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Michigan Department of State Police

Michigan Hazard Analysis

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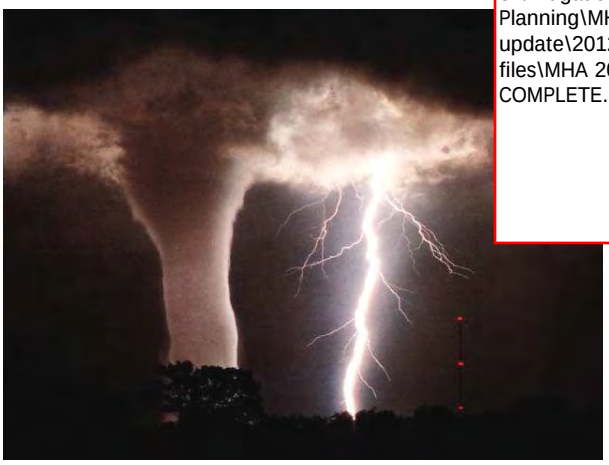

Hail • Lightning • Ice and Sleet Storms • Snowstorms • Severe Winds • Tornadoes • Extreme Temperatures Fog • Riverine Flooding • Great Lakes Shoreline Hazards • Dam Failures • Drought Wildfires • Invasive Species • Earthquakes • Subsidence • Celestial Impact • Structural Fires • Scrap Tire Fires • Hazardous Materials Incidents: Fixed Site • Nuclear Power Plant Emergencies Hazardous Materials Incidents: Transportation • Petroleum and Natural Gas Pipeline Accidents • Oil and Natural Gas Well Accidents Infrastructure Failures • Energy Emergencies • Transportation Accidents • Catastrophic Incidents • Civil Disturbances • Nuclear Attack • Public Health Emergencies • Terrorism and Similar Criminal Activities

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INTRODUCTION

Michigan is vulnerable to a wide range of natural, technological and human-related hazards. Periodic disasters result from floods, tornadoes, winter storms, severe thunderstorms and other events, causing injuries and loss of life, disruption of services, economic impacts, and significant property damage. Such events often have negative impacts on the affected communities long after the recovery has been completed. Major disasters such as the 2010 Enbridge oil spill, the 2008 derecho, the 2004 floods, the 2003 power outage, the 1997 and 1998 severe thunderstorms, the 1987 crash of Northwest Airlines Flight 225, and the 1953 Flint tornado that killed 115 persons, have heightened awareness of Michigan's vulnerability to such events.

Advancements in technology, increased development and use of hazardous materials, and vulnerabilities in public and private utility infrastructure have resulted in a new range of technological hazards. Major incidents have increased public awareness and concern about technological threats in Michigan. In addition, human-related threats can cause significant injuries, loss of life, and property destruction. Public health emergencies, terrorism and similar criminal incidents, and the impacts of civil disturbances are examples of some of the wide array of problems that emergency managers must address in their hazard mitigation and emergency preparedness efforts.

Emergency managers must also consider how events in other States may affect Michigan communities. The terrorist events of 9/11 (and subsequent anthrax threats) had a national effect. When New Orleans was struck by hurricanes, Michigan was active in providing assistance to Louisiana, as well as receiving and housing evacuees from that area. A major disaster or national-level emergency might occur in the form of a New Madrid earthquake, another act of major terrorism, cyber-attack, or some other event that is of national significance even if it doesn't directly harm Michigan's physical territory. The era of globalization means that distant events tend to affect prices, supplies of goods and energy, communication and information systems, and other services that are important to Michigan's residents, businesses, and agencies.

Managing these varied threats to protect life and property is the primary challenge faced by emergency managers at all levels of government. In order to meet that challenge, emergency managers must first obtain a thorough understanding of the array of hazards that confront the state. The first step in the process of building an effective emergency management capability is the preparation of a hazard analysis that provides an understanding of that array of threats.

Through the process of conducting a detailed hazard analysis, emergency managers become aware of the nature, extent and magnitude, and destructive potential of the natural, technological, and human-related hazards that might impact their area. By pinpointing the locations where these hazards have occurred in the past, and by examining knowledge of new or emerging risks, it is possible to estimate the probability of such events occurring in a given area, as well as the vulnerability of people and property located there. Coupled with relevant land use and demographic information, a hazard analysis becomes a powerful planning tool that enables emergency managers to set priorities and goals for resource allocation, hazard mitigation, and emergency preparedness activities.

The Emergency Management and Homeland Security Division of the Michigan Department of State Police (EMHSD/MSP) is the coordinating agency for all emergency management and homeland security activities of state and local government in Michigan. In conjunction with other governmental agencies and private organizations, the EMHSD/MSP mitigates, prepares for, responds to, and assists in the recovery from disasters and emergencies in the state. The EMHSD/MSP regularly updates the Michigan Emergency Management Plan (MEMP), which outlines federal, state, and local emergency management responsibilities within Michigan, and the Michigan Hazard Mitigation Plan (MHMP). The Michigan Hazard Analysis is coordinated with these other documents, and also serves as a foundation for the development of other state plans. It provides a large array of information for local communities to use in developing their own hazard analyses. Local emergency managers can also refer to EMHSD Publication 201 (Local Emergency Planning Workbook) and EMHSD Publication 207 (Local Hazard Mitigation Planning Workbook) to develop a hazard analysis for their community.

BRIEF PROFILE OF THE STATE OF MICHIGAN

Michigan has a land area of 58,216 square miles and a population of about 9.9 million persons. Its 83 counties include numerous urbanized areas, including Metropolitan Detroit. Most Michigan residents live within these urbanized areas, which are mostly located in the southern portion of the State. Michigan is completely covered by local, incorporated government entities—every inch of the State is part of a township, city, or village, and all residents of these minor civil divisions are also residents within one of Michigan's counties. This constitutes a general political and taxation structure for Michigan's many communities, although additional districts overlay these areas as well, such as school districts and congressional districts.

Located in the midst of four of the Great Lakes, Michigan's fundamental geographic feature is its division into Lower and Upper Peninsulas. The Lower Peninsula encompasses approximately 70% of Michigan's total land area, and the Upper Peninsula accounts for the other 30%. The two peninsulas are divided by the Straits of Mackinac, which allow Lake Michigan to drain into Lake Huron. The southern half of the Lower Peninsula has a level to gently rolling surface, with hills rising to elevations between 1,000 and 1,200 feet. The northern half of the Lower Peninsula has higher elevations, with hilly belts of glacial origin reaching elevations of 1,200 to 1,700 feet. The eastern half of the Upper Peninsula is fairly level and often swampy. The western half is higher and more rugged. Michigan has borders on four of the five Great Lakes and has the longest shoreline of any inland state—about 3,200 miles. Michigan also has over 10,000 inland lakes and 36,000 miles of streams.

Michigan has a diversified economy based on agriculture, manufacturing, tourism, services, and professional trades. More automobiles and trucks are produced in Michigan than in any other state. Michigan is the nation's top producer of office furniture, a major source of information technology and software, and a national leader in machine tools, chemicals, and plastics. Michigan is also one of the nation's leading agricultural producers, consistently ranking number one in several product categories.

Michigan has a well-developed, multi-modal transportation system that supports the state's diversified economic activities. The highway system consists of a network of interstate, federal, state, and local routes that connect Michigan communities to major metropolitan areas and economic markets around the country. Michigan has 19 airports that offer commercial passenger jet service to major domestic and international destinations. Freight railroad lines link Detroit and other metropolitan areas with Chicago and other major manufacturing and business centers in the United States and Canada. Michigan also offers 40 Great Lakes ports to facilitate waterborne commerce. Each year, Michigan's transportation system helps move 240 million tons of cargo by truck, rail, air, and ship.

Due to its geography and location, Michigan will always be threatened by natural hazards. The State of Michigan and local governments must always be prepared to manage those types of events when they occur. Due to the frequency of occurrence and the historical vulnerability of the population to those hazards, most communities should probably rate natural hazards as their primary emergency management concern. The principal natural hazard threats to Michigan are tornadoes, floods, thunderstorm winds and lightning, severe winter weather, wildfires, and extreme temperatures.

Michigan's principal technological hazard threats include infrastructure failures, hazardous material incidents, structural fires, major transportation accidents, and petroleum and natural gas pipeline accidents. (It should be noted that many of these threats are a direct or indirect result of the state's position as a major national and international manufacturing and business center. The technological threats present in Michigan are not unlike those present in other industrialized states of similar size and character.)

Michigan's principal human-related hazards include public health emergencies, terrorism and similar criminal activities (including cyber-attacks), and civil disturbances.

State of Michigan Profile Map

Michigan has a diverse population, a diversified economy, and a broad array of physical environments, community types, and living arrangements. A new map of Michigan has been created specifically to explain some of this diversity for readers who need to quickly estimate the potential impacts of a disaster event within some area of the state. It appears on the next page.

Many maps of Michigan (or the United States as a whole) do not include relevant information about neighboring lands, so this brief profile of Michigan will first make mention of the fact that it is adjacent to the states of Ohio, Indiana, and Wisconsin, as well as the Canadian province of Ontario. Michigan's area includes substantial portions of four of the Great Lakes (Superior, Michigan, Huron, and Erie), as well as smaller Lake St. Clair (northeast of Detroit). Despite the prominence of Great Lake shorelines in Michigan's geographic situation, it is extensively connected with its three neighboring states, and with the Canadian province of Ontario. These connections include physical highways, marine ferries and shipping traffic, critical infrastructure (e.g. pipelines, power lines), and communication networks (phone lines, cellular towers, broadcast signals, the internet).

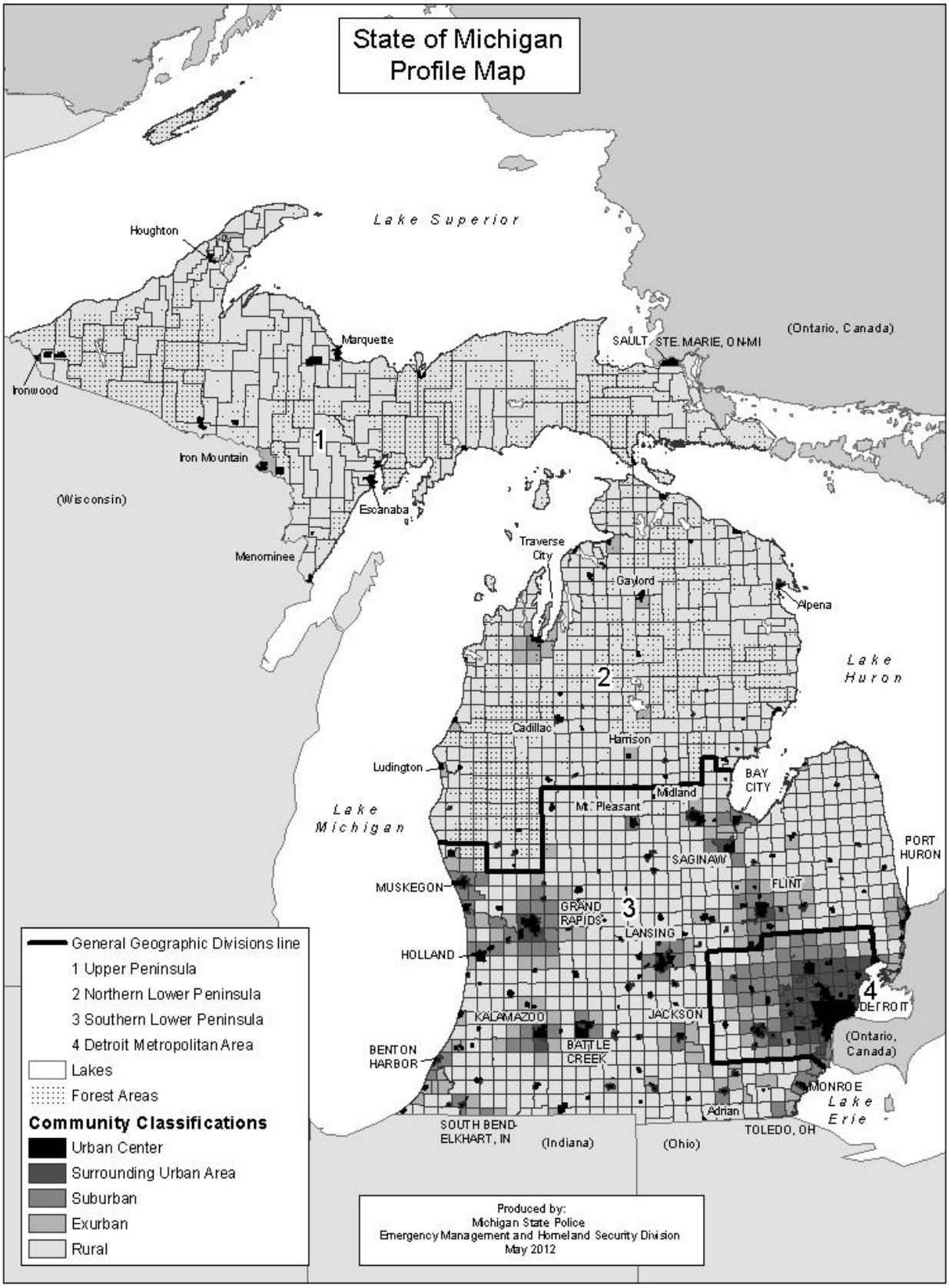
The new Michigan Profile Map presents the State of Michigan in a manner that emphasizes its large number of local governments, and provides basic information about how most of its people, industry, and resources are geographically distributed. The next few pages will provide an explanation of the information shown on this map, with suggestions about how to interpret and use the information in assessing risks at the state and local levels, as well as emergency management concerns and needs.

The Michigan Profile Map is primarily intended for use in emergency management assessments, and an analysis of various kinds of hazards—natural, technological, and human-related. No single map can contain all the information that is relevant for these tasks, so the Michigan Profile Map should merely serve as a starting point, to be supplemented by the many other specialized maps that have been made by Michigan's state government departments (or that are available from other sources).

The Michigan Profile Map was designed to present a selective overview of the general characteristics of Michigan's present settlement, land use, and industrial patterns. Since many of these patterns correspond with differences in climate and vegetation, it was deemed useful to designate four general geographic divisions within the state:

Geographic Division	Number of Counties	Population (2010 census)	Percent of State Total
1. The Upper Peninsula	15	311,361	3.2%
2. Northern Lower Peninsula	29	717,977	7.3%
3. Southern Lower Peninsula	34	4,464,620	45.2%
4. Metropolitan Detroit	5	4,389,682	44.4%
STATE TOTAL	83	9,883,640	

It must be emphasized that these divisions are not meant to correspond with existing planning regions, emergency management districts, Urban Area Security Initiative areas, or census economic areas. The "Community Classification" categories on the map need to be thoroughly explained, in order to fully understand how the map was designed (and how the general geographic divisions were defined). This explanation follows the map on the next page. It is worth noting at the outset that some communities may include areas that better resemble the description for a different category (e.g. a large park may have a rural character within a large central city), and this map doesn't attempt to provide such detail. These classifications are meant only to provide an overview of the State, rather than to precisely indicate local land use patterns.


State of Michigan
Profile Map
Lake Superior
Houghton
Marquette
Ironwood
Iron Mountain
Escanaba
Menominee
(Wisconsin)
SAULT STE. MARIE, ON-MI
(Ontario, Canada)
1
Traverse City
Gaylord
Alpena
Lake Huron
2
Cadillac
Harrison
Ludington
BAY CITY
Midland
Mt. Pleasant
Lake Michigan
SAGINAW
PORT HURON
MUSKEGON
FLINT
GRAND RAPIDS
3
LANSING
HOLLAND
4
DETROIT
KALAMAZOO
JACKSON
(Ontario, Canada)
BENTON HARBOR
BATTLE CREEK
MONROE
Lake Erie
Adrian
SOUTH BEND-ELKHART, IN
(Indiana)
(Ohio)
TOLEDO, OH
General Geographic Divisions line
1 Upper Peninsula
2 Northern Lower Peninsula
3 Southern Lower Peninsula
4 Detroit Metropolitan Area
Lakes
Forest Areas
Community Classifications
Urban Center
Surrounding Urban Area
Suburban
Exurban
Rural
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Emergency Management and Homeland Security Division
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Urban Centers

Michigan has many cities located across its lands, from the very small (Omer, population 313) to the very large (Detroit, population 713,777), and many of these date back to the 1800s as official corporate entities. These historical cities appear in black on the map, representing areas that tend to have the greatest densities in population, infrastructure, and the built environment. Only cities have been included in this classification (not villages or townships), but not all cities have been designated as urban centers. Because of the different forms that urban development took in the post-depression, post-WWII period in which automobile accommodations had become the norm, only cities that had incorporated before the end of World War II were included in this category.

Most of these cities contain a traditional downtown area that has long attracted people from outlying areas to engage in commercial or recreational activities, to meet with government representatives, to visit hospitals, or to meet with others in other social, civic, or religious activities. Some of the most historically significant structures in Michigan are located within these cities, and they also contain a vast amount of Michigan's vital government facilities, hospitals, police and military resources, large educational institutions, and major industrial firms. Some of these "urban center" cities contain relatively small downtowns, in cases where they function as "suburbs" near a larger central city, but they have still been classified here as urban centers because their initial formation conformed to a particular style of development that was predominant before World War II. For example, the streets tended to be laid out in the form of a grid, urban designs tended to be focused upon regular access to a thriving central downtown district, and much less accommodation was made for the use of private automobiles by residents.

Dense development patterns and an emphasis upon efficiency characterized most urban center construction projects. Historically, it was to the advantage of most residents and businesses to locate as close as possible to shared transportation and utility resources, and these were designed to accommodate the needs of the persons using them at their time of construction. Many of these designs (for example, combined sewer systems that handle both sanitary and storm drainage functions) are still being changed even today, to accommodate the needs of a larger population that is more productive, enjoys a higher standard of living, and uses more energy to power its higher-technology devices, buildings, and industries. The systems present in these urban centers tend to be the most complex found in the state, and although the capacity to repair most breakdowns in these systems is usually readily available within the larger cities, the complexity and corollary impacts of such breakdowns are also likely to be greater. For example, if a power failure causes traffic signals to fail, this will have a smaller impact upon roadway congestion in a rural area than it would in a central city. Despite the great population density within large urban centers, these communities tend to have a large number of roadways available for use, and the traditional "grid" pattern of street design has long offered a huge number of alternative routes by which people could evacuate an area by car (for short distances).

Surrounding Urban Areas

Since World War II, most of the urban functions that had historically been contained within the urban centers quickly grew beyond the boundaries of those cities. It used to be that the costs of transportation, construction, and urban utilities had required most developments to take place within a city. After World War II, the widespread availability of affordable automobiles, and an increased capacity to affordably build and supply utilities to outlying areas, meant that new projects of all kinds could be built in many possible locations beyond the existing central cities. For many businesses and residents, it still made sense to live near the central city, but many decided not to stay within the political boundaries of the existing cities. A great many new cities incorporated near the older central cities after World War II, typically by converting part or all of an existing township into a city, through a special voting process. Some recent geography texts refer to these areas as "the outer city" (with central cities termed as "the inner city").

Even though some of these new cities (e.g. Southfield) grew to include impressive high-rise office buildings and major expressway interchanges, they still tend to be distinguished from the older urban centers by having a lower average density of population, more widely spaced and modern buildings and infrastructure, and transportation arrangements that are focused upon the predominance of private automobiles. In these locations, it is harder for a resident to choose a residence that allows convenient access to public transit, places of work, hospitals, government offices, and shopping areas unless a car is used to access them. For some types of hazards, the less dense design of these cities is very helpful. For example, contagious illness is much easier to control when people do not need to use public transit systems, and do not live in very crowded residential patterns.

The function of these areas within a broader metropolitan area becomes clearer when looking at the overall land development patterns, as shown on the Michigan Profile Map, rather than focusing only upon the political boundaries between adjacent cities. Whereas large cities in the 19th Century tended to expand through the annexation of adjacent lands, and to contain numerous wards (districts) within them, the 20th Century tended to instead favor urban expansion across a contiguous array of politically (and fiscally) independent cities. On the positive side, this development pattern provided a greater amount of political control by residents over their local governments. On the negative side, certain parts of each urban area tended to become increasingly worse off in fiscal terms, since local taxes were no longer shared throughout an entire urban area. Similarly, various types of infrastructure and services sometimes became increasingly difficult to coordinate across municipal boundaries, and the functions and services provided by urban centers were sometimes not adequately compensated for by users who lived outside of the providing city. Neighboring cities would often spend money on redundant services and facilities, rather than pooling their funds together into combined systems that could benefit from an economy of scale. However, from an emergency management perspective, these redundancies of services and infrastructure could sometimes result in increased local resilience—the seeming inefficiencies of duplicate systems and services could sometimes pay off when an infrastructure breakdown in one city could be offset by the continued functioning of the infrastructure in an adjacent city.

