. Projects are undertaken to protect lives and property and can range from simple precautions to filling the void with cement to stabilize the area affected.

Subsidence events that do not qualify as emergencies (where people and infrastructure are not directly involved) must follow the standard state project development and bid process. Repeated emergency incidents can lead to larger non-emergency response. The City of North Canton (Region 2), Village of Cadiz (Region 3) and Village of New Lexington (Region 3) each experienced repeated emergency events culminating in area-wide engineering studies to address the problems. In each case comprehensive mitigation activities, including the installation of in-mine support columns and the filling of voids, stabilized large areas which were subsidence-prone.

The ODOT has inventoried over 1,200 sites where abandoned underground mines underlie state highways, U.S. routes, and interstate highways. Since 1998, ODOT has been actively inventorying these geologic hazards and conducting risk assessments to determine the potential impact on the state's transportation infrastructure. The statewide inventory and risk assessment of these mine sites continues. However, there are an estimated 7,000+ underground mines across Ohio. As of 2005, only 50% of these mines had been recorded in the state's (ODNR) database. Approximately 2,700 of the 7,000 underground mines are unmapped. Both mapped and unmapped underground mines pose a continuing threat of subsidence to Ohio's transportation system.


State of Ohio
Mine Subsidence Events
and Investigations
1
2
2
3
Legend
Region Boundaries
Investigation
County
County Designations
Counties Without Mines
Counties With Mines
Produced by the Ohio EMA
Disclaimer: The information presented on this map has been compiled through various sources. The Ohio EMA doesn not guarantee its accuracy.
Source: Ohio Geological Survey
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0 15 30 60
Miles

Map 2.14.c

Whenever an event affecting transportation infrastructure occurs, an initial site investigation is launched. The first step in the process involves the collection of basic information on the location, type of event, geologic setting, mining information for the area, impact on the roadway, and how it was discovered. The next step involves a site reconnaissance and the completion of a series of data collection forms starting with the Initial Site Evaluation. Compiled information is then used by the geologist or engineer to complete the risk assessment rating form. Each inventoried site receives a matrix score based on standardized criteria and scoring methods. Some examples of key scoring criteria are: number of surface deformation features, number of mine openings, thickness of unconsolidated material over the mine, thickness of rock overburden, height of the mine void(s), average daily traffic volume, hydrology, and secondary mining evidence. The overall rating provides ODOT a planning tool to prioritize sites across the state for remediation. With limited resources and the large number of mine subsidence problems, the abandoned underground mine inventory and risk assessment provides ODOT the means to direct expenditure of funds in a cost-effective and logical manner.

The most notable event occurred in 1986 when an abandoned mine located in Guernsey County collapsed underneath Interstate 70 resulting in the closure of the entire interstate. Remediation included stabilizing the void and repairing the damaged roadway costing over $10 million dollars.

Underground salt mining under Lake Erie has not generated any known subsidence to date; however, solution mining in Lake, Summit and Medina Counties has. The most dramatic case in Ohio is in the Lake County community of Painesville where an abandoned mine is responsible for a six foot surface depression. Due to the proximity of the impacted area to Lake Erie, it is now filled with water. Other solution mines in Summit and Medina counties have experienced minor surface impacts. The potential affect of salt mining is epitomized in the failure of the Retsof mine in New York. The event was first misinterpreted as an earthquake. The collapse of the mine roof resulted in several 50-foot deep sinkholes, which closed roadways, produced changes in the aquifer, and caused the release of methane and hydrogen sulfide gases.

Until recently, Karst events in Ohio had very little direct impact from a subsidence perspective on the built environment; however, they have been very costly in terms of pollution and flooding. Two well documented karst related events deal with contamination of aquifers. The oldest researched event in Ohio is associated with the Village of Bellevue straddling the Huron / Sandusky County border. The 1961 study documents how from 1919 to 1946 the community permitted untreated wastewater injection wells and unimpeded groundwater runoff into sink holes as an acceptable water management program. In 1946 after the groundwater was determined unfit for human consumption, the Village abandoned its last well and has since spent millions of dollars to develop a potable system based on piping water from safe sources. In February 2008, more than 200 homes experienced flooding in Bellevue when runoff from heavy snows and spring rains flooded underground karst chambers. Experts believed building pressure caused the pent-up water to surge up existing sinkholes and cracks, flooding homes and yards. A section of State Route 269 was swamped from February through June 2008.

The Village of Put-in-Bay, located on South Bass Island in Lake Erie, was the site of an extensive gastrointestinal illness outbreak in 2004. The island is a popular warm-weather tourist destination and, at the height of the season, over 1,000 cases of digestive related maladies were documented in people who had recently vacationed there. The investigation began with the municipal systems and quickly shifted to a number of transient non-community public water systems used for geothermal cooling, flushing toilets and outdoor cleaning. These systems were found interconnected to the main water system. The karst topography allowed groundwater to travel quickly between locations and is easily affected by seasonal precipitation.

The only known karst-related subsidence impact to the built environment is roadway damage. In 2007 State Route 19 was closed in Crawford County when an adjacent karst feature expanded destabilizing the road bed. Engineering studies including sonar and LIDAR analyses of the associated void are underway to determine the extent of the developing cavity and to determine a long-term solution. Although this is the first documented event where damage to the built environment can be directly attributed to karst formations, there is an effort underway thought the ODOT to collect detailed historical data of karst-related roadway impacts to better understand and address future events.

During the construction of U.S. Route 33 near East Liberty, karst was encountered. Construction crews had to perform considerable back-filling and reinforcing, creating a land-bridge to make sure the highway was secure.

Another example of the impact of karst was the construction of tunnels for sewage pipelines by the City of Dublin (Franklin County). Sinkholes, filled with clayey overburden caused the expensive rock-boring machinery to clog and break, resulting in tremendous cost overruns.

Finally, one housing development in the City of Westerville (Franklin County) contains homes which have been dislodged and damaged by the effects of soils which dramatically expand when wet and contract when dry. Since 2000 the Ohio EMA has purchased 6 damaged homes; however, this is the only known impact from this form of land subsidence.

Probability of Future Events

Mine-related land subsidence is an annual event impacting an average of five homes or roadways. Approximately 20 additional events occur each year that do not impact the built environment, yet may require remediation.

Unlike mine-related events, karst events historically have manifested their impact in the form of groundwater contamination. Based on past exposure, a significant event occurs approximately each decade. As the ODOT begins to collect detailed data regarding the impact of karst events on federal highways, both the profile of the hazard and frequency of occurrence may experience significant change.

VULNERABILITY ANALYSIS & LOSS ESTIMATION

Methodology

The only predictable impact which can be quantified for analysis is damage to Ohio's roadways. The Ohio Department of Transportation, Office of Geotechnical Engineering has a comprehensive inventory of the federal and state routes which intersect with known and estimated abandoned mines. The location, length of each segment, potential for failure, along with a host of other data is maintained in a database. The failure potential is broken into three categories: high, with failure expected within 50 years; medium, with failure expected within 100 years; and low, with failure expected beyond 100 years. The segments are reported by length of the segment, with a 500-foot buffer, and the number of road lanes. The final and key piece of information supplied is the proven cost of $1,000,000 per lane mile to replace roadways impacted by mine subsidence. For loss estimates that full cost per-mile is used, with 50% and 25% used for medium and low, respectively.

STATE-OWNED / CRITICAL FACILITIES VULNERABILITY ANALYSIS & LOSS ESTIMATION

Land subsidence is a spatial hazard and has the potential to affect few, if any, state-owned structures and critical facilities, but as seen could impact numerous lifelines. Beyond this the default section for the discussion of state-owned structures and critical facilities is in Section 2.1, Table 2.1.a, and Appendix C.

2.15 FUTURE GROWTH AND POTENTIAL RISK AREAS

This edition of the state plan has the requirement to address future growth throughout Ohio and what impact natural hazards will have upon it. To determine growth patterns, the Ohio Office of Strategic Research published cumulative county statistics that were reviewed. The profiles cover a broad range of characteristics ranging from demographics to taxable land value. The percentage of population growth or decline was calculated for the current planning period in counties where change was indicated. Since the approval of the original mitigation plan, the State of Ohio has had very little change in population, with relatively equal numbers of increases and decreases.

Two counties were found to have double-digit population growth in Ohio; Delaware (Columbus Metropolitan Area) and Warren (Cincinnati Metropolitan Area). The Delaware county multi-jurisdictional mitigation plan clearly describes the problems associated with double digit increases in population and the associated growth of the built environment. Large sections of farmland are being developed into residential housing, retail commercial facilities and office parks with the associated roads and parking areas. As a direct result, older neighborhoods adjacent to local waterways have experienced a marked increase in water levels and flows during rain events. The county has a clear understanding of the problems, their implications and is working to address them through mitigation planning and educational outreach. Part of the difficulty in addressing the situation is that the growth areas are creating high value real estate for Ohio, while the impacted areas range from mobile home parks to older structures built in or close to the floodplain. Over time the size of the 100-year regulatory floodplain can be expected to increase due to development. Two other greater Columbus counties, Union and Fairfield, showed moderate growth, however no adverse impacts were observed.