Any city known to have incorporated after World War II has been included in the "surrounding urban area" category instead of being classified as part of an urban center. However, some heavily populated townships have also been classified in this category, as urban. (No effort has been made in these classifications to try to preserve the often contradictory and overly simplistic ideas that many persons still have about the concept of a "suburb"—there is often little practical difference in the character of communities that did or did not vote to officially become cities.) Any Michigan township with a population density of at least 1400 persons per square mile of land area has been classified within this category, as "urban." These communities (whether townships or cities) often may not contain traditional downtown districts, but frequently do have specialized areas for shopping (shopping malls), conducting business (office complexes), and manufacturing products (industrial parks). Although these highly separated land uses may seem inconvenient from the perspective of transportation access, economic efficiency, and design regulations, there are often emergency management benefits realized from this design, in that a disaster in one location (e.g. an industrial explosion or hazardous materials spill) might not affect any of the other locations (or types of activities associated with them).

In terms of evacuation potential, most of these cities have very few local roads that were laid out in the traditional "grid" pattern, but there still tend to be a limited number of alternative routes available. Many neighborhoods might seem maze-like at first, but may allow traffic to eventually wind its way to the other side. Many of these cities (and urban townships) do have a moderate number of "collector" roads that can provide some congestion relief for traffic.

Suburban Areas

In this classification system, a suburb indicates only a township of moderate development and population density, located near an urban center. No cities are included in this classification. Townships with a population density between 277 and 1399 persons per square mile of land area have generally been given this classification as "suburban."

Many of these suburban areas are charter townships, and the main distinctions between a charter township and a city involve a cap on the township's tax rate, a charter township's acceptance of a pre-defined charter, and a self-imposed set of restrictions upon the types and densities of land uses permitted in the township. Although some of these land use restrictions might seem at first to be artificial and arbitrary to an observer, in most cases the restrictions are roughly in accordance with the level of development that one would ordinarily expect to occur in the outlying and newest districts of a city, anyway. Thus, although one tends not to see a skyscraper in the midst of a low-density residential neighborhood, there are many cases in which new factories or warehousing operations are built on the outskirts, especially along rivers or railroad tracks that may be vital to these facilities. Indeed, one of the main trends of the 20th Century that continues to this day is the increased economic feasibility of building many types of projects in outlying locations, and some suburban areas contain important industrial, office, shopping, and recreational facilities.

For emergency management purposes, the main distinction between the previous "urban" classification and the "suburban" one is that a lesser density of development will be typical in the suburban areas. A disaster in a suburban area will tend to affect fewer people than a comparable disaster within an urban area. However, due to the limited revenue streams for developing the suburban area's infrastructure, suburban areas tend to be more vulnerable to transportation back-ups, to the point of making some areas excessively difficult to evacuate quickly. Few, if any, suburban neighborhood streets are laid out in "grid" fashion, and many neighborhoods may not provide any way for vehicles to cross through them to main roads on their other side. Expressway ramps and bridges over rivers might be far too few in number and capacity, leading to excessive traffic backups on area expressway routes (and the few main streets that connect with it), if one of those ramps or bridges becomes unusable. The community's main (arterial) roads are often just slightly revamped versions of the original "country roads" that existed before all the new suburban growth. Often, the addition of occasional turn lanes have been the only upgrades that have taken place during the community's recent decades of development, and these two-lane roads would quickly become clogged with traffic when an accident occurs or an evacuation is attempted.

SPECIAL NOTE: Every inch of Michigan's land area is not only considered to be a part of one of Michigan's 83 counties, but is also considered to be part of a "minor civil division" (a city, village, or township). The United States census tends to treat villages more like special taxation areas within townships, rather than as small cities, but Michigan also has a great number of small communities that are neither villages nor cities. In this document, these communities will be called "towns," with the understanding that this word has a distinctive meaning to refer to the communities located within Michigan's townships. The Michigan Profile Map shows the boundaries of all of these many townships, but does not show all the small villages and "towns." Most rural areas include such "towns," and although some are mere hamlets, barely distinguished from the rural areas around them, others may be quite sizeable. Such "towns" tend to include either their own post office or school district, and thus may be called by a completely different name than the surrounding township (or may cross over the borders of adjacent townships).

Exurban Areas

The term "exurb" refers to a fairly low-density township whose residents commute regularly to a larger area for many or most of their needs. Suburbs tend to provide a moderate number of urban amenities, including employment, to their residents, but exurbs tend merely to provide residential housing areas and a few minimal services and provisions. In many cases, basic groceries are obtained from a traditional village, "town," or small city that had existed before a commuter population had moved into the area. Exurbs do not contain enough employment opportunities for the residents who live there, and so in addition to residents who choose to commute long distances to work (or who are able to "telecommute"), exurbs may also be home to a large proportion of retirees. Exurbs are generally low in population and development density (except for the central villages or small urban centers that tend to serve them). Various services (including health care) tend to be very limited in these areas.

Townships with a population density between 139 and 276 persons per square mile of land area have generally been classified as exurbs. Some exceptions were granted, such as Breitung Township (near Iron Mountain), in which part of the very large township (67.7 square miles of land area) functioned as a suburb, while another part was quite rural. Another exception was made for the City of Mackinac Island, since its overall population density was rural (it has one of the smallest populations among Michigan cities) and it is generally only accessible by ferry or airplane. Although most suburbs exist on the farthest fringes of urban areas, a few additional types of areas also received this classification, such as communities that are not connected with cities, used for resorts, retirement living, or seasonal homes. An example is Houghton Lake, in Roscommon County, which has a "town" around the lake's shores, but is not actually a city. Some communities were designated as exurbs merely because its center was a "town" or village rather than a city. The United States census tends to treat villages as a special taxation zone within a township, and the Michigan Profile Map was predominantly based upon census data.

Rural Areas

Most of Michigan has been classified as "rural" on the Michigan Profile Map. This does not in any way indicate that these areas are unimportant! In addition, it must be noted that a great number of villages and "towns" exist throughout these rural areas, but are not marked on the map, due to their comparatively small sizes. (Please review the SPECIAL NOTE on the previous page, for more information about the meaning of "town" in this document.)

Some of Michigan's most productive, famous, and important industries are found throughout its rural areas. For example, extraction industries have been quite important to Michigan, whether the mining that had once caused the Western Upper Peninsula to thrive, or the petroleum and natural gas deposits that are increasingly in demand worldwide, or even just Michigan's abundant supplies of fresh water. Logging, farming, the cattle industry, and facilities for renewable energy (e.g. wind farms or hydroelectric dams) are other important facilities and infrastructure that exist in Michigan's rural areas. Due to the limitations inherent in the use of only a single statewide map, these types of production were not represented graphically. However, more information is presented later in this document, as well as in the passages that follow, describing Michigan's general geographic divisions.

With this in mind, the following paragraphs provide general descriptions of each area's characteristics that were considered to be most relevant for an analysis of risks and hazard impacts. Where information is provided about population centers, the 2010 census has been the source of information used. The "urban areas" designated by the U.S. Census have tended to be presented here as the most relevant means of conveying information about most of Michigan's populated areas, since they are defined in terms of actual land use rather than mere political boundaries. Some of the official urban areas have already been classified as part of a larger metropolitan area (e.g. Ann Arbor), and that status will be clarified in the descriptions that follow (along with alternative ways of conceptualizing and classifying these areas).

1. The Upper Peninsula

As shown on the Michigan Profile Map, most of the Upper Peninsula is covered with forest lands, and most inhabitants live in small cities, villages, and towns in the midst of these forests. These communities are often very old. The Upper Peninsula used to have a huge timber and mining industry, during the 19th Century, and had lost most of its population during the 20th Century after these industries had declined in size. (In 1910, Calumet-Laurium used to be one of Michigan's most populous communities—Houghton County had a population of 88,008 and Calumet Township's population of 32,845 was comparable to that of Jackson, Kalamazoo, or Lansing at the time, but today the township only has 6,489 residents.) The Upper Peninsula's historic mining industry makes certain portions of it more vulnerable than the rest of the State to a ground subsidence hazard.

The Upper Peninsula is predominantly rural, and every one of its counties has a population density that is well below the State's average. Because the area developed during the 1800s, most of its cities have areas that are very old and date from that time period. The Upper Peninsula is adjacent to Wisconsin and Ontario, Canada, and some cities are part of urban areas that cross over state (and national) borders. These cross-border urban areas include Sault Ste. Marie (Ontario and Michigan), Iron Mountain-Kingsford (Michigan and Wisconsin), and Marinette-Menominee (Wisconsin and Michigan).

Taking into account the broader metropolitan areas, then, the city of Sault Ste. Marie might be considered the most significant for the Upper Peninsula. Although the Michigan portion of this area has only about 14,000 people, the much larger Canadian city of Sault Ste. Marie dominates an urban area of nearly 100,000 total population. All marine traffic going from Lake Huron to Lake Superior passes through the Soo Locks, in this area. This includes marine traffic traveling to and from major ports such as Duluth (Minnesota) and Thunder Bay (Ontario, Canada). The only Interstate Highway in the Upper Peninsula (I-75) goes through this city and crosses the International Bridge into Canada. The Mackinac Bridge is another vital element of Michigan's infrastructure, providing a highway connection between Michigan's Upper Peninsula and its Lower Peninsula. Several high-quality surface highways cross the Upper Peninsula and provide the main routes for its truck traffic. Along with freight trains, these highways pass through large areas of State and National Forest Lands, which means that wildfires are one of the most significant threats in the area.

The Upper Peninsula's urban areas, ranked by population size according to the 2010 U.S. census, are:

(Sault Ste. Marie Ontario-MI)	92,914 (2011 Canadian statistics plus 2010 U.S. census)
Marquette	26,946
Escanaba	20,850
(Marinette-Menominee, WI-MI)	19,431
Iron Mountain-Kingsford	19,228
Houghton	15,452

Sault Ste. Marie (Michigan part only)	14,144	(within the city, rather than in the defined Urban Area)
Ishpeming-Negaunee	12,301	(in Marquette County)
Laurium-Calumet	7,325	(in Houghton County)
Ironwood	7,134	(in Gogebic County)
Kinross	6,555	(in Chippewa County)
Manistique	3,482	(in Manistique County)
Newberry	3,225	(in Luce County)
Iron River	3,208	(in Iron County)
Munising	2,972	(Alger County)
St. Ignace	2,531	(Mackinac County)

The Upper Peninsula has a much larger forestry sector than the other parts of the state. Its percentages employed in the construction, manufacturing, and retail trade sectors are significantly larger than for Michigan as a whole. This is also true for the "accommodation and food services" sector of the economy.

2. The Northern Lower Peninsula

This area is predominantly rural in nature, and (as shown on the Michigan Profile Map) is widely covered with forest lands, but includes significant resort and tourist areas, and profitable groves of fruit-growing trees. It is a popular area for hunters, and has a large proportion of its housing units dedicated to seasonal and recreational uses (e.g. hunting lodges, summer cabins). Large state and national forest areas are located in this part of the state, as indicated on the Michigan Profile Map. Many small cities, villages, and towns are located throughout the area's 29 counties. A generally good system of surface highways connects the area. Trains are limited to freight uses, rather than passenger travel. A few airports and passenger ferries are in operation within the area, and there are some excellent ports for handling marine traffic.

The urban areas in the Northern Lower Peninsula, ranked by population according to the 2010 U.S. census, are:

Traverse City	47,109	
Alpena	14,258	
Cadillac	11,690	
Ludington	10,710	(in Mason County)
Manistee	9,606	(in Manistee County)
Houghton Lake	8,300	(in Roscommon County)
Gaylord	8,298	(in Otsego County)
Petoskey	8,210	(in Emmet County)
Au Sable-Oscoda	6,384	(in Iosco County)
Clare	5,597	(in Clare County)
Cheboygan	4,517	(in Cheboygan County)
Fremont	4,496	(in Newaygo County)
East Tawas	4,372	(in Iosco County)
Charlevoix	4,179	(in Charlevoix County)
Grayling	3,858	(in Crawford County)
Harrison	3,589	(in Clare County)
Boyne City	3,501	(in Charlevoix County)
Newaygo	3,335	(in Newaygo County)
Gladwin	2,934	(in Gladwin County)
Kalkaska	2,668	(in Kalkaska County)
Rogers City	2,560	(in Presque Isle County)
Hart	2,556	(in Oceana County)

The Northern Lower Peninsula has larger forestry, fishing, and hunting sectors than most other parts of the state, as well as the majority of Michigan's employment in extractive industries (oil, gas, mining, and quarrying). The area's percentages employed in the construction, retail trade, and the health care and social assistance sectors are significantly

larger than for Michigan as a whole. This is also true for the "accommodation and food services" sector of the economy.

3. The Southern Lower Peninsula (excluding Metro Detroit)

This area contains many medium-sized urban areas and most of Michigan's traditional farming and livestock grazing lands. It is adjacent to the States of Indiana and Ohio, and the Canadian province of Ontario. Some out-of-state metropolitan areas extend into this part of Michigan, such as South Bend, Elkhart, Michigan City, Toledo, and Sarnia. This part of the state is extremely well-served by the Interstate Highway System, and many colleges and State universities are found throughout the area. Many features of historic and scenic interest draw tourists from other parts of the state and country. University sports venues, the Michigan International Speedway, minor league baseball, many different museums, zoos, professional theaters, historic sites, and well-known manufacturing facilities (e.g. Kellogg breakfast cereals) are numbered among the area's many cultural attractions.

The largest urban areas connected with the Southern Lower Peninsula (outside of Metropolitan Detroit) are:

Grand Rapids	589,060	(Grand Rapids UA plus exurban Lowell, Dorr, Sparta, Cedar Springs UAs)
(Toledo, OH-MI)	507,643	(Monroe County has suburban/exurban parts of the Toledo UA.)
Flint	362,078	(or 370,307 if suburban Holly is included from the Metro Detroit area)
Lansing	319,849	(Lansing's UA of 313,532 plus exurban Williamston's UA of 6,317)
(South Bend, IN-MI)	278,165	(Some suburban/exurban parts are located in Berrien and Cass counties.)
Kalamazoo	221,443	(Kalamazoo's UA of 209,703 plus exurban Otsego-Plainwell pop. of 11,740)
(Sarnia-Port Huron, ON-MI)	176,661	(Port Huron UA from 2010 U.S. census + Sarnia 2011 population statistic)
Muskegon	171,848	(161,280 Muskegon UA, plus exurban Whitehall-Montague UA of 10,568)
(Elkhart, IN-MI)	143,592	(Some suburban/exurban parts are located in Berrien and Cass counties.)
Saginaw	126,265	
Holland	99,941	
Jackson	90,057	
Port Huron	87,106	(Michigan UA only, not including the Canadian Sarnia area)
Battle Creek	78,393	
Bay City	70,585	
(Michigan City-LaPorte, IN-MI)	66,025	(One exurb of the UA is located in the southwest corner of Berrien Co.)
Benton Harbor-St. Joseph	61,022	
Midland	59,014	
Monroe	51,240	(Detroit's southern suburbs do overlap with Monroe's northern suburbs.)
Adrian	44,823	(in Lenawee County)
Mt. Pleasant	37,447	(in Isabella County)
Owosso	22,426	(in Shiawassee County)
Alma-St. Louis	16,924	(in Gratiot County)
Coldwater	16,876	(in Branch County)
Ionia	14,409	(in Ionia County)
Big Rapids	14,241	(in Mecosta County)
Lapeer	13,424	(in Lapeer County)
Sturgis	13,040	(in St. Joseph County)
Charlotte	12,682	(in Eaton County)
Hillsdale	11,646	(in Hillsdale County)
Paw Paw Lake-Hartford	11,589	(in Berrien and Van Buren Counties)
Three Rivers	10,820	(in St. Joseph County)
Greenville	9,743	(in Montcalm County)
Albion	9,219	(in Calhoun County)
Paw Paw	8,684	(in Van Buren County)
St. Johns	8,425	(in Clinton County)
Hastings	7,713	(in Barry County)
Marshall	7,683	(in Calhoun County)
Berrien Springs	7,358	(in Berrien County)

Allegan	6,322 (in Allegan County)
Dowagiac	6,082 (in Cass County)
South Haven	5,791 (in Van Buren County)
Belding	5,789 (in Ionia County)
Eaton Rapids	5,408 (in Eaton County)
Caro	5,113 (in Tuscola County)
Portland	5,020 (in Ionia County)
Frankenmuth	4,972 (in Saginaw County)
Durand	4,854 (in Shiawassee County)
Wayland	4,518 (in Allegan County)
Perry	4,290 (in Shiawassee County)
Constantine	4,074 (in St. Joseph County)
Coopersville	3,951 (in Ottawa County)
Dundee	3,799 (in Monroe County)
Imlay City	3,792 (in Lapeer County)
Vassar	3,714 (in Tuscola County)
Bad Axe	3,490 (in Huron County)
Blissfield	3,303 (in Lenawee County)
Middleville	3,236 (in Barry County)
Somerset	2,910 (in Hillsdale County)
Sandusky	2,775 (in Sanilac County)
Brooklyn	2,773 (in Jackson County)
Almont	2,719 (in Lapeer County)
Gun Lake	2,660 (in Barry County)
Douglas-Saugatuck	2,570 (in Allegan County)

The Southern Lower Peninsula (outside of Metro Detroit) has a larger proportion of its workers in the manufacturing sector than other parts of the state. Its percentages employed in educational and other services are significantly larger than for Michigan as a whole. It has many colleges and universities. Lansing is the state capital and contains many government agencies. Among the many recreational and cultural attractions are large stadiums and performance venues, which tend to require special preparation and management when it comes to protecting attendees from threats and hazards. Various convention centers and downtown areas tend to regularly attract large numbers of persons, who similarly may require special planning to protect them from threats and hazards.

4. Metropolitan Detroit

This area contained the first large Michigan settlements, which developed into the expanding City of Detroit throughout the industrial revolution and then became world-famous as "The Motor City." The largest American automobile companies tended to develop in this area of Michigan, and eventually became "the big three"—Ford, General Motors, and Chrysler, with their world headquarters located in Dearborn, Detroit, and Auburn Hills, respectively. Although the area's population increased by the greatest amount during the first half of the 20th Century (Detroit's peak census population was in 1950, at 1,849,568 persons), the metro area continued to increase slowly for 50 years thereafter—until the most recent census revealed the effects of various economic challenges, which registered an overall decline of modest proportions (while most of the metropolitan counties continued to grow at a decent rate).

The largest urban areas in the Metropolitan region, according to the 2010 U.S. census, are:

Detroit 3,863,533 (or 4,182,779, including 319,246 in the Windsor area in Ontario)

(NOTE: 3,734,090 are in Metro Detroit, plus 119,509 in the Howell-Brighton suburban UA and the exurbs of Richmond and Fowlerville, 6,140 and 3,794 respectively.)

Ann Arbor 313,536 (306,022 in Ann Arbor plus 7,514 in the exurb of Milan)

(NOTE: Detroit and Ann Arbor might be considered one Metro area of 4,177,069; or 4,496,315 with Windsor.)

Holly 8,229 (suburb of Flint)

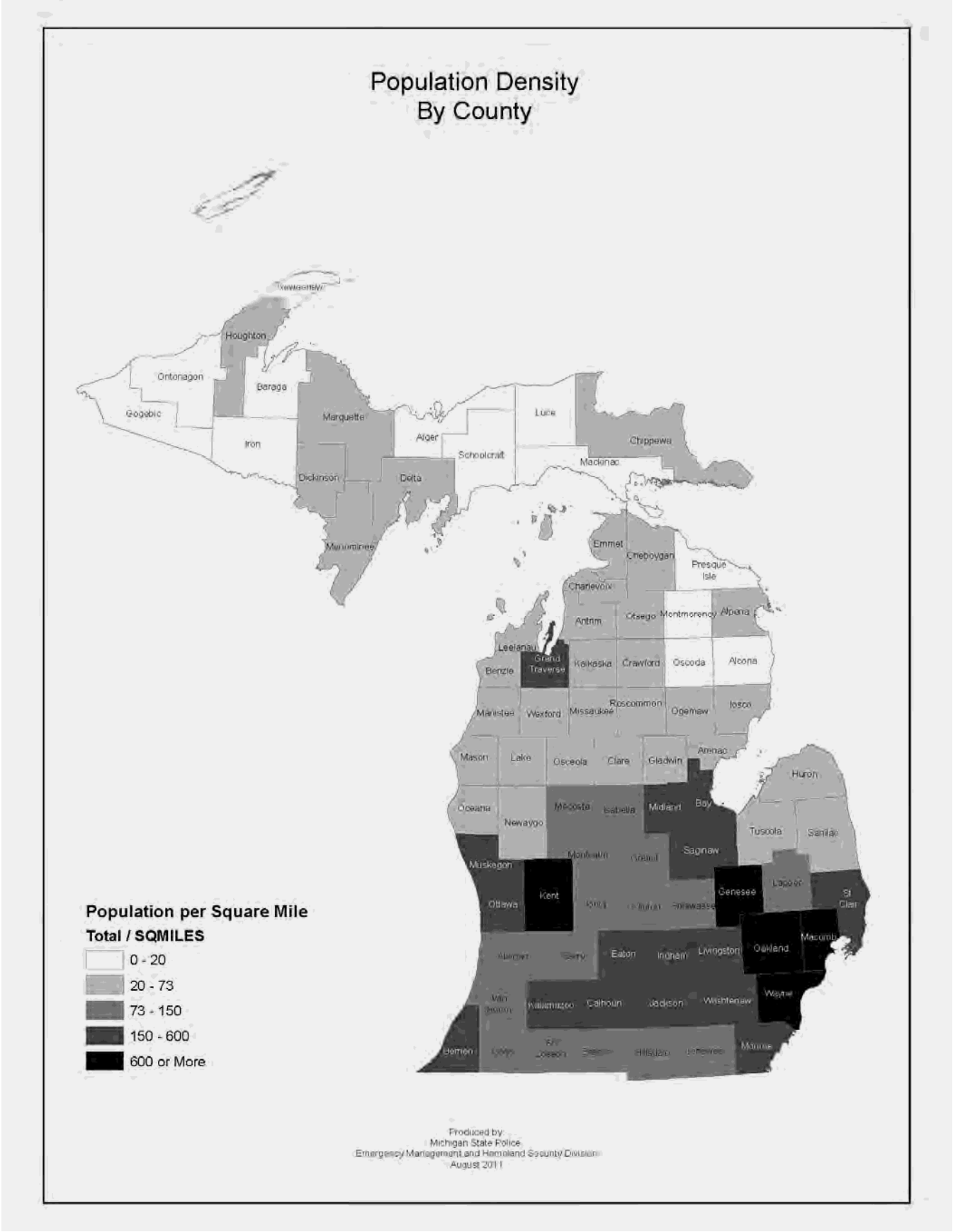
Chelsea 5,329

The area employs a larger percentage of its workforce in certain economic sectors than other parts of Michigan do. These sectors include wholesale trade, transportation and warehousing, information, finance and insurance, real estate, management, and professional, scientific, and technical services. The arts, entertainment, and recreation sector is also a bit larger, percentagewise, than it is in other parts of the State.

Michigan's Significant Hazards in each Geographic Division

The following list summarizes the hazards that have been proven to be likely within the following geographic divisions within Michigan. A hazard is still possible in these areas even if it is not listed here, but this list merely provides a rough indicator of the different kinds of events that are typically identified as a major threat within local and regional hazard analyses across different parts of the State.

1. Upper Peninsula (15 counties)
   Natural Hazards: Thunderstorms, Severe Winter Weather, Severe Winds, Tornadoes, Extreme Temperatures, Flooding, Shoreline Hazards, Dam Failures, Drought, Wildfires, Invasive Species, Subsidence.
   Technological Hazards: Structural fires, Infrastructure Failures.
   Human-Related Hazards: Civil Disturbances, Nuclear Attack, Public Health Emergencies, Terrorism.
2. Northern Lower Peninsula (29 counties)
   Natural Hazards: Thunderstorms, Severe Winter Weather, Severe Winds, Tornadoes, Extreme Temperatures, Flooding, Shoreline Hazards, Dam Failures, Drought, Wildfires, Invasive Species.
   Technological Hazards: Structural fires, Scrap Tire Fires, Oil and Gas Well Accidents, Infrastructure Failures.
   Human-Related Hazards: Nuclear Attack, Public Health Emergencies, Terrorism.
3. Southern Lower Peninsula (34 counties)
   Natural Hazards: Thunderstorms, Severe Winter Weather, Severe Winds, Tornadoes, Ice/Sleet Storms, Extreme Temperatures, Flooding, Shoreline Hazards, Dam Failures, Drought, Invasive Species, Earthquakes.
   Technological Hazards: Structural fires, Scrap Tire Fires, Hazardous Materials Incidents, Nuclear Power Plant Emergencies, Pipeline Accidents, Oil and Gas Well Accidents, Infrastructure Failures, Energy Emergencies, Transportation Accidents.
   Human-Related Hazards: Civil Disturbances, Nuclear Attack, Public Health Emergencies, Terrorism.
4. Metropolitan Detroit (5 counties)
   Natural Hazards: Thunderstorms, Severe Winter Weather, Severe Winds, Tornadoes, Ice/Sleet Storms, Extreme Temperatures, Flooding, Shoreline Hazards, Dam Failures, Drought, Invasive Species.
   Technological Hazards: Structural fires, Scrap Tire Fires, Hazardous Materials Incidents, Nuclear Power Plant Emergencies, Pipeline Accidents, Infrastructure Failures, Energy Emergencies, Transportation Accidents.
   Human-Related Hazards: Civil Disturbances, Nuclear Attack, Public Health Emergencies, Terrorism.


Population Density
By County
Houghton
Ontonagon
Baraga
Gogebic
Marquette
Iron
Alger
Luce
Chippewa
Schoolcraft
Mackinac
Dickinson
Delta
Menominee
Emmet
Cheboygan
Presque Isle
Charlevoix
Antrim
Otsego
Montmorency
Alpena
Leelanau
Grand Traverse
Kalkaska
Crawford
Oscoda
Alcona
Benzie
Manistee
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Mason
Lake
Osceola
Clare
Gladwin
Arenac
Huron
Oceana
Newaygo
Mecosta
Isabella
Midland
Bay
Tuscola
Sanilac
Muskegon
Montcalm
Gratiot
Saginaw
Genesee
Lapeer
St Clair
Ottawa
Kent
Ionia
Clinton
Shiawassee
Macomb
Ottawa
Barry
Eaton
Ingham
Livingston
Oakland
Wayne
Van Buren
Kalamazoo
Calhoun
Jackson
Washtenaw
Berrien
Cass
St Joseph
Branch
Hillsdale
Lenawee
Monroe
Population per Square Mile
Total / SQMILES
0 - 20
20 - 73
73 - 150
150 - 600
600 or More
Produced by
Michigan State Police
Emergency Management and Homeland Security Division
August 2011

The following table presents selected economic information for Michigan and its four geographic divisions (as defined in this document). Various economic sectors have been listed, along with their shares of Michigan's annual payroll and employment (as of March 2009 information from the County Business Patterns source). The percentage of total employment within each geographic division is also presented. Please note that because of the way this data was compiled from subcomponents (some of which were unavailable), the division totals do not equal 100%. Nevertheless, this information is considered useful to identify the sectors that are comparatively more important in different parts of the state.

2009 County Business Patterns		MICHIGAN	MICHIGAN	U.P.	N.L.P.	S.L.P.	Metro
NAICS code	**NAICS code description**	**% annual payroll**	**% of workers**	**% of workers**	**% of workers**	**% of workers**	**% of workers**
------	Total for all sectors	100.0%	100.0%	89.1%	94.1%	97.1%	97.9%
11----	Forestry, fishing, hunting, and Agriculture Support	0.1%	0.1%	0.6%	0.2%	0.0%	0.0%
21----	Mining, quarrying, and oil and gas extraction	0.2%	0.2%	0.0%	0.8%	0.1%	0.0%
22----	Utilities	1.4%	0.6%	0.3%	0.1%	0.0%	0.1%
23----	Construction	4.2%	3.4%	4.9%	4.9%	3.6%	3.1%
31----	Manufacturing	16.8%	13.9%	16.6%	14.7%	17.3%	11.1%
42----	Wholesale trade	6.4%	4.7%	2.2%	2.5%	4.6%	5.1%
44----	Retail trade	7.4%	13.2%	16.9%	17.9%	14.1%	12.2%
48----	Transportation and warehousing	2.7%	2.8%	1.9%	1.7%	2.6%	3.2%
51----	Information	3.1%	2.2%	1.1%	1.2%	1.7%	2.7%
52----	Finance and insurance	6.4%	4.6%	3.5%	3.5%	4.0%	5.0%
53----	Real estate and rental and leasing	1.2%	1.5%	0.9%	1.0%	1.3%	1.8%
54----	Professional, scientific, and technical services	11.3%	7.1%	3.9%	3.5%	4.2%	8.5%
55----	Management of companies and enterprises	7.1%	3.0%	0.0%	0.3%	1.6%	4.1%
56----	Administrative & Support & Waste Management & Remediation Services	5.8%	7.8%	4.0%	2.8%	6.0%	7.6%
61----	Educational services	1.3%	2.1%	0.4%	0.8%	2.2%	1.7%
62----	Health care and social assistance	17.3%	16.8%	13.9%	19.6%	17.2%	16.5%
71----	Arts, entertainment, and recreation	1.1%	1.5%	0.8%	1.3%	1.3%	1.7%
72----	Accommodation and food services	3.2%	9.7%	12.5%	12.5%	10.0%	9.2%
81----	Other services (except public administration)	2.8%	4.7%	4.7%	4.9%	5.2%	4.3%
99----	Industries not classified	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Michigan's position as a national and international manufacturing and business center virtually assures that the state will remain vulnerable to hazardous material incidents and other technological hazards. Extensive planning and preparation has been done to aid in responding to these types of events, and that work must continue and perhaps even be expanded as the number and potential impacts of technological hazards continues to grow.

Michigan, which contains three operating commercial nuclear power plants, has continued to develop and expand its capabilities to respond to a nuclear accident. Although stringent steps are taken at each plant to ensure safe and trouble-free power generation, accidents can occur. To combat that possibility, Michigan must continue to be a leader in nuclear safety to ensure that the state's residents are adequately protected from the potentially harmful effects of an accidental radioactive material release.

Unfortunately, Michigan has experienced major acts of terrorist-like criminal action. On May 18, 1927, a disgruntled taxpayer set off a bomb in a schoolhouse in Bath, killing 45 persons (mostly children) and injuring 58 others. Most recently, in 2009, Michigan narrowly avoided having a major terrorist act occur on its soil, as an attempt to bomb a passenger airline over Detroit did not succeed. As evidenced by the mounting history of criminal and terrorist events and plots—the bomb blasts at the World Trade Center in 1993, the tragic destruction of the Murrah Federal Center in Oklahoma City in 1995, the September 2001 terrorist strikes in New York City and Washington D.C., the 1996 Summer Olympics bomb in Atlanta, lethal shooting events at Columbine High School (1999), Fort Hood in Texas (2009), and Washington D.C. in 2002—constant vigilance is needed by all citizens to prevent and deter future events of this type.

Finally, substantial actions must be taken to mitigate the hazards outlined in this report. Hazard mitigation is defined as "any action taken before, during or after a disaster or emergency situation to permanently eliminate or reduce the long-term risk to human life and property from natural, technological and human-related hazards." Hazard mitigation actions, especially if implemented in a coordinated, inter-governmental, inter-disciplinary manner, can effectively reduce the damage, suffering, injury, and loss of life and property associated with these hazards. That, in turn, helps reduce disaster response and recovery costs, saving untold millions of dollars in public and private disaster relief assistance. In addition, hazard mitigation can greatly reduce the social, economic and political disruptions that disasters bring to bear on Michigan communities. The old adage "an ounce of prevention is worth a pound of cure" is certainly true when it comes to disasters.

It is for those reasons that this Hazard Analysis is coordinated with the Michigan Hazard Mitigation Plan, the Michigan Emergency Management Plan, the Michigan Citizen-Community Emergency Response and Coordinating Council, the Threat and Hazard Identification and Risk Assessment process (THIRA), and other plans, groups, agencies, and processes. Continuing to promote and advance the art and science of hazard mitigation will help ensure that Michigan's citizens are protected, to the maximum extent possible, from the harmful impacts of future disasters.

The following table attempts to "compare apples with oranges" by presenting estimated annual impacts from each type of hazard (although some hazards are too new or unclear to have a precise set of impacts accurately estimated in such a clear-cut manner). This table is still a work in progress and could benefit from the insights, research, and analysis of subject matter experts. The more detailed chapters that follow will present more information and explanations about each type of hazard, organized into overarching sections by general hazard type (natural, technological, human-related).

Hazard Analysis Summary Table

	Average annual events	Average annual deaths	Average annual injuries	Average annual property damage	Development trend effects	Risk rating: casualties	Risk rating: property	Risk Rating: economic costs	Risk rating: Infrastructure	Risk rating: Environment	Frequency as a top local hazard
Hail	**~25**	**0.0**	**0.0**	**$15 million**	**+**	**0**	**2**	**2**	**1**	**1**	**Some**
Lightning	**~12**	**1.5**	**10.7**	**$1.4 million**	**=**	**1**	**1**	**2**	**2**	**2**	**Some**
Ice and sleet storms (damage estimate includes snowstorms)	**2.2**	**>1**	**>1**	**~$12 million**	**+**	**1**	**2**	**3**	**3**	**1**	**Some**
Snowstorms	**>1**	**>1**	**>1**	(included above)	**+**	**1**	**1**	**2**	**2**	**1**	**Many**
Severe winds	**~8**	**2**	**20**	**~$25 million**	**+**	**1**	**2**	**3**	**3**	**1**	**Many**
Tornadoes	**~16**	**4**	**60**	**$17.8 million**	**+**	**2**	**2**	**3**	**3**	**2**	**Many**
Extreme heat	**~7**	**2?**	**?**	**?**	**=**	**2**	**0**	**2**	**2**	**0**	**Some**
Extreme cold	**~30**	**5?**	**?**	**$millions**	**=**	**2**	**2**	**3**	**3**	**1**	**Some**
Fog	**0.5**	**?**	**?**	**?**	**+**	**1**	**0**	**1**	**1**	**0**	**None**
Flooding	**>1**	**0.4**	**0.5**	**~$80 million**	**+**	**1**	**2**	**3**	**3**	**2**	**Some**
Shoreline hazards	**>1**	**~2**	**~4**	**>$10 million**	**+**	**1**	**2**	**3**	**2**	**1**	**Some**
Dam failures	**~2?**	**0?**	**0?**	**$thousands**	**+**	**2**	**2**	**3**	**2**	**2**	**Some**
Drought	**0.5**	**0**	**0**	**$millions**	**?**	**0**	**0**	**3**	**1**	**2**	**Few**
Wildfires	**>550**	**3.7**	**?**	**~$1 million +**	**+**	**2**	**2**	**3**	**2**	**3**	**Some**
Invasive species	**?**	**?**	**>1**	**$millions**	**?**	**1**	**2**	**3**	**1**	**3**	**None**
Earthquakes	**0.3**	**0**	**0**	**$165,000**	**+**	**1**	**1**	**2**	**2**	**2**	**Few**
Subsidence	**0.4**	**0**	**0**	**mere thousands?**	**+**	**1**	**1**	**1**	**1**	**1**	**Few**
Celestial impacts (impacting object)	**<1**	**0**	**0**	**<$1,000**	**+**	**0**	**1**	**1**	**1**	**1**	**None**
Celestial impacts (space weather)	**~0.3**	**0**	**0**	**$millions?**	**+**	**0**	**1**	**2**	**2**	**0**	**None**
Structural fires (major)	**>1**	**>5**	**>10**	**>$many millions**	**-**	**2**	**2**	**2**	**1**	**2**	**Few**
Scrap tire fires	**0.5**	**0**	**0**	**$thousands**	**=**	**0**	**1**	**2**	**1**	**2**	**Few**
Hazardous materials incident (fixed site)	**~7**	**>1**	**>1**	**$millions**	**+**	**2**	**2**	**2**	**2**	**2**	**Some**
Nuclear Power Plant	**0.02**	**0**	**0**	**0**	**+**	**0**	**1**	**2**	**2**	**2**	**Few**
Hazardous materials (transportation)	**~13**	**>1**	**>1**	**$many thousand**	**+**	**2**	**2**	**2**	**2**	**2**	**Some**
Oil & gas pipelines	**>1**	**~0.7**	**~1.4**	**$millions**	**+**	**1**	**2**	**2**	**2**	**2**	**Few**
Oil & gas wells	**0.2**	**<1**	**<1**	**?**	**+**	**1**	**1**	**1**	**1**	**1**	**Few**
Infrastructure failures	**>1**	**<1**	**<1**	**$many millions**	**+**	**1**	**1**	**3**	**3**	**2**	**Some**
Energy emergencies	**~1**	**0**	**0**	**?**	**+**	**0**	**0**	**2**	**2**	**1**	**None**
Transportation accidents (major)	**>1**	**>1**	**>1**	**$many thousands**	**+**	**2**	**1**	**2**	**1**	**1**	**Few**
Catastrophic incidents	**<1**	**>1**	**>1**	**?**	**=**	**1**	**0**	**2**	**2**	**2**	**None**
Civil Disturbances	**<1**	**>1**	**>1**	**$thousands**	**=**	**2**	**2**	**2**	**1**	**1**	**Few**
Nuclear Attack	**0**	**0**	**0**	**?**	**-**	**2**	**2**	**2**	**2**	**2**	**Many**
Public Health Emergencies	**?**	**>1**	**>1**	**?**	**-**	**2**	**0**	**2**	**2**	**1**	**Few**
Terrorism and Similar Activities	**<1**	**>1**	**>1**	**?**	**=**	**2**	**2**	**2**	**2**	**2**	**Some**

"**Average annual**" numbers are medium-term estimates only. Medium-term means that most estimates were based upon decades' worth of data, to predict future decades' risk. Numbers that could not yet be validly determined are marked "?"

Development trend effects use the following symbols to estimate the effects from Michigan's recent land use trends (which still mainly involve the construction of suburban, exurban, and rural detached homes for persons moving out of denser areas).

"+" means increasing risks, "=" means few net effects, "-" means decreasing risks, "?"means trends are unclear

Risk Ratings are based upon the estimated severity of average annual impacts (medium-term), as follows:

"0" means negligible: The risks as currently known are not likely to cause any emergency-level event.

"1" means minor: There is a known although infrequent chance for impacts of moderate or purely local severity.

"2" means significant: A regular pattern of moderate effects, or an infrequent chance of severe impacts.

"3" means major: A regular pattern or high risk of major impacts, of statewide significance.

"**Frequency as a top local hazard**" refers to the number of local plans listing this as one of their top hazards. Categories include "Many," "Some," "Few," and "None." Note that because FEMA requires the analysis of natural hazards, but not technological and human-related hazards, local plans are inclined to favor the listing of natural hazards.

Hazard Analysis Introduction

This hazard analysis has been extensively revised from the previous 2006 edition of the Michigan Hazard Analysis. This updated 2012 document includes a full array of sections dealing with more than 30 identified types of hazards. This section now provides a comprehensive update of all the material that had previously appeared in the Michigan Hazard Analysis, but it has also been expanded to include two additional sections—one on Catastrophic Incidents (National Emergencies) and another on Celestial Impacts. The Catastrophic Incidents section has been added, in part, to better tie in with similar concepts being addressed in the Michigan Emergency Management Plan, and other documents and recommendations at the federal level. These changes make the plan not only compliant with FEMA planning standards, but with larger EMAP standards as well, with a full consideration of natural hazards, technological hazards, human-related hazards, as well as greater linkages between hazard mitigation and the other phases of emergency management—preparedness, response, and recovery.

In order to make such a large array of hazards more comprehensible, they have now been reorganized so that the most closely-related hazards are located near each other in the same section of this document (instead of the alphabetical arrangement that had been used previously). There is extensive overlap between natural hazards. Similarly, technological hazards and human-related hazards tend to share a great deal in common with each other. Therefore, this document now includes three major divisions that correspond to these three major hazard classifications. Each of these three major sections has been further organized so that readers and responders can more easily find information about hazards that are closely related to each other. Persons who need information about weather hazards, for example, do not need to switch between sections separated by hundreds of pages, but instead can refer specifically to a single section of this document.

This reorganized hazard analysis begins with a section on **natural hazards**. It makes sense to list these hazards first, because they so commonly affect Michigan. There is not a single part of Michigan that isn't susceptible to severe weather, for example. Within the natural hazards section, weather hazards have been listed first. Most of the weather hazards subsection deals with violent weather events such as thunderstorms and tornadoes, but there is also an entire component that addresses hazardous winter weather. One of the weather-related hazards, extreme temperatures, addresses both summer and winter weather issues in one section.

Many weather hazards affect the hydrological conditions in Michigan and its local communities, and therefore the weather hazards section is immediately followed by a section dealing with hydrological hazards—flooding and drought. The flood hazard section includes three major components—inland (riverine) flooding, Great Lakes shoreline hazards, and dam failures. The shoreline hazards component not only includes information about flooding, but other topics relevant to coastline areas along the Great Lakes—storm surges (seiches), rip currents, Great Lakes water recession, and shoreline erosion.

The first two natural hazard subsections flow well into a consideration of Michigan's two main ecological hazards—wildfires and invasive species. Both weather and hydrological conditions affect Michigan's ecological conditions, and its vulnerability to wildfires and invasive species. The natural hazards section wraps up with a subsection on Michigan's geological hazards. Although these are not insignificant, they tend not to pose as much direct risk to Michigan as the other types of natural hazards. This plan now includes a section titled "Celestial Impact," which considers such issues as solar storms that have the potential to disrupt important infrastructure, and the impact or threatened impact of physical bodies upon the Earth's land, sea, or atmosphere, the latter of which is rare as a hazard but has the potential for impacts that are truly catastrophic. These issues are here treated for the first time in State-level planning, and are given a realistic assessment (which can offset some of the alarmist media presentations that have appeared in recent years).