The Warren County Regional Planning Commission has planned for structured growth, which has resulted in minimal adverse impact. The Warren County multi-jurisdictional mitigation plan outlines the program objectives to:

- Discourage small, isolated subdivisions where soil conditions and lot size are not conducive to on-site wastewater disposal systems, where applicable;
- Encourage a logical pattern of residential development where future growth would occur in proximity to existing residential areas, within the designated Urban Service Areas of the township;
- Build multi-family housing at a scale that can accommodate the need, combined with prudent use of the Planned Unit Development process, to accomplish quality development, mitigating the impact of county utilities and other public services;
- Develop adequate, well designed and affordable housing for the elderly population, the handicapped and families with children;

- Give a stronger emphasis to establishing open space/green belt areas, separating developing residential areas from incompatible uses;
- Establish a system to encourage housing maintenance through a coordinated, ongoing inspection program by county and local officials;
- Encourage the repair or removal of dilapidated/substandard structures;
- Identify, document and protect older homes or residential areas of historical and/or architectural significance from unwanted, incompatible land uses; and
- Explore the establishment of an historical zoning district to protect individual structures or neighborhoods of historical and/or architectural significance.

2.16 CONSEQUENCE ANALYSIS

The EMAP standard for a HIRA requires the state program to include a consequence analysis for hazards identified in state HIRAs. The consequence analysis should consider the impact on the public; responders; continuity of operations including delivery of services; property, facilities and infrastructure; the environment; the economic condition of the state, and public confidence in the state's governance.

Impact on the public

Based on the HIRA in the SOHMP, there is neither record of a historical event or impacts as identified in the vulnerability analysis that would be considered catastrophic from a statewide perspective. Historically, other than emerging disease/pandemic outbreaks, hazard events in Ohio tend to be moderate in size – possibly approaching widespread, but not necessarily rising to the level of catastrophic. Three natural hazard events that may have a broader impact on the public would be a large earthquake on the New Madrid fault, a statewide blizzard (such as the blizzard of 1978) or a widespread flood (Great Flood of 1913). Still, the impacts on the public from these three events would be moderate. Perhaps the hazard with the greatest impact on the public (in terms of numbers of individuals adversely affected) would be an emerging disease/pandemic outbreak or a terrorism event that included a nuclear dispersion device.

Impact on responders

Because it is unlikely that hazard event would be widespread enough in Ohio to be "catastrophic," existing mutual aid mechanisms and the ability to exercise Emergency Management Assistance Compact (EMAC) should be sufficient to handle any hazard event. The exception to this may be an emerging disease/pandemic outbreak.

Continuity of Operations (COOP)

Communities and the State of Ohio continually develop and update COOP plans in the event facilities and/or agencies are impacted. State agencies also maintain disaster recovery plans which are largely IT focused. It is expected that affected agencies would exercise their COOP plans as appropriate. Private sector businesses are encouraged to develop business continuity plans, but they are not mandated by the state.

Property, facilities, and infrastructure

The SOHMP has attempted to collect and create risk assessments and vulnerability analyses for the different hazards it profiled. One note of caution in utilizing these data is that aggregate dollar damage amounts and facilities affected by a multi-county region are for purposes of comparison in the SOHMP only. The SOHMP does not imply that a whole region would actually have an event occur where the maximum damages are sustained in all of the counties identified in the region.

Environment

Certainly any hazard event has the potential for environmental impact. Flood events for example may result in pollution of streams and rivers due to combined sewage overflows, and a tornado/wind event will disperse materials, trash and debris over a widespread area. A drought may affect the environment in a different way by drying up wetlands, and weakening/killing trees and forestlands. The three hazards that have a significant potential for environmental impact are: nuclear detonation/dispersion, emerging disease/pandemic outbreak, and flooding.

Economic condition of the state

Because most hazards in Ohio would not result in a statewide catastrophe, the economic impacts, while potentially severe, would be recoverable. Also, Ohio has a diverse economy even though there are areas where certain segments of the economy are concentrated (manufacturing in Cleveland/Akron/Youngstown, for example). From a geographic perspective, an event that would affect the greater Cleveland, Columbus, or Cincinnati area would have a greater impact than would a hazard affecting other areas of the state. Similarly, an invasive species or pest that would affect the corn or soybean crop statewide, or a drought, might result in a more widespread deterioration of the economic condition of the state. Finally, an event affecting Columbus (Franklin County), as it is the seat of state government, could have a significant impact as centralized processing of payments to citizens for a variety of programs could be interrupted.

Public confidence in state governance

As has been demonstrated in catastrophic events in other states and countries, public confidence in state governance is tightly linked to the government’s response to a hazard event. Even in more regionalized or local disasters this is the case; although, the effect of the disaster on public confidence is similarly regionalized or localized. The hazards most likely to have a widespread effect on public confidence in state governance are those that either have the probability of statewide effect (drought, blizzards), those that have a high impact or consequence (terrorism, nuclear detonation/dispersion, emerging disease/pandemic outbreak) and those that have a short speed of onset (terrorism).