The **technological hazards** section includes two major subsections—one dealing with industrial hazards and the other with infrastructure problems. Within the industrial hazards subsection are components dealing with fires, hazardous materials incidents of various kinds, nuclear power plant issues, and accidents involving Michigan's oil and gas pipelines and wells. Within the subsection on infrastructure problems are components dealing with various forms of infrastructure failure, energy emergencies, and major transportation accidents.

The final major section of the hazard analysis, **human-related hazards**, contains five components, including a new consideration of the general topic of catastrophic incidents (national emergencies). In the past decade, major national incidents involving terrorism and hurricanes have made it clearer than ever how interconnected we all must be. We as a state experience both direct and indirect effects from events that take place elsewhere in the nation and the world. This new component of the hazard analysis provides an overview of events, such as 9/11 and Hurricanes Katrina and Rita, whose scale may necessitate extensive activities within Michigan even though the direct impacts of the event primarily occurred outside of our state. The section on civil disturbances has been extensively rewritten, to add additional information from social science research. Similarly, the section on nuclear attack has also been rewritten, to better reflect the new post-Cold War era in which the role of terrorist nuclear threats is of even greater concern. This is followed by an updated section on public health emergencies, which includes new information about the threat of pandemics, and the final section on terrorism has, like the nuclear attack section, been almost entirely rewritten, to better reflect the current geopolitical situation, as well as advances in our understanding of the threat, as informed by recent events and new research in homeland security studies.

The result of these changes is meant to be a document that is much more comprehensive, up-to-date, and valid than has appeared before, while also being easier to use. It is worth noting that many of the sources used in previous documents were not always cited in a manner that allowed them to remain clearly connected with the material as it was adapted for use here. Although this information was all reviewed and, in many cases, double-checked, the sources cited in this new edition tend to only be ones used for the new material that was added. Citations for text adapted from earlier documents (e.g. the 2006 edition of the Michigan Hazard Analysis) might be tracked down through those earlier documents, but many government documents have differed over the years from academic documents, in the precision and consistency of citation use. Due to the large number of events described in lists throughout this document, the decision was made not to provide citations for every item. Some of the sources used are not ones that allow verification by most readers (such as LEIN messages, Flash Reports, local hazard mitigation plans, internal MSP documentation from disasters, and emergency management correspondence). If there is a question about any of the information in this document, inquiries can be directed to Mike Sobocinski at (517) 336-2053 (or sobocinskim@michigan.gov) and the information can then be double-checked or its basis explained. Amidst some internal discussion, there have been some references to the Wikipedia online encyclopedia included—not as a final information source, but to give it credit as providing a handy gateway to identifying numerous articles and internet sources whose validity was then judged and then considered for use as an authoritative source. For example, many of the Wikipedia entries led to articles that had originally appeared in peer-reviewed scientific journals.

One final note may also be helpful regarding the sometimes lengthy lists of historical incidents included in this document. Some of the rarer types of incidents may use examples from outside of Michigan, when it was felt that an insufficient number or variety of Michigan examples was available, or because they involved scenarios that in some manner were deemed to be noteworthy for an analysis of that hazard. On the other hand, lengthy lists of Michigan examples have been provided for other hazards—often with a reduced font size. These lists sometimes contain specific local information, and are intended to help provide links between state level planning and the analysis of hazards at the local level. The inclusion of some specific local information here can be helpful in the development and update of local hazard mitigation plans, just as the review and consideration of local plans has been helpful for the latest update of the State plan. Readers may scrutinize or skim over those sections as they like, but this plan has been revised from the perspective that the best means of analyzing hazards is to maintain a solid historical grounding.

With an introductory overview now provided to readers, an outline of the full hazard analysis section is hereby presented, as a quick guide to the hundreds of pages that follow:

I. Natural Hazards
- A. Weather Hazards
  - 1. Storms
    - a. Thunderstorms, including hail and lightning
    - b. Winter storms, including ice, sleet, and snow
  - 2. Severe winds
  - 3. Tornadoes
  - 4. Extreme temperatures
  - 5. Fog
- B. Hydrological Hazards
  - 1. Flooding
    - a. Riverine flooding
    - b. Great Lakes shoreline hazards
    - c. Dam failures
  - 2. Drought
- C. Ecological Hazards
  - 1. Wildfires
  - 2. Invasive species
- D. Geological Hazards
  - 1. Ground Movement
    - a. Earthquakes
    - b. Subsidence
  - 2. Celestial Impacts **(new section)**

II. Technological Hazards
- A. Industrial Hazards
  - 1. Fires
    - a. Structural fires
    - b. Scrap tire fires
  - 2. Hazardous Materials Incidents
    - a. Hazardous materials incidents – fixed site (including industrial accidents)
    - b. Nuclear power plant emergencies
    - c. Hazardous materials incidents – transportation
    - d. Petroleum and natural gas pipeline accidents
    - c. Oil and natural gas well accidents
- B. Infrastructure Problems
  - 1. Infrastructure failures
  - 2. Energy emergencies
  - 3. Transportation accidents (air, rail, highway, marine)

III. Human-Related Hazards
- A. Catastrophic Incidents (National Emergencies) **(new section)**
- B. Civil Disturbances
- C. Nuclear Attack
- D. Public Health Emergencies
- E. Terrorism and Similar Criminal Activities

Information about these hazards is summarized in the following table. Note that it was not yet considered valid at this point to attempt to fill in <u>every</u> part of the table with summary information.

Hazard Analysis Summary Table

	Average annual events	Average annual deaths	Average annual injuries	Average annual property damage	Development trend effects	Risk rating: casualties	Risk rating: property	Risk Rating: economic costs	Risk rating: Infrastructure effects	Risk rating: Environment	Frequency as a top local hazard
Hail	**~25**	**0.0**	**0.0**	**$15 million**	**+**	**0**	**2**	**2**	**1**	**1**	**Some**
Lightning	**~12**	**1.5**	**10.7**	**$1.4 million**	**=**	**1**	**1**	**2**	**2**	**2**	**Some**
Ice and sleet storms (damage estimate includes snowstorms)	**2.2**	**>1**	**>1**	**~$12 million**	**+**	**1**	**2**	**3**	**3**	**1**	**Some**
Snowstorms	**>1**	**>1**	**>1**	(included above)	**+**	**1**	**1**	**2**	**2**	**1**	**Many**
Severe winds	**~8**	**2**	**20**	**~$25 million**	**+**	**1**	**2**	**3**	**3**	**1**	**Many**
Tornadoes	**~16**	**4**	**60**	**$17.8 million**	**+**	**2**	**2**	**3**	**3**	**2**	**Many**
Extreme heat	**~7**	**2?**	**?**	**?**	**=**	**2**	**0**	**2**	**2**	**0**	**Some**
Extreme cold	**~30**	**5?**	**?**	**$millions**	**=**	**2**	**2**	**3**	**3**	**1**	**Some**
Fog	**0.5**	**?**	**?**	**?**	**+**	**1**	**0**	**1**	**1**	**0**	**None**
Flooding	**>1**	**0.4**	**0.5**	**~$80 million**	**+**	**1**	**2**	**3**	**3**	**2**	**Some**
Shoreline hazards	**>1**	**~2**	**~4**	**>$10 million**	**+**	**1**	**2**	**3**	**2**	**1**	**Some**
Dam failures	**~2?**	**0?**	**0?**	**$thousands**	**+**	**2**	**2**	**3**	**2**	**2**	**Some**
Drought	**0.5**	**0**	**0**	**$millions**	**?**	**0**	**0**	**3**	**1**	**2**	**Few**
Wildfires	**>550**	**3.7**	**?**	**~$1 million +**	**+**	**2**	**2**	**3**	**2**	**3**	**Some**
Invasive species	**?**	**?**	**>1**	**$millions**	**?**	**1**	**2**	**3**	**1**	**3**	**None**
Earthquakes	**0.3**	**0**	**0**	**$165,000**	**+**	**1**	**1**	**2**	**2**	**2**	**Few**
Subsidence	**0.4**	**0**	**0**	**mere thousands?**	**+**	**1**	**1**	**1**	**1**	**1**	**Few**
Celestial impacts (impacting object)	**<1**	**0**	**0**	**<$1,000**	**+**	**0**	**1**	**1**	**1**	**1**	**None**
Celestial impacts (space weather)	**~0.3**	**0**	**0**	**$millions?**	**+**	**0**	**1**	**2**	**2**	**0**	**None**
Structural fires (major)	**>1**	**>5**	**>10**	**>$many millions**	**-**	**2**	**2**	**2**	**1**	**2**	**Few**
Scrap tire fires	**0.5**	**0**	**0**	**$thousands**	**=**	**0**	**1**	**2**	**1**	**2**	**Few**
Hazardous materials incident (fixed site)	**~7**	**>1**	**>1**	**$millions**	**+**	**2**	**2**	**2**	**2**	**2**	**Some**
Nuclear power plant incidents	**0.02**	**0**	**0**	**0**	**+**	**0**	**1**	**2**	**2**	**2**	**Few**
Hazardous materials (transportation)	**~13**	**>1**	**>1**	**$many thousand**	**+**	**2**	**2**	**2**	**2**	**2**	**Some**
Oil & gas pipelines	**>1**	**~0.7**	**~1.4**	**$millions**	**+**	**1**	**2**	**2**	**2**	**2**	**Few**
Oil & gas wells	**0.2**	**<1**	**<1**	**?**	**+**	**1**	**1**	**1**	**1**	**1**	**Few**
Infrastructure failures	**>1**	**<1**	**<1**	**$many millions**	**+**	**1**	**1**	**3**	**3**	**2**	**Some**
Energy emergencies	**~1**	**0**	**0**	**?**	**+**	**0**	**0**	**2**	**2**	**1**	**None**
Transportation accidents (major)	**>1**	**>1**	**>1**	**$many thousands**	**+**	**2**	**1**	**2**	**1**	**1**	**Few**
Catastrophic incidents	**<1**	**>1**	**>1**	**?**	**=**	**1**	**0**	**2**	**2**	**2**	**None**
Civil disturbances	**<1**	**>1**	**>1**	**$thousands**	**=**	**2**	**2**	**2**	**1**	**1**	**Few**
Nuclear attack	**0**	**0**	**0**	**?**	**-**	**2**	**2**	**2**	**2**	**2**	**Many**
Public health emergencies	**?**	**>1**	**>1**	**?**	**-**	**2**	**0**	**2**	**2**	**1**	**Few**
Terrorism and similar activities	**<1**	**>1**	**>1**	**?**	**=**	**2**	**2**	**2**	**2**	**2**	**Some**

"**Average annual**" numbers are medium-term estimates only. Medium-term means that most estimates were based upon decades' worth of data, to predict future decades' risk. Numbers that could not be validly determined are marked "?"

Development trend effects use the following symbols to estimate the effects from Michigan's recent land use trends (which still mainly involve the construction of suburban, exurban, and rural detached homes for persons moving out of denser areas). "+" means increasing risks, "=" means few net effects, "-" means decreasing risks, "?"means trends are unclear

Risk Ratings are based upon the estimated severity of average annual impacts (medium-term), as follows:

"0" means negligible: The hazard, as currently known, is not likely to cause any emergency-level event.

"1" means minor: There is a known although infrequent chance for impacts of moderate or purely local severity.

"2" means significant: A regular pattern of moderate effects, or an infrequent chance of severe impacts.

"3" means major: A regular pattern or high risk of major impacts, of statewide significance.

"**Frequency as a top local hazard**" refers to the number of local plans listing this as one of their top hazards. Categories include "Many," "Some," "Few," and "None." Note that because FEMA requires the analysis of natural hazards, but not technological and human-related hazards, local plans are inclined to favor the listing of natural hazards.

I. Natural Hazards
A. Weather Hazards

The following outline summarizes the significant weather hazards covered in this section:

1. Storms
    a. Thunderstorms, including hail and lightning
    b. Winter storms, including ice, sleet, snow
2. Severe Winds
3. Tornadoes
4. Extreme Temperatures
5. Fog

These weather hazards can be thought of in general terms, according to whether they involve winter weather conditions or not. The winter storms section, and half of the extreme temperatures section, should be referred to for a good overview of Michigan's winter weather hazards. The other sections focus upon weather conditions that predominate in the non-winter months. However, it must be admitted that fog and strong winds may be present during the winter season as well, (although the strongest winds in Michigan usually occur during transition periods between warm and cool weather, and in association with severe thunderstorms). Strong winter winds may occur in conjunction with sleet and ice, and are a specific part of blizzard events, all described in the winter weather section. When ice and sleet have already weakened an area's tree limbs, power lines, and infrastructure, winter winds are often the final straw that causes tree limbs (or entire trees) to topple across roads or utility lines, causing life-threatening infrastructure breakdowns during periods of extreme cold. A big part of why this updated analysis now addresses all weather hazards within a single section is because there may not always be neat and precise distinctions between the different events. It makes sense to study these related topics together and then consider areas of overlap and similarity. But the most essential aspects of Michigan's winter weather hazards are described in the two sections: winter storms and extreme temperatures.

The non-winter months usually see the other types of severe weather hazards—thunderstorms and tornadoes, lightning and hail, and extreme heat. Thus, most of this section of the hazard analysis describes hazards that regularly occur during the non-winter months. The seasons in Michigan do not completely match those seen on the standard calendar, and they vary a little bit depending upon the area of the State being considered. As will be described further in the material on each hazard, Michigan's weather is affected by its location in the middle of the Great Lakes. Locations next to, or distant from, a Great Lakes shoreline, will often have different weather patterns and hazard risks. There is also a general trend relating to how far to the north the area under consideration is located. Michigan may be thought of in terms of three broad geographic divisions: the Upper Peninsula, the Northern Lower Peninsula, and the Southern Lower Peninsula. The Upper Peninsula, in addition to containing the northernmost locations and the areas of highest elevation (e.g Mount Arvon in Baraga County, at 603m), also has areas that are more exposed to weather patterns blowing in from the west, without the extent of moderating Lake Michigan influence enjoyed by the Lower Peninsula. This exposes the Upper Peninsula to colder average temperatures and longer winters. The Lower Peninsula contains a northern region that contains large areas of woodland, as well as areas of hilly landscape and higher elevation (e.g. Grove Hill, in northern Osceola County, at 522m) than its southern region, in which agricultural and urban land uses are predominant.

In terms of population density, a difference can also be clearly found between the three general regions of Michigan. The Upper Peninsula has extensive stretches of highly rural areas across its 15 large and irregularly-shaped counties (Luce and Iron are the only ones with simple rectangular borders on three sides), with moderately-sized cities (or urban areas) fairly widely separated from each other. Although the largest of these is currently the city of Marquette, Marquette County's population density (an average of 36 persons per square mile) is the same as that for the counties of Dickinson (with the Iron Mountain/Kingsford urban area as its economic focus) and Houghton (with the Houghton/Hancock urban area as its current economic focus area, although a

century or more ago it would have been the thriving mining area around Calumet), followed closely by Delta County (with its Escanaba/Gladstone metro area and an average of 33 persons per square mile). The population density ranges to as low as 4 persons per square mile (in Keweenaw, which is also Michigan's northernmost and least populous county).

In the Northern Lower Peninsula, the population densities by county tend to be higher, and Traverse City stands out as the key city whose urban area is significantly larger than any others in the region. Grand Traverse County has an average of 167 residents per square mile—more than double the population density of any other county in the Northern Lower Peninsula, and nearly five times as much as any of the (geographically larger) Upper Peninsula counties just named. Apart from this exception, all other counties in the Northern Lower Peninsula range from 17 to 67 persons per square mile. The southern "boundary" of the Northern Lower Peninsula, in terms of county population density, might reasonably be described as the line of counties from Arenac across to Lake County, and then slightly south to include the counties of Newaygo and Oceana. Every county south of this "line" has a significantly higher population density (although the two agricultural "Thumb" counties of Huron and Saniliac, which could be described as lying to the East of this "line," are exceptions, at 43 and 46 persons per square mile but are classified as part of the Southern Lower Peninsula since they are located across the Saginaw Bay and have primarily agricultural functions amidst a "ring" of major metropolitan areas).

In the Southern Lower Peninsula, apart from the two agricultural "Thumb" counties of Huron and Sanilac, every county has a higher population density than any of the counties within the Northern Lower Peninsula region just described (excluding Grand Traverse County). Population densities range from 72 persons per square mile (Tuscola County) up through the Wayne County maximum of 3,356 persons per square mile. (All statistics here are based upon figures from the 2000 census.)

Although these three general Michigan regions each have different degrees of risk and vulnerability from weather hazards, it is important to note that <u>all</u> of them are at-risk from each of the hazards in this section. The risks merely vary by degree and severity of the "typical" impact. Every one of Michigan's 83 counties has experienced severe thunderstorms and at least one confirmed tornado. Every county is also susceptible to strong winds, extreme temperatures, and severe winter weather. The variation across Michigan is primarily one of likelihood and the range of intensity.

Therefore, for the weather hazards, it may make sense to think in terms of two parts of the year: winter and non-winter. Although mild snowfall and cold temperatures may occur a little bit outside of the main period of wintry weather, such events tend not to be serious ones, and therefore a general distinction can be made between the "winter weather risk season" and the "non-winter weather risk season." The winter weather risk season is defined in terms of historically documented events involving extreme cold and significant snowstorms. Seasons of winter weather risk include months during which record low temperatures are near enough to zero to make it likely that wind chill advisories would be issued, and when record snowfall levels have amounted to several inches. Even if these events are less likely on the "edges" of the season, since they have occurred, it made sense to define risk periods in terms of these possibilities. On the flip side, all the other months are susceptible to extreme heat (months in which record high temperatures go above 90 degrees Fahrenheit and thus make it likely that a heat advisory might need to be issued.

On the basis of this historical analysis, it was determined that the risk periods for extreme temperature and snowfall events can be assigned to the following months, for Michigan's three general regions. (NOTE: Do not use these seasons to define severe wind risks. For example, strong tornadoes have occurred recently in October.)

1. Southern Lower Peninsula: Winter risk season from late November to early April
Non-winter risk season from early May to late September
(extend that last risk season to early October for the southernmost tiers of counties, such as Berrien and Wayne)

2. Northern Lower Peninsula: Winter risk season from early November to April
Non-winter risk season from late May to late September

3. Upper Peninsula — Winter risk season from Late September to May
Non-winter risk season from late May to early September

Some variation may be expected between counties, especially shoreline counties that observe the tempering effect of the Great Lakes, but these may be good "rules of thumb" for the times of the year when different types of weather risks will occur in different parts of Michigan. The extreme heat hazard, for example, will affect the Upper Peninsula for a somewhat shorter time period each year than it does the Southern Lower Peninsula. However, this difference does not change the fact that once the risk season has arrived, both areas are at risk. In July, for example the City of Ironwood has recorded a record high temperature of 103 degrees, and although the record high temperatures in the Southern Lower Peninsula have reached 108 degrees, the all-time highest recorded temperature in Michigan actually came from the Northern Lower Peninsula, when Oscoda County hit 112 degrees (although the major weather stations at other locations across the region report records of 106 degrees). Thus, although there are differences and trends between regions and within them, the fact that all have experienced extreme heat waves must be recognized. In other words, the commonalities shared by Michigan's regions are more important than the differences, when it comes to weather-hazard preparedness and mitigation.

Historic Precipitation and Snowfall Records at Various Michigan Locations

Southern Lower Peninsula	**Record Precipitation**	**Record Snowfall**
Adrian (Lenawee County)	4.74" (Sept. 3)	15.0" (Jan. 26)
Benton Harbor (Berrien County)	6.60" (May 30)	25.0" (Dec. 6)
Coldwater (Branch County)	5.37" (June 26)	17.0" (Jan. 26)
Ann Arbor (Washtenaw County)	4.54" (Aug. 6)	15.8" (Dec.1)
Bloomingdale (Van Buren Co.)	9.78" (Sept. 1)	20.0" (Dec. 10)
Detroit (Wayne County)	4.74" (July 31)	24.5" (April 6)
Jackson (Jackson County)	5.31" (June 21)	16.0" (March 17)
Pontiac (Oakland County)	4.75" (Oct. 1)	18.0" (Dec. 2)
Flint (Genesee County)	6.04" (Sept. 10)	14.5" (Jan. 26)
Grand Rapids (Kent County)	4.22" (June 5 & Aug. 19)	16.1" (Jan. 26)
Port Huron (St. Clair County)	3.97" (Sept. 7)	14.3" (March 27)
Harbor Beach (Huron County)	6.04" (Sept. 10)	18.0" (Feb. 21)
Big Rapids (Mecosta County)	7.64" (Sept. 11)	16.0" (Jan. 30)

The counties listed above start with the southernmost tier in Michigan, and proceed generally northward, tier by tier.

Northern Lower Peninsula	**Record Precipitation**	**Record Snowfall**
Alpena (Alpena County)	5.14" (Sept. 3)	18.2" (Feb. 22)
East Tawas (Iosco County)	3.72" (Aug. 16)	20.0" (Feb. 14)
Gaylord (Otsego County)	5.00" (Aug. 17)	20.0" (Nov. 23)
Gladwin (Gladwin County)	5.00" (May 20)	15.0" (Dec. 11)
Traverse City	4.30" (Aug. 23)	16.0" (Jan. 25 & Nov. 29)
Upper Peninsula	**Record Precipitation**	**Record Snowfall**
Hancock (Houghton County)	3.58" (May 17 & Sept. 4)	26.5" (Jan. 18)
Ironwood (Gogebic County)	6.72" (July 21)	24.0" (Dec. 16)
Munising (Alger County)	3.51" (May 31)	20.0" (March 15)
Sault Ste. Marie (Chippewa Co.)	5.92" (Aug. 3)	26.6" (Dec. 10)

Source: Extreme Michigan Weather, by Paul Gross (2010, University of Michigan Press, Ann Arbor)

NOTE: The updated and newly added text for this section of the 2012 Michigan Hazard Analysis has benefited greatly from the following two books:
Extreme Michigan Weather, by Paul Gross. University of Michigan Press, Ann Arbor, 2010. (including its extensive records of weather extremes, selections of which have been added above, and to the section on extreme temperatures in the main text itself, plus additional feedback from direct contact with the author.)
Michigan Geography and Geology, edited by Randall Schaetzl, Joe Darden, and Danita Brandt. Pearson Custom Publishing, New York, et al., 2009. (especially chapter 19)

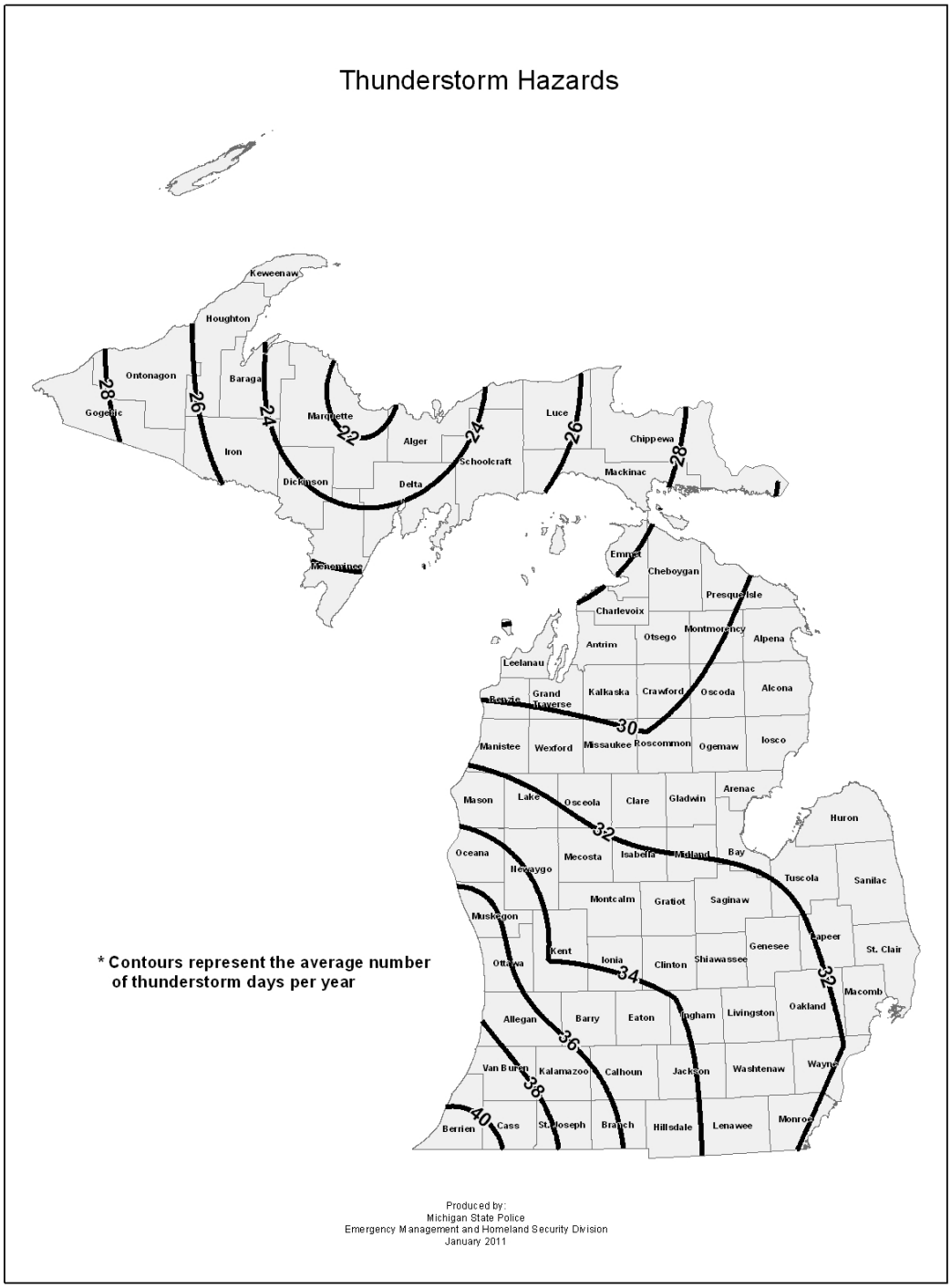
Overlap Between Weather Hazards and Other Sections of the Hazard Analysis

Extreme summer heat can increase the chances of wildfires (which has its own chapter in the "Ecological Hazards" section of this plan). Weather events involving precipitation have effects upon local hydrology. Heavy precipitation, and/or melting snow, can cause flooding. Ice jams and log jams (a source of which may include woody debris toppled into drains and streams by strong winds) can also cause flooding. For more information about flooding, please refer to the sections on Riverine and Shoreline flooding in the next section of this hazard analysis, dealing with "Hydrological Hazards." Also in the hydrological section is a chapter on droughts, which also have their origin in weather, but stem from experiencing too little precipitation rather than too much.

There is a strong connection between all of these extreme weather events and the "technological hazard" of infrastructure failure, which has its own chapter in the "Technological Hazards" section of this plan. Severe weather has also been a factor in major transportation accidents, which also has a chapter of its own in the Technological Hazards section.

Thunderstorm Hazards

Severe thunderstorms are weather systems accompanied by strong winds, lightning, heavy rain, and possibly hail and tornadoes. Severe thunderstorms can occur at any time in Michigan, although they are most frequent during the warm spring and summer months from May through September. The potential thunderstorm threat is often measured by the number of "thunderstorm days" – defined as days in which thunderstorms are observed. As the map below indicates, various areas in Michigan are subject to an average of at least 20 thunderstorm days per year, and up to just over 40 days per year in the state's southwestern corner. The Lower Peninsula, in general, is subject to approximately 28-40 thunderstorm days per year, while the Upper Peninsula average is closer to 20-30 thunderstorm days per year. This new map was based upon new weather service data from various weather stations within (and near) Michigan.



Thunderstorms form when a shallow layer of warm, moist air is overrun by a deeper layer of cool, dry air. Cumulonimbus clouds, frequently called "thunderheads," are formed in these conditions. These clouds are often enormous (up to six miles or more across and 40,000 to 50,000 feet high) and may contain tremendous amounts of water and energy. That energy is often released in the form of high winds, excessive rains, lightning, and possibly hail and tornadoes.

Thunderstorms are typically short-lived (often lasting no more than 30-40 minutes) and fast moving (30-50 miles per hour). Strong frontal systems, however, may spawn one squall line after another, composed of many individual thunderstorm cells. Severe thunderstorms may also cause severe flood problems because of the torrential rains that they may bring to an area. Thunderstorms sometimes move very slowly, and can thus dump a tremendous amount of precipitation onto a location. Flooding can result, including flash floods, "urban flooding," and riverine flooding. Please refer to the hydrological hazard section for more information about these hazards.

The following sections address in greater detail these specific thunderstorm hazards: 1) hail; 2) lightning; 3) severe winds; and 4) tornadoes (although several of these hazards can also occur when no thunderstorm activity is evident).

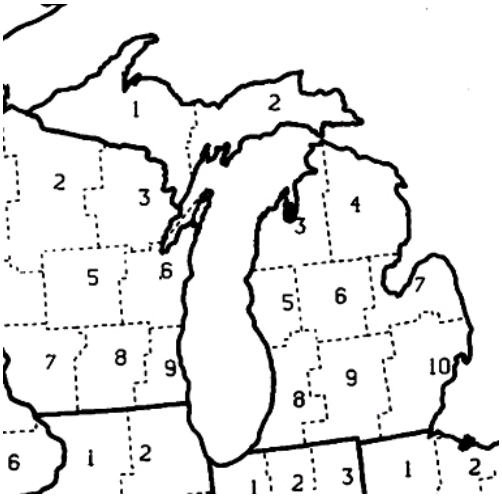
One positive aspect of assessing thunderstorm risks comes from the fact that thunderstorm hazards have some degree of predictability and are closely monitored by the National Weather Service. In addition to daily forecasts, which predict the probability of rainy or stormy weather, the NWS system of Watches and Warnings helps communities understand when there is a potential risk of severe thunderstorms, or if severe thunderstorms are imminent. When the NWS issues a "Severe Thunderstorm Watch," it means that thunderstorms with large hail and damaging winds are possible in your area. When the NWS issues a "Severe Thunderstorm Warning," it signifies that severe thunderstorms (with the damaging winds and hail) are in your area or are imminent.

The NWS has five offices that serve Michigan and are responsible for monitoring and providing predictions and bulletins for the entire state. The five offices are in Grand Rapids, Detroit, Gaylord, Marquette, and North Webster (Indiana). These stations provide information on severe weather watches and warnings, but also provide useful Doppler Radar images that track the movement of thunderstorms in your area. The North Webster office covers portions of southwest Michigan (www.weather.gov/iwx); the Grand Rapids station covers the remainder of southwest Michigan (www.weather.gov/grr); the Detroit station covers Southeast Michigan (www.weather.gov/dtx); the Gaylord station covers the north central portion of the Lower Peninsula and the eastern edge of the Upper Peninsula (www.weather.gov/apx); and the Marquette station examines the majority of the Upper Peninsula (www.weather.gov/mqt).

Since thunderstorms bring the potential for dangerous hail, lightning, straight-line winds, and tornadoes, it is necessary to further examine each of those hazards. **Useful historical information on hail, severe winds, lightning, and tornadoes for your county can be found through the National Climatic Data Center's Storm Data website at** http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms. Data for each county in the state are listed there, and there are historical records of significant events for hail (from 1955 for most counties); lightning (from 1993); severe winds (from 1955); and tornadoes (from 1950).

Michigan's 10 climate divisions (for the monitoring and analysis of precipitation)

Source: Rainfall Frequency Atlas of the Midwest, by Floyd A Huff and James R. Angel. Midwestern Climate Center and Illinois State Water Survey, 1992



Instructions for the Use of This Section

This section is useful for the assessment of rain and thunderstorm events, with implications also for flash flooding. It allows various levels of rainfall precipitation events to be interpreted in terms of their severity, based upon the historical frequency with which such events had occurred in the past.

The map at left shows Michigan's ten climate divisions, each of which is matched with data in the multi-page table below. (See page 136 for a list of counties located within each division.) The table contains sections listing numbers for each of Michigan's ten divisions. For a given precipitation event, find the row that most closely matches the duration of the rainfall event. Move across the row to find the number that is closest to the number of inches of rainfall for that event. The column in which that number appears tells the "recurrence interval" for that level of precipitation. A recurrence interval is the average amount of time that elapses between precipitation events of that particular severity level. Longer recurrence intervals indicate a more severe event. The most extreme events listed in the table are those with a 100-year recurrence interval. Such events are so severe that they are expected (on average) to occur only about one time per century. Precipitation-based flooding is more likely to result from events with a longer recurrence interval. Any Michigan rainfall amounts that exceed the values listed in the table are very rare and severe indeed!

As an example of the procedure described above, if an Ingham County event had caused 3 inches of rain to fall during a 6-hour period, the Division 9 section of the table contains a row labeled "6-hr" and the column that most closely matches the 3" rainfall amount contains a value of 3.07", matching up with a 25-year recurrence interval (definitely a major rainfall event).

Table: Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days, by Climate Division, and Recurrence Intervals of 2 Months to 100 Years in Michigan (for use with thunderstorm and flood hazards)

		Rainfall (inches) for each given recurrence interval											
Division	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	1.69	2.04	2.35	2.76	3.17	3.45	4.28	5.34	6.17	7.27	8.11	8.99
01	5-day	1.41	1.69	1.91	2.22	2.55	2.77	3.38	4.23	4.91	5.86	6.65	7.50
01	72-hr	1.24	1.46	1.65	1.91	2.20	2.39	2.96	3.69	4.29	5.11	5.79	6.49
01	48-hr	1.14	1.33	1.48	1.72	1.98	2.15	2.64	3.31	3.84	4.59	5.20	5.86
01	24-hr	1.07	1.25	1.37	1.58	1.79	1.95	2.39	3.00	3.48	4.17	4.73	5.32
01	18-hr	1.01	1.17	1.28	1.48	1.68	1.83	2.25	2.82	3.27	3.92	4.45	5.00
01	12-hr	0.94	1.09	1.19	1.38	1.56	1.70	2.08	2.61	3.03	3.63	4.12	4.63
01	6-hr	0.80	0.93	1.02	1.18	1.34	1.46	1.79	2.25	2.61	3.13	3.55	3.99
01	3-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.53	1.92	2.23	2.67	3.03	3.40
01	2-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.39	1.74	2.02	2.42	2.74	3.09
01	1-hr	0.51	0.59	0.64	0.75	0.85	0.92	1.12	1.41	1.64	1.96	2.22	2.50
01	30-min	0.40	0.46	0.50	0.58	0.66	0.72	0.88	1.11	1.29	1.54	1.75	1.97
01	15-min	0.29	0.34	0.37	0.43	0.49	0.53	0.65	0.81	0.94	1.13	1.28	1.44
01	10-min	0.23	0.26	0.29	0.33	0.38	0.41	0.50	0.63	0.73	0.88	0.99	1.12
01	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.29	0.36	0.42	0.50	0.57	0.64
02	10-day	1.61	1.94	2.23	2.62	3.02	3.28	3.93	4.78	5.44	6.43	7.22	7.98
02	5-day	1.25	1.50	1.70	1.97	2.26	2.46	3.00	3.71	4.25	5.11	5.81	6.55
02	72-hr	1.15	1.35	1.52	1.77	2.03	2.21	2.62	3.27	3.78	4.57	5.23	5.94
02	48-hr	0.97	1.13	1.26	1.46	1.68	1.83	2.31	2.98	3.49	4.24	4.88	5.55
02	24-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.09	2.71	3.19	3.87	4.44	5.03
02	18-hr	0.86	1.00	1.09	1.26	1.44	1.56	1.96	2.55	3.00	3.64	4.17	4.73
02	12-hr	0.79	0.92	1.01	1.17	1.32	1.44	1.82	2.36	2.78	3.37	3.86	4.38
02	6-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.57	2.03	2.39	2.90	3.33	3.77
02	3-hr	0.58	0.68	0.74	0.86	0.98	1.06	1.34	1.73	2.04	2.48	2.84	3.22
02	2-hr	0.53	0.61	0.67	0.78	0.88	0.96	1.21	1.57	1.85	2.24	2.58	2.92
02	1-hr	0.43	0.50	0.55	0.63	0.72	0.78	0.98	1.27	1.50	1.82	2.09	2.36
02	30-min	0.34	0.39	0.43	0.49	0.56	0.61	0.77	1.00	1.18	1.43	1.64	1.86
02	15-min	0.25	0.29	0.31	0.36	0.41	0.45	0.56	0.73	0.86	1.04	1.20	1.36
02	10-min	0.19	0.22	0.24	0.28	0.32	0.35	0.44	0.57	0.67	0.81	0.93	1.06
02	5-min	0.11	0.13	0.14	0.16	0.18	0.20	0.25	0.33	0.38	0.46	0.53	0.60

Page 2 of Table: Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days, by Climate Division, and Recurrence Intervals of 2 Months to 100 Years in Michigan (for use with thunderstorm and flood hazards)

		Rainfall (inches) for each given recurrence interval											
Division	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
03	10-day	1.63	1.96	2.26	2.66	3.06	3.33	3.99	4.92	5.65	6.66	7.50	8.35
03	5-day	1.29	1.54	1.75	2.02	2.33	2.53	3.10	3.91	4.57	5.46	6.23	7.04
03	72-hr	1.09	1.27	1.44	1.67	1.92	2.09	2.62	3.36	3.96	4.86	5.56	6.35
03	48-hr	0.97	1.13	1.26	1.46	1.68	1.83	2.34	3.02	3.55	4.31	4.94	5.60
03	24-hr	0.89	1.04	1.13	1.31	1.49	1.62	2.09	2.70	3.21	3.89	4.47	5.08
03	18-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.96	2.54	3.02	3.66	4.20	4.78
03	12-hr	0.78	0.90	0.99	1.14	1.30	1.41	1.82	2.35	2.79	3.38	3.89	4.42
03	6-hr	0.67	0.78	0.85	0.99	1.12	1.22	1.57	2.03	2.41	2.92	3.35	3.81
03	3-hr	0.57	0.67	0.73	0.84	0.96	1.04	1.34	1.73	2.05	2.49	2.86	3.25
03	2-hr	0.52	0.60	0.66	0.76	0.86	0.94	1.21	1.57	1.86	2.26	2.59	2.95
03	1-hr	0.42	0.49	0.53	0.62	0.70	0.76	0.98	1.27	1.51	1.83	2.10	2.39
03	30-min	0.33	0.38	0.42	0.49	0.55	0.60	0.77	1.00	1.19	1.44	1.65	1.88
03	15-min	0.24	0.28	0.31	0.36	0.40	0.44	0.56	0.73	0.87	1.05	1.21	1.37
03	10-min	0.19	0.22	0.24	0.28	0.31	0.34	0.44	0.57	0.67	0.82	0.94	1.07
03	5-min	0.10	0.12	0.13	0.15	0.17	0.19	0.25	0.32	0.39	0.47	0.54	0.61
04	10-day	1.56	1.88	2.17	2.55	2.93	3.19	3.77	4.56	5.22	6.10	6.85	7.60
04	5-day	1.26	1.51	1.70	1.98	2.27	2.47	2.99	3.68	4.23	4.97	5.58	6.23
04	72-hr	1.12	1.31	1.48	1.72	1.98	2.15	2.63	3.27	3.75	4.45	5.00	5.60
04	48-hr	1.00	1.17	1.30	1.51	1.74	1.89	2.32	2.88	3.33	3.93	4.43	4.95
04	24-hr	0.94	1.09	1.20	1.39	1.57	1.71	2.11	2.62	3.04	3.60	4.06	4.53
04	18-hr	0.89	1.03	1.13	1.30	1.48	1.61	1.98	2.46	2.86	3.38	3.82	4.26
04	12-hr	0.82	0.95	1.04	1.21	1.37	1.49	1.84	2.28	2.64	3.13	3.53	3.94
04	6-hr	0.70	0.82	0.90	1.04	1.18	1.28	1.58	1.96	2.28	2.70	3.05	3.40
04	3-hr	0.60	0.70	0.76	0.88	1.00	1.09	1.35	1.68	1.95	2.30	2.60	2.90
04	2-hr	0.54	0.63	0.69	0.80	0.91	0.99	1.22	1.52	1.76	2.09	2.35	2.63
04	1-hr	0.44	0.51	0.56	0.65	0.74	0.80	0.99	1.23	1.43	1.69	1.91	2.13
04	30-min	0.35	0.40	0.44	0.51	0.58	0.63	0.78	0.97	1.12	1.33	1.50	1.68
04	15-min	0.25	0.29	0.32	0.37	0.42	0.46	0.57	0.71	0.82	0.97	1.10	1.22
04	10-min	0.20	0.23	0.25	0.29	0.33	0.36	0.44	0.55	0.64	0.76	0.85	0.95
04	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.25	0.31	0.36	0.43	0.49	0.54
05	10-day	1.64	1.97	2.27	2.67	3.07	3.34	4.14	5.28	6.21	7.59	8.75	10.02
05	5-day	1.38	1.65	1.86	2.16	2.48	2.70	3.36	4.30	5.07	6.25	7.26	8.36
05	72-hr	1.18	1.38	1.56	1.81	2.08	2.26	2.88	3.74	4.46	5.45	6.31	7.26
05	48-hr	1.04	1.22	1.36	1.58	1.81	1.97	2.53	3.34	4.01	4.97	5.81	6.73
05	24-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.28	3.00	3.60	4.48	5.24	6.07
05	18-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.14	2.82	3.38	4.21	4.93	5.71
05	12-hr	0.85	0.99	1.08	1.25	1.42	1.54	1.98	2.61	3.13	3.90	4.56	5.28
05	6-hr	0.73	0.85	0.93	1.08	1.22	1.33	1.71	2.25	2.70	3.36	3.93	4.55
05	3-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.46	1.92	2.30	2.87	3.35	3.88
05	2-hr	0.57	0.66	0.72	0.83	0.95	1.03	1.32	1.74	2.09	2.60	3.04	3.52
05	1-hr	0.46	0.53	0.58	0.67	0.76	0.83	1.07	1.41	1.69	2.11	2.46	2.85
05	30-min	0.36	0.42	0.45	0.53	0.60	0.65	0.84	1.11	1.33	1.66	1.94	2.25
05	15-min	0.26	0.31	0.34	0.39	0.44	0.48	0.62	0.81	0.97	1.21	1.41	1.64
05	10-min	0.20	0.24	0.26	0.30	0.34	0.37	0.48	0.63	0.76	0.94	1.10	1.27
05	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.27	0.36	0.43	0.54	0.63	0.73
06	10-day	1.76	2.12	2.44	2.87	3.30	3.59	4.31	5.36	6.21	7.46	8.51	9.54
06	5-day	1.44	1.72	1.95	2.26	2.59	2.82	3.40	4.22	4.89	6.11	7.17	8.31
06	72-hr	1.23	1.45	1.64	1.90	2.18	2.37	2.88	3.62	4.24	5.27	6.17	7.18
06	48-hr	1.09	1.28	1.42	1.65	1.90	2.06	2.51	3.17	3.71	4.59	5.35	6.20
06	24-hr	1.02	1.19	1.30	1.51	1.71	1.86	2.27	2.85	3.34	4.15	4.84	5.62
06	18-hr	0.96	1.12	1.23	1.42	1.61	1.75	2.13	2.68	3.14	3.90	4.55	5.28
06	12-hr	0.89	1.04	1.13	1.31	1.49	1.62	1.97	2.48	2.91	3.61	4.21	4.89
06	6-hr	0.76	0.89	0.97	1.13	1.28	1.39	1.70	2.14	2.50	3.11	3.63	4.22
06	3-hr	0.65	0.76	0.83	0.96	1.09	1.19	1.45	1.82	2.14	2.66	3.10	3.60
06	2-hr	0.59	0.69	0.76	0.87	0.99	1.08	1.32	1.65	1.94	2.41	2.81	3.26
06	1-hr	0.48	0.56	0.61	0.70	0.80	0.87	1.07	1.34	1.57	1.95	2.27	2.64
06	30-min	0.38	0.44	0.48	0.56	0.63	0.69	0.84	1.05	1.24	1.54	1.79	2.08
06	15-min	0.28	0.32	0.35	0.41	0.46	0.50	0.61	0.77	0.90	1.12	1.31	1.52
06	10-min	0.21	0.25	0.27	0.32	0.36	0.39	0.48	0.60	0.70	0.87	1.02	1.18
06	5-min	0.12	0.14	0.15	0.18	0.20	0.22	0.27	0.34	0.40	0.50	0.58	0.67

Page 3 of Table: Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days, by Climate Division, and Recurrence Intervals of 2 Months to 100 Years in Michigan (for use with thunderstorm and flood hazards)

		Rainfall (inches) for given recurrence interval											
Division	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
07	10-day	1.57	1.89	2.18	2.56	2.94	3.20	3.88	4.75	5.39	6.21	6.83	7.48
07	5-day	1.22	1.46	1.66	1.92	2.21	2.40	2.96	3.68	4.23	4.99	5.61	6.26
07	72-hr	1.11	1.30	1.47	1.70	1.96	2.13	2.62	3.28	3.78	4.49	5.05	5.66
07	48-hr	1.02	1.20	1.33	1.54	1.78	1.93	2.37	2.97	3.41	4.03	4.52	5.04
07	24-hr	0.96	1.12	1.23	1.42	1.61	1.75	2.14	2.65	3.05	3.56	3.97	4.40
07	18-hr	0.90	1.05	1.15	1.33	1.51	1.64	2.01	2.49	2.87	3.35	3.73	4.14
07	12-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.86	2.31	2.65	3.10	3.45	3.83
07	6-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.61	1.99	2.29	2.67	2.98	3.30
07	3-hr	0.62	0.72	0.78	0.91	1.03	1.12	1.37	1.70	1.95	2.28	2.54	2.82
07	2-hr	0.56	0.65	0.71	0.82	0.93	1.01	1.24	1.54	1.77	2.06	2.30	2.55
07	1-hr	0.45	0.52	0.57	0.66	0.75	0.82	1.01	1.25	1.43	1.67	1.87	2.07
07	30-min	0.36	0.42	0.45	0.53	0.60	0.65	0.79	0.98	1.13	1.32	1.47	1.63
07	15-min	0.26	0.30	0.33	0.38	0.43	0.47	0.58	0.72	0.82	0.96	1.07	1.19
07	10-min	0.20	0.24	0.26	0.30	0.34	0.37	0.45	0.56	0.64	0.75	0.83	0.92
07	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.26	0.32	0.37	0.43	0.48	0.53
08	10-day	1.81	2.18	2.51	2.95	3.39	3.69	4.33	5.23	5.96	7.39	8.63	10.03
08	5-day	1.48	1.77	2.00	2.32	2.67	2.90	3.45	4.27	4.95	6.16	7.28	8.46
08	72-hr	1.29	1.52	1.72	1.99	2.29	2.49	3.00	3.75	4.41	5.50	6.45	7.51
08	48-hr	1.14	1.33	1.48	1.72	1.98	2.15	2.63	3.32	3.91	4.93	5.83	6.82
08	24-hr	1.07	1.25	1.37	1.58	1.79	1.95	2.37	3.00	3.52	4.45	5.27	6.15
08	18-hr	1.01	1.17	1.28	1.48	1.68	1.83	2.23	2.82	3.31	4.18	4.95	5.78
08	12-hr	0.94	1.09	1.19	1.38	1.56	1.70	2.06	2.61	3.06	3.87	4.58	5.35
08	6-hr	0.80	0.93	1.02	1.18	1.34	1.46	1.78	2.25	2.64	3.34	3.95	4.61
08	3-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.52	1.92	2.25	2.85	3.37	3.94
08	2-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.37	1.74	2.04	2.58	3.06	3.57
08	1-hr	0.51	0.59	0.64	0.75	0.85	0.92	1.11	1.41	1.65	2.09	2.48	2.89
08	30-min	0.40	0.46	0.50	0.58	0.66	0.72	0.88	1.11	1.30	1.65	1.95	2.28
08	15-min	0.29	0.34	0.37	0.43	0.49	0.53	0.64	0.81	0.95	1.20	1.42	1.66
08	10-min	0.23	0.26	0.29	0.33	0.38	0.41	0.50	0.63	0.74	0.93	1.11	1.29
08	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.28	0.36	0.42	0.53	0.63	0.74
09	10-day	1.77	2.13	2.45	2.89	3.32	3.61	4.26	5.15	5.83	6.81	7.60	8.40
09	5-day	1.43	1.71	1.93	2.24	2.58	2.80	3.36	4.10	4.71	5.57	6.27	6.99
09	72-hr	1.27	1.49	1.68	1.95	2.24	2.44	2.93	3.59	4.16	4.95	5.59	6.28
09	48-hr	1.17	1.37	1.52	1.77	2.03	2.21	2.66	3.28	3.79	4.50	5.10	5.73
09	24-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.42	2.98	3.43	4.09	4.63	5.20
09	18-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.27	2.80	3.22	3.84	4.35	4.89
09	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.11	2.59	2.98	3.56	4.03	4.52
09	6-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.82	2.24	2.57	3.07	3.47	3.90
09	3-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.55	1.91	2.20	2.62	2.96	3.33
09	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.40	1.73	1.99	2.37	2.69	3.02
09	1-hr	0.52	0.61	0.66	0.77	0.87	0.95	1.14	1.40	1.61	1.92	2.18	2.44
09	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.90	1.10	1.27	1.51	1.71	1.92
09	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.65	0.80	0.93	1.10	1.25	1.40
09	10-min	0.24	0.28	0.30	0.35	0.40	0.43	0.51	0.63	0.72	0.86	0.97	1.09
09	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.29	0.36	0.41	0.49	0.56	0.62
10	10-day	1.56	1.88	2.17	2.55	2.93	3.19	3.82	4.64	5.27	6.11	6.79	7.51
10	5-day	1.28	1.53	1.73	2.01	2.31	2.51	3.05	3.68	4.16	4.78	5.26	5.74
10	72-hr	1.18	1.38	1.56	1.81	2.08	2.26	2.74	3.34	3.76	4.31	4.74	5.16
10	48-hr	1.08	1.26	1.41	1.63	1.88	2.04	2.48	3.04	3.44	3.96	4.36	4.78
10	24-hr	1.03	1.20	1.31	1.51	1.72	1.87	2.26	2.75	3.13	3.60	3.98	4.36
10	18-hr	0.97	1.13	1.23	1.43	1.62	1.76	2.12	2.59	2.94	3.38	3.74	4.10
10	12-hr	0.90	1.04	1.14	1.32	1.50	1.63	1.97	2.39	2.72	3.13	3.46	3.79
10	6-hr	0.77	0.90	0.98	1.13	1.29	1.40	1.69	2.06	2.35	2.70	2.99	3.27
10	3-hr	0.66	0.77	0.84	0.97	1.10	1.20	1.45	1.76	2.00	2.30	2.55	2.79
10	2-hr	0.59	0.69	0.76	0.87	0.99	1.08	1.31	1.59	1.82	2.09	2.31	2.53
10	1-hr	0.48	0.56	0.62	0.71	0.81	0.88	1.06	1.29	1.47	1.69	1.87	2.05
10	30-min	0.38	0.44	0.48	0.56	0.63	0.69	0.84	1.02	1.16	1.33	1.47	1.61
10	15-min	0.28	0.32	0.35	0.41	0.46	0.50	0.61	0.74	0.85	0.97	1.07	1.18
10	10-min	0.21	0.25	0.27	0.32	0.36	0.39	0.47	0.58	0.66	0.76	0.84	0.92
10	5-min	0.12	0.14	0.15	0.18	0.20	0.22	0.27	0.33	0.38	0.43	0.48	0.52

Hail

Conditions where atmospheric water particles from thunderstorms form into rounded or irregular lumps of ice that fall to the earth.

Hazard Description

Hail is a product of the strong thunderstorms that frequently move across the state. As one of these thunderstorms passes over, hail usually falls near the center of the storm, along with the heaviest rain. Sometimes, strong winds occurring at high altitudes in the thunderstorm can blow the hailstones away from the storm center, causing an unexpected hazard at places that otherwise might not appear threatened.

Most hailstones range in size from a pea to a golf ball, but hailstones larger than baseballs have occurred with the most severe thunderstorms. Hail is formed when strong updrafts within the storm carry water droplets above the freezing level, where they remain suspended and continue to grow larger until their weight can no longer be supported by the winds. They finally fall to the ground, battering crops, denting autos, and injuring wildlife and people. Large hail is a characteristic of severe thunderstorms, and it may precede the occurrence of a tornado.

Hazard Analysis

The National Weather Service began recording hail activity in Michigan in 1967. Statistics since that time indicate that approximately 50% of the severe thunderstorms that produce hail have occurred during the months of June and July, and nearly 80% have occurred during the prime growing season of May through August. As a result, the damage to crops from hail is often extensive.

The incidence of hail follows the incidence of severe thunderstorms. Therefore, those areas of the state most prone to severe thunderstorms are also the areas most prone to large and damaging hail. Generally, severe thunderstorms that produce hail occur more frequently in the southern half of the Lower Peninsula than any other area of the state. However, damaging hail has occurred in every part of Michigan. A major damaging hail event can be expected at least every 2 to 3 years.

The National Weather Service forecasts of severe thunderstorms usually give sufficient warning time to allow residents to take appropriate action to reduce the effects of hail damage on vehicles and some property. However, little can be done to prevent damage to crops. More details about the severity of Michigan events, and resulting damages, will be presented in the subsection, below, about significant Michigan hailstorms. At least $100 million in property and crop damage has occurred from hail events in Michigan since 1990. In 2009, the official cut-point that denotes severe hail events was increased from 0.75” to 1.00”.

Impact on the Public

Hail generally causes minor property damage within its area of impact, but large hail also discourages the public from outdoor activities and events, due to concerns involving safety and comfort.

Impact on Public Confidence in State Governance

If hail causes infrastructure failures, a question may be raised about the adequacy of that infrastructure, its maintenance, and its design and regulation. In events that require mass sheltering, such as schools or large gatherings (e.g. a county fair or community-sponsored event), the ability of local and state government to adequately plan for severe weather is often vital to the success of such events, which themselves are often important for various sectors of the local and state economy. Citizen discontent and media-exacerbated controversies have arisen from situations in which inadequate planning was evident, or provisions for public sheltering were inadequate.

Impact on Responders

Responders tend to be working outdoors in conditions from which most residents are taking shelter. Although special training and safety precautions have usually been taken (e.g. for line-repair workers), nevertheless, responders are more exposed to and at-risk from the impacts of hail. Fortunately, most episodes of hail are brief and it is usually easy to take cover to avoid being injured.

Impact on the Environment

Hail is a product of strong thunderstorms, usually occurs along with the heaviest rain, and ranges in size from a pea to a golf ball (and in some rare occurrences, a baseball). The primary effects on the natural environment include physical damage to vegetation such as forests, plants, and crops, and physical harm to wildlife species. Plants with well-established root systems will seldom die, but some younger or smaller forms of vegetation may not survive a severe hail storm. Hail can damage some fruit and vegetable plants and render them unsuitable for consumption by humans. This can also lead to an increased risk of bacteria that can kill healthy trees as well as nearby wildlife. The impact of hail can cause soil erosion that can exacerbate flooding, and large ice can potentially clog or reduce the effectiveness of drainage paths, culverts, and grates.

Significant Hailstorms in Michigan since 1985

May 1985 - Lower Peninsula (western and eastern counties)

In May 1985, severe thunderstorms accompanied by hail struck the western and eastern counties of the Lower Peninsula, causing great damage. Two-inch hail was reported in Cass County and $2 million in damages to fruit crops were reported in Kent County.

March 27, 1991 - Lower Peninsula (central and southern counties)

On March 27, 1991 severe thunderstorms and accompanying high winds and hail caused considerable damage across a large portion of central and southern Lower Michigan, damaging homes, businesses, farms and some public facilities. A total of three deaths and 27 injuries were attributed to the storms. Egg to baseball-sized hail, some exceeding 2.5" in diameter, was reported in the vicinity of Buchanan in Berrien County. In Kalamazoo and Portage in Kalamazoo County, softball size hail, up to 4.5" in diameter, did extensive damage to automobiles, windows and trees.

April 12, 1996 - Lower Peninsula (southern counties)

Up to golf ball sized hail fell across southern Michigan along the path of severe thunderstorms. Tree limbs, power lines, windows, aluminum and vinyl siding on houses were damaged. Numerous recreational vehicles parked at a dealership were badly damaged. The event resulted in $6 million in property damage throughout southern Michigan.

July 2, 1997 - Lower Peninsula (Berrien County)

A severe thunderstorm during the early morning hours of July 2, 1997 pounded Berrien County with 1" to 2.25" diameter hail that caused agricultural losses of nearly $1 million. The hail destroyed 280 acres of fruits and 100 acres of vegetables in a two-mile wide swath from Stevensville southeast to the county line. Damaging hail was reported in numerous other locations across the Lower Peninsula on July 2 – just one of the impacts of a storm system that would eventually spawn deadly tornadoes in southeast Michigan and lead to a Presidential Disaster Declaration. (Refer to the Tornadoes section for additional information.)

June 24, 1998 - Lower Peninsula (central and southern counties)

On June 24, 1998 two tracts of severe thunderstorms crossed the state moving east to west – one tract stretched across central Lower Michigan, while the other moved into the southern portion of the state. The more northerly thunderstorms produced large amounts of hail in several counties, ranging from dime to quarter sized hail up to baseball size (2.75" in diameter) hail. Damage was widespread, but not overly severe. However, in Petoskey, hail (2.5" in diameter) caused $100,000 in damage to cars on two lots west of town. In Ingham County, near Onondaga, baseball-sized hail damaged auto glass and roofs, but specific damage figures were not available.

Sept. 26, 1998 - Lower Peninsula (northern counties)

A line of severe thunderstorms that ravaged northern Lower Michigan during the weekend of September 26-27, 1998 produced hail up to 2" in diameter in Manistee County, destroying an estimated 30,000-35,000 bushels of apples at area farms. The same storm system produced tennis ball-sized hail north of the town of Gladwin, which damaged several homes and vehicles. In Arenac County, near Sterling, 3.5" diameter hail damaged crops and injured some livestock at area farms, and damaged several homes, satellite dishes, and vehicles.

June 9, 2000 - Iron River (Iron County); Randville-Grand Bluff (Dickinson County)

In the early morning hours of June 9, 2000 a line of thunderstorms moved through Iron County, producing 1.75" hail that damaged approximately 575 homes and 700 vehicles in a two-mile wide swath across the northern two-thirds of the city of Iron River. The hail caused approximately $2.3 million in roof and siding damage. Ping-pong ball sized hail in the Randville-Grand Bluff area in Dickinson County caused $225,000 in damage to 20 homes and 20 vehicles. Total hail damage in Iron and Dickinson Counties was $4.1 million.

July 14, 2000 - Algonac (St. Clair County)

On the afternoon of July 14, 2000 severe thunderstorms producing large hail struck St. Clair County. Hailstones as large as baseballs (2.75" in diameter) fell in Algonac, causing $125,000 in damage to cars and homes. The hailstones damaged roofs, ripped gutters off of homes, dented air conditioning units, and broke windows. The force of impact when the hailstones landed in the canals in Algonac caused the water to splash five feet into the air.

July 13, 2004 - Posen (Presque Isle County)

On July 13, 2004 a devastating hailstorm caused extensive damage in the small town of Posen in Presque Isle County. The hail (2.75" in diameter) was driven at times by wind gusts around 60 miles per hour. Most buildings and vehicles in the community suffered some sort of damage. Holes were punched in roofs and siding, cars were dented and windows were broken. A local church had to patch 300 holes in its roof. Damage to a school roof was estimated at nearly $200,000, and a local greenhouse lost over a thousand two-foot by two-foot window panes. One individual suffered a badly bruised back as he tried to move his vehicle to shelter. Substantial damage was done to crops (largely potatoes, along with some beans, tomatoes and corn) in nearby fields.

July 6, 2006 – Menominee (Menominee County)

Severe thunderstorms moved across Menominee County during the afternoon of July 6, 2006. Hail of up to golf ball size was driven by winds in excess of 60mph and caused significant damage to roofs, siding, and automobiles. The worst of the damage occurred about three miles northeast of Menominee. Total damage was estimated to be more than $100,000.

July 28, 2006 – Wakefield (Gogebic County)

An approaching cold front interacting with an extremely unstable airmass triggered a widespread outbreak of severe weather across western and central Upper Michigan from the late afternoon on the 28th until just after sunrise on the 29th. Hail of up to 4 inches in diameter resulted in significant damage to roofs, siding, and automobiles. Damage estimates in Wakefield and surrounding areas were reported to be over $60 million.

May 14, 2007 – 1 Mile Southeast of Negaunee (Marquette County)

A few of the many thunderstorms that passed through the area produced large hail over several counties. Especially large hail fell in Marquette County, however, southeast of Negaunee. Most hailstones were a half-inch to an inch in diameter, but a few stones were three inches and shattered car windows, resulting in an estimated $6,000 in damage.

June 20, 2007 – Marquette (Marquette County)

One of the most significant hailstorms in memory pummeled downtown Marquette and Harvey during the afternoon of June 20, 2007. While most of the hail was less than golf ball size, there were a few reports of hail that was three inches in diameter. The hail accumulated to several inches deep in downtown Marquette, and storm drains clogged from shredded leaves caused melting hail to result in street flooding. Hundreds of houses sustained significant damage to roofs and sidings. In addition, thousands of cars were damaged. Damage estimates from the storm for Marquette and surrounding areas were reported to total over $60 million.

July 26, 2007 – Durand (Shiawassee County)

Large hail hammered areas in a 3 mile radius around Durand for 50 minutes. The hail, at times, was as big as golf balls. A local newspaper reported $1.8 million in hail damages to homes alone. Hundreds of homes and vehicles were significantly damaged, with the latter averaging $4,000 per vehicle. This resulted in an estimate of $1 million in total vehicle damages. Many crops in the area were also destroyed. One farmer estimated $400,000 in losses to soybeans alone. Total crop damages were conservatively estimated at $2 million, bringing the total cost of the hailstorm to nearly $5 million. This event will be remembered for the extreme intensity of large hail that it generated.

April 5, 2010 – Southwestern Michigan

Severe thunderstorms produced large hail and winds greater than 80 mph. The most significant damage occurred in the southern portions of Kalamazoo County, with damages estimated at $125 million, but Van Buren County was also struck heavily, with damages estimated at $50 million. To the west-southwest of Schoolcraft (Kalamazoo County), the siding of many homes was destroyed on the homes' western sides, where it was battered by large hail of about 1.75 inches in diameter. The estimated damages from this storm event include strong wind effects, not just hail impacts.

Programs and Initiatives

Note: Many of the programs and initiatives in place to mitigate, prepare for, respond to, and recover from other severe thunderstorms hazards (straight-line winds, lightning and tornadoes) have the dual purpose of also protecting against hail. As a result, there is some overlap in the narrative programs and initiatives descriptions for each respective hazard. This redundancy allows each hazard section to stand alone, eliminating the need to refer to other hazard sections for basic information.

National Weather Service Doppler Radar

The National Weather Service (NWS) has completed a major modernization program designed to improve the quality and reliability of weather forecasting. The keystone of this improvement is Doppler Weather Surveillance Radar, which can more easily detect severe weather events that threaten life and property – including storms that are likely to produce damaging hail. Most important, the lead time and specificity of warnings for severe weather have improved significantly.

Doppler technology calculates both the speed and the direction of wind motion inside of severe storms. By providing data on the wind patterns within developing storms, the system allows forecasters to better identify the conditions leading to severe weather such as tornadoes, severe straight-line winds, lightning and damaging hail. This means early detection of the precursors to severe storms, as well as information on the direction and speed of storms once they form.

National Weather Service Watches/Warnings

The National Weather Service issues severe thunderstorm watches for areas when the meteorological conditions are conducive to the development of severe thunderstorms. People in the watch area are instructed to stay tuned to National Oceanic and Atmospheric Administration (NOAA) weather radio and local radio or television stations for weather updates, and watch for developing storms. Once radar or a trained Skywarn spotter detects the existence of a severe thunderstorm, the National Weather Service will issue a severe thunderstorm warning. The warning will identify where the storm is located, the direction in which it is moving, and the time frame during which the storm is expected to be in the area. Persons in the warning area are instructed to seek shelter immediately.

The State and local government agencies are warned via the Law Enforcement Information Network (LEIN), NOAA weather radio, and the Emergency Managers Weather Information Network (EMWIN). Public warning is provided through the Emergency Alert System (EAS). The National Weather Service stations in Michigan transmit information directly to radio and television stations, which in turn pass the warning on to the public. The National Weather Service also provides detailed warning information on the Internet at www.weather.gov, where an interactive map can be used.

Severe Weather Awareness Week

Each spring, the Emergency Management and Homeland Security Division of the Department of State Police, in conjunction with the Michigan Committee for Severe Weather Awareness, sponsors Severe Weather Awareness Week. This annual public information and education campaign focuses on such severe weather events as tornadoes, thunderstorms, lightning, high winds, flooding and hail. Informational materials on hail and other thunderstorm hazards are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public.

Lightning

The discharge of electricity from within a thunderstorm.

Hazard Description

Lightning is a random and unpredictable product of a thunderstorm's tremendous energy. The energy in the storm produces an intense electrical field like a giant battery, with the positive charge concentrated at one end and the opposite charge concentrated at the other. Lightning strikes when a thunderstorm's electrical potential (the difference between its positive and negative charges) becomes great enough to overcome the resistance of the surrounding air. Bridging that difference, lightning can jump from cloud to cloud, cloud to ground, ground to cloud, or even from the cloud to the air surrounding the thunderstorm. Lightning strikes can generate current levels of 30,000 to 40,000 amperes, with air temperatures often superheated to higher than 50,000 degrees Fahrenheit (hotter than the surface of the sun) and speeds approaching one-third the speed of light.

Hazard Analysis

Globally, there are about 2,000 thunderstorms occurring at any given time, and those thunderstorms cause approximately 100 lightning strikes upon the ground each second. In the United States, approximately 100,000 thunderstorms occur each year, and every one of those storms generates lightning. It is not uncommon for a single thunderstorm to produce hundreds or even thousands of lightning strikes. However, to the majority of the general public, lightning is perceived as a minor hazard. That perception lingers despite the fact that lightning damages many structures and kills and injures more people in the United States per year, on average, than tornadoes or hurricanes. Many lightning deaths and injuries could be avoided if people would have more respect for the threat lightning presents to their safety.

Lightning deaths are usually caused by the electrical force shocking the heart into cardiac arrest or throwing the heartbeat out of its usual rhythm. Lightning can also cut off breathing by paralyzing the chest muscles or damaging the respiratory center in the brain stem. It takes only about one-hundredth of an ampere of electric current to stop the human heartbeat or send it into ventricular fibrillation. Lightning can also cause severe skin burns that can lead to death if complications from infection set in.

As an indicator of the circumstances involving lightning fatalities, injuries and damage in the United States, consider the following statistics compiled by the National Oceanic and Atmospheric Administration (NOAA) and the National Lightning Safety Institute (NLSI) for the period of 1959-1994:

<u>Location of Lightning Strikes</u>

- 40% are at unspecified locations
- 27% occur in open fields and recreation areas (not including golf courses)
- 14% occur to someone under a tree (not including golf courses)
- 8% are water-related (boating, fishing, swimming, etc.)
- 5% are golf-related (on golf course or under tree on golf course)
- 3% are related to heavy equipment and machinery
- 2.4% are telephone-related
- 0.7% are radio, transmitter and antenna-related

<u>Gender of Victims</u>

- 84% are male; 16% are female

<u>Months of Most Strikes</u>

- July (30%); August (22%); June (21%)

<u>Most Likely Time Period of Reported Strikes</u>

- 2:00 PM – 6:00 PM

Number of Victims

- One victim (91%); two or more victims (9%)

The NLSI has estimated that 85% of lightning victims are children and young men (ages 10-35) engaged in recreation or work-related activities. Approximately 20% of lightning strike victims die, and 70% of survivors suffer serious long-term after-effects such as memory and attention deficits, sleep disturbance, fatigue, dizziness, and numbness.

Lightning can be especially damaging for electrical infrastructure, causing localized power outages and damage to phone lines and communication systems. Computers are also especially vulnerable to lightning strikes. In terms of property losses from lightning, statistics vary widely according to source. The Insurance Information Institute (a national clearinghouse of insurance industry information) estimates that lightning damage amounts to nearly 5% of all paid insurance claims, with residential claims alone exceeding $1 billion. Information from insurance companies shows one homeowner's damage claim for every 57 lightning strikes. The NLSI has estimated that lightning causes more than 26,000 fires annually, with damage to property exceeding $5-6 billion. Electric utility companies across the country estimate as much as $1 billion per year in damaged equipment and lost revenue from lightning. The Federal Aviation Administration (FAA) reports approximately $2 billion per year in airline industry operating costs and passenger delays from lightning. Because lightning-related damage information is compiled by so many different sources, using widely varying collection methods and criteria, it is difficult to determine a collective damage figure for the U.S. from lightning. However, annual lightning-related property damages are conservatively estimated at several billion dollars per year, and those losses are expected to continue to grow as the use of computers and other lightning-sensitive electronic components becomes more prevalent.

Lightning-Related Impacts on Michigan

Unfortunately, lightning has taken a tremendous toll on Michigan's citizens in terms of injury and loss of life. According to National Weather Service records through the mid-2000s, Michigan had incurred 101 lightning deaths, 711 lightning injuries, and 810 lightning casualties (deaths and injuries combined) – consistently ranking it near the top of the nation in all three categories. During the period 1959-1995 (the last period for which composite statistics were available), Michigan was ranked 2nd nationally (behind Florida) in lightning injuries, 12th nationally in lightning deaths, and 2nd nationally (again, behind Florida) in lightning casualties. Undoubtedly, the fact that Michigan is an outdoor recreation-oriented state contributes heavily to its high lightning death and injury tolls. As the following tables indicate, Michigan's lightning deaths and injuries were fairly consistent with the national trends in terms of the location of deadly or injury-causing strikes. More recent data suggests some improvement in Michigan's statistics, ranking it #13 in number of lightning deaths (11) between the years 1998 and 2008.

Lightning-Related Deaths in Michigan: 1959-July 2005

Number of Deaths	LIGHTNING DEATHS: 101 Location	Percent of Total
29	Open fields, ball fields	29%
26	Under trees (not golf)	26%
11	Boats / water-related	11%
10	Golf course	10%
4	Near tractors / heavy equipment	4%
2	At telephone	2%
19	Other location / unknown	19%

Source: Storm Data, National Climatic Data Center

Although Michigan's counties experience from about 20 to 40 thunderstorm days per year, there are a smaller number of known damaging lightning events per year (estimated to be at least 13 such events on average, annually). The average Michigan deaths from lightning are approximately 1.5 per year, and about 10.7 injuries per year. Property damage from major events totals over $20 million since 1990 – approximately $1.4 million per year. (Note: these calculations should be considered conservative, with the actual totals likely to be higher were a more extensive study able to be performed from a comprehensive array of sources. In these estimates, data from the National Climatic Data Center have primarily been used.) In terms of lightning risk around the state, Southwestern Michigan has the highest

rate of lightning strikes, according to Global Atmospherics, Inc., with a strike ratio of 4.0 flashes/km²/yr. Locations south of Midland have strike ratios of 3.0 flashes/km²/yr, and areas north of Midland have strike ratios of 2.0 flashes/km²/yr, including the Upper Peninsula.

Lightning-Related Injuries in Michigan: 1959-July 2005

LIGHTNING INJURIES: 711		
Number of Injuries	**Location**	**Percent of Total**
243	Open fields, ball fields	34%
104	Under trees (not golf)	15%
35	Golf course	5%
26	Boats / water-related	4%
19	At telephone	3%
20	Near tractors / heavy equipment	3%
264	Other location / unknown	37%

Source: Storm Data, National Climatic Data Center

Because it is virtually impossible to provide complete protection to individuals and structures from lightning, this hazard will continue to be a problem for Michigan's residents and communities. However, lightning deaths, injuries, and property damage can be reduced through a combination of public education, human vigilance, technology, proper building safety provisions, and simple common sense.

Large outdoor gatherings (e.g., sporting events, concerts, campgrounds, fairs, festivals, etc.) are particularly vulnerable to lightning strikes that could result in many deaths and injuries. This vulnerability underscores the importance of developing site-specific emergency procedures for these types of events, with particular emphasis on adequate early detection, monitoring, and warning of approaching thunderstorms. Early detection, monitoring, and warning of lightning hazards, combined with prudent protective actions, can greatly reduce the likelihood of lightning injuries and deaths. In addition, close coordination between event organizers, local emergency management officials, and response agencies (i.e., police, fire, emergency medical care) can help prevent unnecessary (and often tragic) delays and mistakes in rendering care should a lightning incident occur.

Impact on the Public

Lightning has a discouraging effect on outdoor activities, and has also caused casualties (including death) and severe property damage, including the ignition of structural fires and wildfires, which in turn present serious additional risks and harm to the public and its property. Electrical and communications infrastructure can be affected by lightning strikes, causing widespread inconvenience and, in some cases, life-threatening impairment of needed medical equipment and emergency response.

Impact on Public Confidence in State Governance

When lightning causes infrastructure failure, a question may be raised about the adequacy of that infrastructure, its maintenance, and its design and regulation. In events that require mass sheltering, such as schools or large gatherings (e.g. a county fair or community-sponsored event), the ability of local and state government to adequately plan for severe weather is often vital to the success of such events, which themselves are often important for various sectors of the local and state economy. Citizen discontent and media-exacerbated controversies have arisen from situations in which inadequate planning was evident, or provisions for public sheltering were inadequate.

Impact on Responders

Responders tend to be working outdoors in conditions from which most residents are taking shelter. Although special training and safety precautions have usually been taken (e.g. for line-repair workers), nevertheless, responders are more exposed to and at-risk from lightning. This makes the use of various equipment more difficult and inhibits the ability of responders to work safely outdoors.

Impact on the Environment

Trees can be blown apart completely if struck by lightning, or have branches and bark broken off that can scar and even kill them. Lightning can cause trees and natural vegetation to catch fire, and large wildfires (q.v.) can be devastating upon an area's short-term ecological condition. Dry lightning is lightning that occurs with no precipitation at ground level, and this type of lightning is the most common natural cause of wildfires. Humans and wildlife can both be killed or injured when struck by lightning, and smoke from wildfires is unhealthy to breathe.

Significant Lightning Incidents

As one might expect in a state with a high number of lightning deaths and injuries, lightning incidents involving one individual are fairly common in Michigan. However, lightning incidents involving groups of individuals also take place. Over the past 35 years, numerous lightning incidents in Michigan have resulted in multiple injuries:

Significant Lightning Incidents in Michigan

August 23, 1975 – Leslie (Ingham County)

Ninety people were injured, one seriously, when lightning struck a campground during a severe thunderstorm.

June 20, 1979 – Camp Grayling (Crawford County)

Forty-five National Guardsmen were injured and three of them hospitalized when lightning struck a mess tent during a training mission.

July 7, 1994 – Potterville (Eaton County)

Lightning struck a swimming lake at Fox Memorial Park near Potterville, injuring 22 people (one critically). This strike seemingly came from "out of the blue." That is, there was not a storm actually overhead when it occurred. This is why waters need to be evacuated when there is any indication of lightning nearby.

June 21, 1995 – Ishpeming (Marquette County)

Although no one was injured in this event, a lightning strike caused a fire that destroyed a 100-year old church in downtown Ishpeming, with damages estimated at over a million dollars. Lightning also destroyed the chimney of a downtown house there, during the same storm event.

July 18, 1996 – Gladwin (Gladwin County)

A single bolt of lightning from a distant thunderstorm struck and killed the pitcher in a men's league softball game. Several in the infield were knocked to the ground by the lightning and three were taken to the hospital that day.

May 18, 2000 – Detroit Metro Airport (Wayne County)

Lightning struck the steel superstructure of a new terminal under construction at Detroit Metropolitan Airport, injuring nine workers (two requiring hospitalization).

June 12, 2001 – Benton Harbor (Berrien County)

Lightning struck an apartment complex in Benton Township, resulting in 35 residents being evacuated. The total property damage from the fire was $800,000.

September 19, 2003 – Ann Arbor (Washtenaw County)

One roofer was killed and two others were badly injured in Ann Arbor when they were hit by lightning during a thunderstorm. The storm produced more than 2,300 lightning strikes in Metro Detroit in about three hours.

July 16, 2005 – Macomb Township (Macomb County)

One house was completely destroyed by fire as the result of a lightning strike. Five additional house fires started in the areas of 22 and 23 Mile Roads, due to other lightning strikes from the same storm event. Total damages amounted to about a million dollars.

July 22, 2009 – Big Rapids (Mecosta County) and Gaylord (Otsego County)

At 8:45 am, a non-severe thunderstorm caused lightning to strike pine trees at Ferris State University, as four construction workers were standing nearby. All four workers were injured. That same afternoon, a lightning strike 1 mile north of Gaylord ignited a fire that rapidly spread through the Alpine Haus apartment complex, destroying it and leaving 52 persons without housing. Fortunately, no one was hurt in the apartment fire, but damages were estimated at $500,000.

July 15, 2010 – Vestaburg (Montcalm County)

Lightning struck four young persons between 9 and 18 years of age at a baseball diamond near Vestaburg. Fortunately, all survived the incident, but their injuries required special emergency care, including emergency medical flights to the appropriate care facilities.

September 21, 2010 – Kent County

Various fire departments reported that about a dozen house fires were ignited, in an area from Ada south to Caledonia, by lightning strikes produced by severe storms during the late afternoon.

April 26, 2011 – Portage (Kalamazoo County)

Seven people were injured and sent to the hospital (one severe) after lightning struck a park in Portage during a severe thunderstorm warning. There were several others at the park that were also injured but sought medical treatment on their own.

September 3, 2011 – Ann Arbor (Washtenaw County)

Michigan Stadium (with a capacity of over 100,000 people) was evacuated during a football game, due to a thunderstorm. The game was eventually called off in the third quarter, due to the strong winds, heavy downpours of rain, and several lightning strikes.

Programs and Initiatives

Unfortunately, lightning prevention or protection, in an absolute sense, is impossible. However, the consequences of lightning strikes have been diminished (both in terms of deaths and injuries and property damage) through the implementation of the following programs and special initiatives:

National Weather Service Education

The National Weather Service issues severe thunderstorm watches and warnings when there is a threat of severe thunderstorms. However, lightning, by itself, is not sufficient criteria for the issuance of a watch or warning (every

storm would require a watch or warning). The National Weather Service has an extensive public information program aimed at educating citizens about the dangers of lightning and ways to prevent lightning-related deaths and injuries.

Severe Weather Awareness Week

Each spring, the Emergency Management and Homeland Security Division, Michigan Department of State Police, in conjunction with the Michigan Committee for Severe Weather Awareness, sponsors Severe Weather Awareness Week. This annual public information and education campaign focuses on such severe weather events as tornadoes, thunderstorms, hail, high winds, flooding and lightning. Informational materials on lightning hazards are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public.

Lightning Protection for Structures

The National Lightning Safety Institute (NLSI) has identified a systematic lightning hazard mitigation approach that can be followed to protect structures from lightning damage. That approach attempts to mitigate both the direct and indirect effects of lightning strikes through the application of appropriate structural safety improvements, as identified in a comprehensive lightning safety analysis. Full details of this mitigation approach can be obtained on a web page for NLSI.

National Lightning Detection Network

Despite advancements in electric power system design and equipment, lightning continues to be the single largest cause of outages on electrical distribution and transmission lines. To help combat that problem, the National Lightning Detection Network (NLDN) – a technologically advanced lightning location system operated by a private company in Phoenix, Arizona – was invented. The NLDN helps electric utilities make effective decisions regarding line maintenance priorities, crew dispatch, and future design and placement of utility transmission lines and lightning protection. NLDN lightning data is available in both real-time and archival format (1989-present). The lightning information from NLDN might lead to significant savings in utility maintenance and construction budgets, improved design and placement of future transmission and distribution infrastructure, and reduced outages due to lightning-related damage. Data from the NLDN can also be used to improve the safety of participants at outdoor events such as golf tournaments, air shows, fairs and outdoor festivals, and sporting events and concerts at outdoor stadiums and racetracks.

Local Lightning Detection Systems

Local lightning detection systems are increasingly being installed at golf courses, parks, pools, sports fields and stadiums, and other outdoor venues. These detection devices monitor electrical activity in the atmosphere and identify when favorable lightning conditions exist by activating a warning light or horn. That early warning can give local officials the time necessary to clear outdoor areas before actual lightning strikes occur.

Severe Winter Weather Hazards

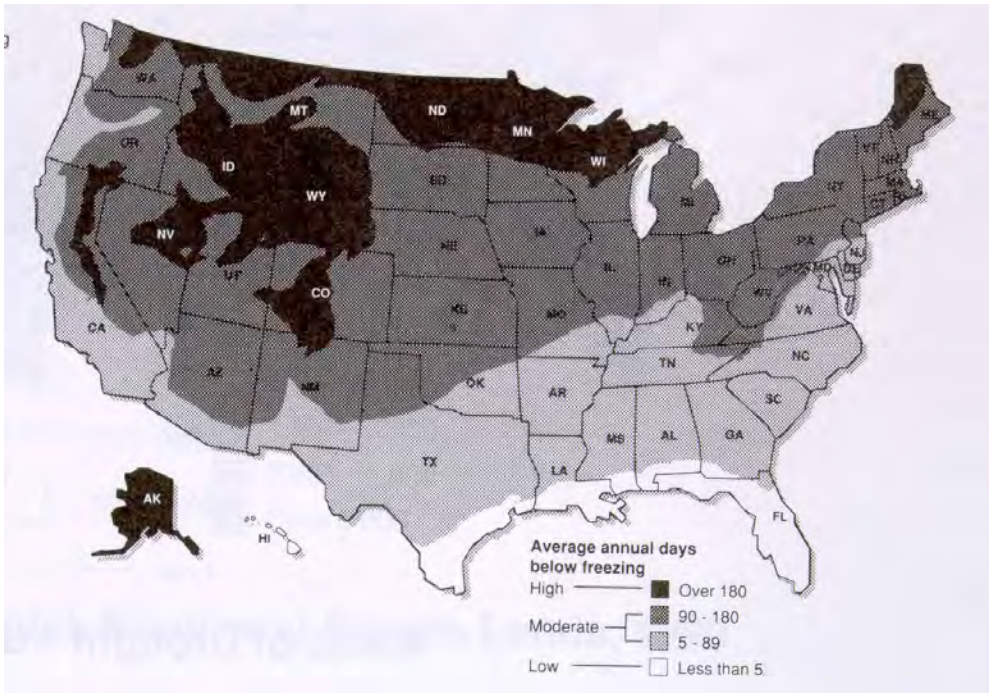
Severe winter weather hazards include snowstorms, blizzards, extreme cold, and ice and sleet storms. As a northern state, Michigan is vulnerable to all of these winter hazards. Most of the severe winter weather events that occur in Michigan have their origin as Canadian and Arctic cold fronts that move across the state from the west or northwest, although some of the most significant winter storms have their origins from the southwest, in combination with Arctic air masses. As the maps on the following pages show, Michigan averages moderate to heavy snowfall and extreme cold, averaging 90-180 days per year below freezing in the Lower Peninsula, and over 180 days below freezing in most of the Upper Peninsula. (For record snowfall amounts and a description of Michigan's three general "regions," please refer to the relevant table and text in the Introduction to the Weather Hazards section in this plan.)

The snowstorms and ice and sleet storms sections that follow provide greater detail on those particular severe winter weather hazards. The extreme temperatures section provides a more detailed overview of the severe cold temperatures hazard.

Winter storm hazards plague Michigan annually from November to March, with the state being vulnerable to snowstorms and ice and sleet storms. No area of the state is immune to severe winter conditions that can clog or paralyze the transportation network, cause widespread power outages, and slow normal daily activities to a standstill. Each community should be prepared for the harsh landscape created by snow and ice extremes. One way to understand the approaching risks of winter weather comes in the form of daily forecasts, and winter watches and warnings from the National Weather Service. The website for the NWS is www.crh.noaa.gov, which covers all regions in Michigan. To obtain recent county-level historical data since 1993 for both severe snowstorms and ice and sleet storms, visit the National Climatic Data Center's Storm Event website, http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms

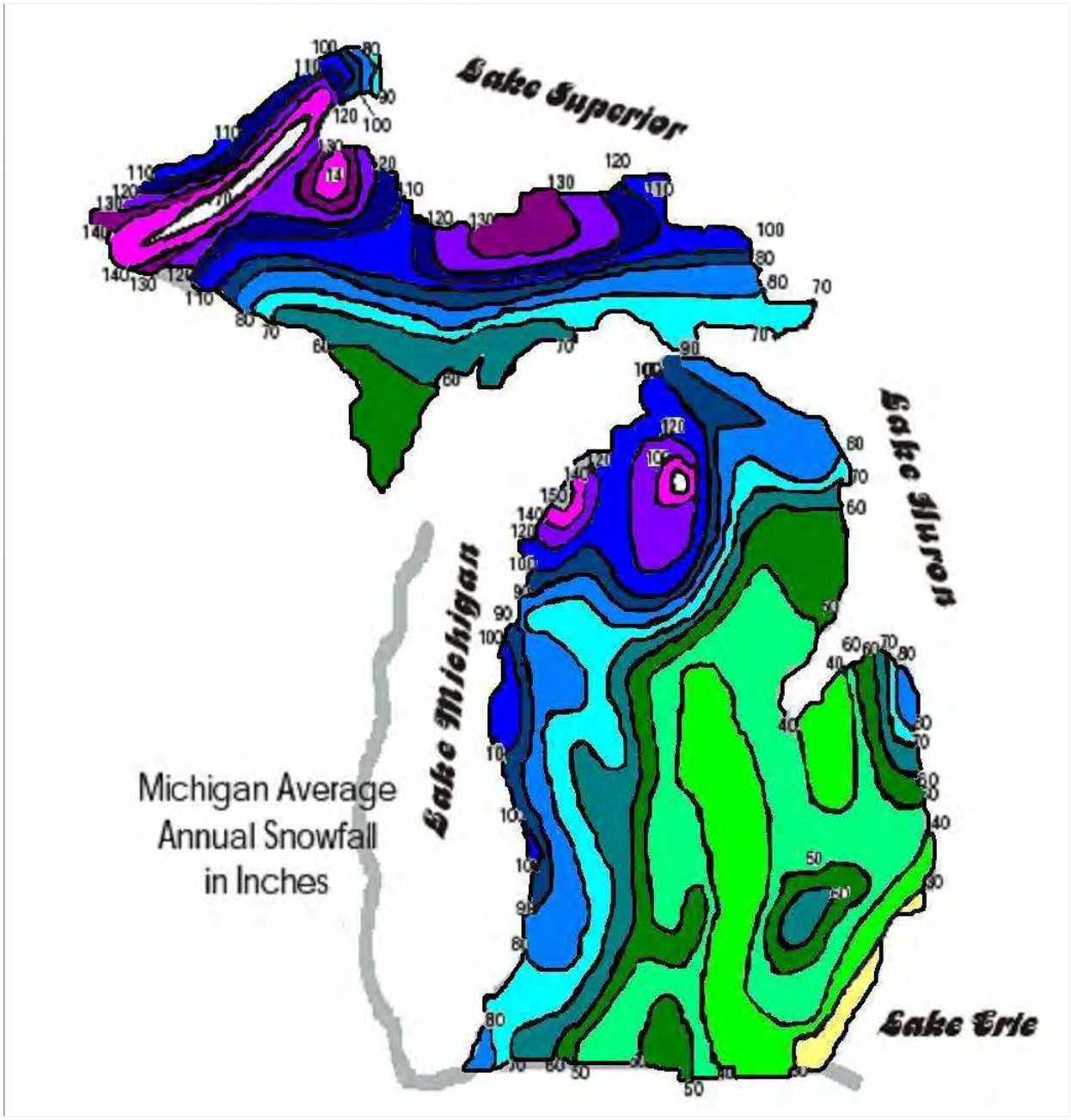
Average Annual Days Below Freezing in the U.S.

Source: Council of State Governments; Federal Emergency Management Agency



Michigan Average Annual Snowfall

Source: Michigan Committee for Severe Weather Awareness



Ice and Sleet Storms

A storm that generates sufficient quantities of ice or sleet to result in hazardous conditions and/or property damage.

Hazard Description

Ice storms are sometimes incorrectly referred to as sleet storms. Sleet is small frozen rain drops (ice pellets) that bounce when hitting the ground or other objects. Sleet does not stick to trees and wires, but sleet in sufficient depth does cause hazardous driving conditions. Ice storms are the result of cold rain that freezes on contact with a surface, coating the ground, trees, buildings, overhead wires and other exposed objects with ice, sometimes causing extensive damage. When electric lines are downed, power may be out for several days, resulting in significant economic losses and the disruption of essential services in affected communities. Often times, ice storms are accompanied by snowfall, in which the ice is camouflaged and covered up by snow, creating treacherous transportation conditions. Both storms occur when the temperature is close to 32°F, but are far more severe when the temperature is in the 20s.

Hazard Analysis

The table below illustrates the frequency distribution of ice and sleet storms in Michigan for the period 1970-July 2007. Approximately 81% of those storms occurred during the months of January, February, March and April, when conditions are most conducive for the development of ice and sleet. One-quarter of all ice and sleet storms in the period occurred during the month of March, and more than a quarter occurred in January.

By observing winter storm watches and warnings, adequate preparations can usually be made to reduce the impacts of ice and sleet conditions on Michigan communities. Providing for the mass care and sheltering of residents left without heat or electricity, and mobilizing sufficient resources to clear broken tree limbs from roadways, are the primary challenges facing community officials. Severe ice and sleet storms can affect every Michigan community. Ice storms usually have a regional effect and groups of communities are usually affected instead of just one community. Therefore, every community should plan and prepare for these emergencies. MSP/EMHSD staff has not yet found specific documentation on sleet and ice storms in the state to verify different vulnerabilities in different areas of the state. The southern parts of the state have annual winter temperatures closer to 32°F, so the prevalence for ice and sleet storms seems more likely there than in the northern areas of the state. Planning and preparedness efforts should include the identification of mass care facilities and necessary resources such as cots, blankets, food supplies and generators, as well as debris removal equipment and services. In addition, communities should develop debris management procedures (to include the identification of multiple debris storage, processing and disposal sites) so that the tree and other storm-related debris can be handled in the most expedient, efficient, and environmentally safe manner possible.

Frequency Distribution of Ice and Sleet Storms

in Michigan: 1970 – July 2007

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
17	10	14	6	0	0	0	0	0	0	3	9	59
29%	17%	24%	10%	0%	0%	0%	0%	0%	0%	5%	15%	100%

Source: National Weather Service; Storm Data, National Climatic Data Center (percentages are rounded off)

There is an average of about 1.6 major storm events in Michigan each year. Many ice storm deaths are actually caused by automobile accidents, heart attacks from overexertion, downed power lines, carbon monoxide poisoning, and other secondary effects that may be difficult to distinguish from other causes. In terms of property damage, major ice storm events have, according to NCDC records, caused more than $200 million in damages since 1993 (averaging $16.4 million per year), and the April 2003 ice storm was particularly severe, reportedly causing $161 million in damage. Due to this type of occasional major incident, a better estimate of annual risks would only come as a longer time-frame of data is accumulated and assessed.

Impact on the Public

Ice and sleet storms tend to cause power or other infrastructure failures that interfere with residents' activities, comfort, and safety (often through the impact of infrastructure failures on needed medical and emergency response capabilities).

Direct physical effects may include frostbite, hypothermia, and other medical conditions, and thus require some citizens to be provided with warm clothing and shelter. Certain types of building designs are susceptible to structural failure from the accumulation of ice or snow on their roofs. Traffic efficiency and road capacity tends to be impeded by these weather events, which cause a large increase in the risks involved in all modes of travel. Injurious accidents may include simple pedestrian falls (due to the difficulty of balancing and walking on ice-coated surfaces), or large-scale transportation accidents (such as multi-car interstate pileups).

Impact on Public Confidence in State Governance

For this hazard, the main issues regarding public confidence in government predominantly involve: (1) the ability of the infrastructure of the impacted area to withstand the ice or sleet event and continue to serve area residents, and (2) the ability of the government(s) to efficiently clear away ice and sleet from areas that are most vitally needed for transportation and other shared public uses (e.g. schools, hospitals). If any shortcomings or failures in one or both of these functions are too evident to citizens (or mass media providers), then the capacity, efficiency, and adequacy of government(s) may be called into question. In many areas, the State and different forms of local governments and agencies will have different types of responsibilities, and where problems arise in the coordination or clarity of these governments' actions and responsibilities, discontent can reasonably be expected to be expressed by citizens.

Impact on Responders

Responders are asked to be outdoors during winter weather events in which most citizens prefer to take shelter. In addition to the risks from winds, obscured vision, impaired control of vehicles, power failures and blocked roadways, winter storm events also expose responders to extremely cold temperatures for long periods of time, and may thus compound the difficulties, risks, and expenses of response. Fatigue can more easily become a problem under extreme temperature conditions, either during winter weather emergencies or during extreme summer heat and humidity. Icy conditions make various travel and outdoor operations treacherous.

Impact on the Environment

Freezing rain drops (sleet) and dangerous ice storms coat surfaces with layers of ice and can also affect the environment. Ice storms can damage trees, as the weight of accumulated ice brings down limbs and branches, or even entire trees. When soil is not frozen, ice loads can cause root damage to forest trees. An ice coating over widespread forest lands can destroy natural forest vegetation and disrupt species' habitats, species composition, and forest land diversity. Dried dead trees may be more prone to fire, contributing to wildfires in other seasons if not removed properly. Dead trees can become breeding areas for beetles and other pests that can harm the healthy green trees. Floods often occur when ice melts, and can cause environmental effects (as described in the flooding section).

Climate Change Considerations

Climate change effects may cause an increase in the number of ice and sleet storm events. The reason involves an average temperature that is closer to the norms for these events during certain times of the year.

Significant Ice and Sleet Storms in Michigan since 1976

March 2-7, 1976 - Central Lower Michigan

During the period from March 2-7, 1976 an ice storm with accompanying high winds and tornadoes struck a 29 county area in the central Lower Peninsula. This storm, one of the worst to ever hit the state, caused over $56 million in damage, and widespread power outages. The storm impacts were so severe that a Presidential Major Disaster Declaration was granted for the 29 affected counties, to assist in the recovery from the storm.

April 8, 1979 - Southern Lower Michigan

On April 8, 1979 an ice storm struck Lower Michigan south of a line from Grand Haven to Bay County. The storm left 240,000 utility customers without power for several days. In addition, numerous injuries resulted from the downed power lines.

January 1, 1985 - Southern Lower Michigan

On January 1, 1985 a severe ice storm struck a 13 county area in the southern Lower Peninsula. Freezing rain accumulating up to one inch in thickness downed tree limbs, trees and power lines, blocked roads, and caused widespread power outages. There were three deaths and eight injuries directly related to the ice storm. Approximately 13,000 homes and 260 businesses sustained damage or were destroyed, with losses estimated at nearly $25 million. Another 160 businesses lost inventory as a result of the storm damage and power outages. Over 430,000 electrical customers were without power, some for as long as 10 days. At the height of the power outage, 28 public shelters were opened to provide shelter to nearly 1,000 residents without power or heat. Several nursing homes and adult foster care facilities had to be evacuated due to the loss of power and heat. Total public and private damage from this ice storm was estimated at nearly $50 million. A Governor's Disaster Declaration was issued to mobilize state resources to assist in the storm response and recovery.

March 13, 1997 - Central and Southeast Michigan

In the late evening hours of March 13, 1997 an ice storm struck the central and southeastern Lower Peninsula, causing widespread power outages, icy roads, downed trees and numerous school closings. Many of the counties in the southern third of Michigan were impacted by the storm. In the storm's aftermath, 514,000 Detroit Edison and Consumers Energy electrical customers were without power. Major outages occurred in Jackson, Kalamazoo, Cass, Branch, St. Joseph

and Calhoun counties, as well as in Lansing. Many local communities opened shelters to accommodate residents unable to remain in their homes due to the lack of power. Response efforts were severely hampered by snow and windy conditions the following day.

April 3-5, 2003 - West and Central Lower Michigan

A major ice storm affected much of southern Lower Michigan, causing hundreds of thousands of people to lose power. The weight of the ice brought down thousands of trees and limbs and hundreds of power lines. Many people across the area lost power for several days and some who lived in outlying areas were without power for a week. The ice storm resulted in several million dollars worth of damage across the area. Up to an inch of ice was reported in the Lansing area, and numerous reports of a quarter to one inch of ice were received in the vicinity of I-96. It was one of the biggest ice storms to affect lower Michigan in the last 50 years.

February 16, 2006 – Central Lower Michigan

A major ice storm affected much of central Lower Michigan. There were numerous reports of ice accumulations up to one inch. This glazing caused widespread tree damage and thousands of power outages. Some people were without power for several days, resulting in the opening of numerous temporary shelters due to the extreme cold in the wake of the ice storm. Total damages were in excess of $2 million.

January 14-15, 2007 – Southern Lower Michigan

A major ice storm affected an area from the extreme southwestern part of Lower Michigan northeast into the Flint and Detroit metro areas. There were numerous reports of ice accumulations up to one half inch. This glazing caused widespread tree damage and over 150,000 structures to be without power. Total damages exceeded $2 million.

March 1-2, 2007 – Southeast Michigan

In Huron County, a high-impact ice storm resulted in ice accumulations up to 3 inches thick on power lines and trees. Other “Thumb” counties were also hard-hit. Most of the damage occurred between 10 pm on March 1 and 1am on March 2. Strong winds gusted to 50 mph and brought down trees and utility poles over many miles. More than half of Huron County’s population was without power, some for up to 6 days. Hundreds sought shelter and were assisted by the American Red Cross. Hundreds of traffic accidents took place, including some that were serious and resulted in 6 injuries and one death. Property damage alone amounted to $1.5 million (mostly in Huron County).

Programs and Initiatives

Note: Many of the programs and initiatives designed to mitigate, prepare for, respond to, and recover from snowstorms have the dual purpose of also protecting against ice and sleet storms. As a result, there is some overlap in the narrative programs and initiatives descriptions for each respective hazard. This redundancy allows each hazard section to stand alone, eliminating the need to refer to other hazard sections for basic information.

National Weather Service Doppler Radar

The National Weather Service (NWS) has completed a major modernization program designed to improve the quality and reliability of weather forecasting. The keystone of this improvement is Doppler Weather Surveillance Radar, which can more easily detect severe weather events that threaten life and property – including severe winter weather events such as ice and sleet storms. Most important, the lead time and specificity of warnings for severe weather have improved significantly.

National Weather Service Watches/Warnings

Sufficient warning can do much to reduce the damage from ice and sleet storms by permitting people to prepare properly. The National Weather Service uses the terms "ice storm," "freezing rain," and "freezing drizzle" to warn the public when a coating of ice is expected on the ground and on other exposed surfaces. The qualifying term "heavy" is used to indicate ice coating which, because of the extra weight of the ice, could cause significant damage to trees, overhead wires, and other exposed objects.

The State and local government agencies are warned via the Law Enforcement Information Network (LEIN), National Oceanic and Atmospheric Administration (NOAA) weather radio, and the Emergency Managers Weather Information Network (EMWIN). Public warning is provided through the Emergency Alert System (EAS). The National Weather Service stations in Michigan transmit information directly to radio and television stations, which in turn pass the warning on to the public. The National Weather Service also provides detailed warning information on the Internet, at www.weather.gov, where an interactive map can be used.

Winter Hazards Awareness Week

Each fall, the Emergency Management and Homeland Security Division, Department of State Police, in conjunction with the Michigan Committee for Severe Weather Awareness, sponsors Winter Hazards Awareness Week. This annual public information and education campaign focuses on winter weather hazard events such as snowstorms, blizzards, extreme cold, and ice and sleet storms. Informational materials on winter weather hazards and safety are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public.

Electrical Infrastructure Reliability

One of the major problems associated with ice storms is the loss of electric power. Michigan has had numerous widespread and severe electrical power outages caused by ice storms, several of which have resulted in a power loss to 250,000 – 500,000 electrical customers for several hours to several days at a time. Ice-related damage to electric power facilities and systems is a concern that is being actively addressed by utility companies across the state. Detroit Edison, Consumers Energy and other major electric utility companies have active, ongoing programs to improve system reliability and protect facilities from damage by ice, severe winds, and other hazards. Typically, these programs focus on trimming trees to prevent encroachment of overhead lines, strengthening vulnerable system components, protecting equipment from lightning strikes, and placing new distribution lines underground. The Michigan Public Service Commission (MPSC) monitors power system reliability to help minimize the scope and duration of power outages.

Urban Forestry/Tree Maintenance Programs

Urban forestry programs can be very effective in minimizing ice storm damage caused by falling trees or tree branches. In almost every ice storm, falling trees and branches cause power outages and clog public roadways with debris. However, a properly designed, managed and implemented urban forestry program can help keep tree-related damage and impact to a minimum. To be most effective, an urban forestry program should address tree maintenance in a comprehensive manner, from proper tree selection, to proper placement, to proper tree trimming and long-term care.

Every power company in Michigan has a tree trimming program, and numerous local communities have some type of tree maintenance program. The electrical utility tree trimming programs are aimed at preventing encroachment of trees and tree limbs within power line rights-of-way. Typically, professional tree management companies and utility work crews perform the trimming operations. At the local government level, only a handful of Michigan communities have actual urban forestry departments or agencies. Often, crews from the area public works agency or county road commission perform the bulk of the tree trimming work.

When proper pruning methods are employed, and when the work is done on a regular basis with the aim of reducing potential storm-related damage, these programs can be quite effective. Often, however, tree trimming work is deferred when budgets get tight or other work is deemed a higher priority. When that occurs, the problem usually manifests itself in greater storm-related tree debris management problems down the line.

Snowstorms

A period of rapid accumulation of snow often accompanied by high winds, cold temperatures, and low visibility.

Hazard Description

As a result of being surrounded by the Great Lakes, Michigan experiences large differences in snowfall over relatively short geographic distances. The average annual snowfall accumulation in different areas ranges from 30 to 200 inches of snow. The highest accumulations are in the northern and western parts of the Upper Peninsula, as some areas of Baraga and Houghton Counties receive over 200 inches of snow per year. In Lower Michigan, the highest snowfall accumulations occur near Lake Michigan and in the higher elevations of northern Lower Michigan. Areas in the northwest portion of the Lower Peninsula average greater than 120 inches of snow annually. On the low end of snowfall totals, areas in the east central and southeastern portions of the state receive less than 50 inches of snow per year. Communities in West Michigan typically receive 60-100 inches of snow.

Blizzards are the most dramatic and perilous of all snowstorms, characterized by low temperatures and strong winds (35+ miles per hour) bearing enormous amounts of snow. Most of the snow accompanying a blizzard is in the form of fine, powdery particles that are wind-blown in such great quantities that, at times, visibility is reduced to only a few feet. Blizzards have the potential to result in property damage and loss of life. Just the cost of clearing the snow can be enormous.

Hazard Analysis

The snowfall map before the preceding section shows that the western Upper Peninsula experiences the most snowstorms and snowfall in Michigan each year. The western half of the Lower Peninsula also experiences heavy snowfall and a relatively large number of snowstorms. One reason for this is the "lake effect," a process by which cold winter air moving across Lakes Michigan and Superior picks up moisture from the warmer lake waters, resulting in larger snowfall amounts in the western part of the state.

Please refer to the table in the Introduction to the Weather Hazards section to find a table of record snowfall amounts at various locations across Michigan, and for a description and comparison of the state's three general "regions," as defined in this document. In general, the snowstorm season of the Southern Lower Peninsula runs from November to April each year. (Although snow occasionally does fall outside of this "season," such snowfall would be comparatively light, rather than the sort of snowstorm event that is here being considered as a hazard.) The snowstorm season in the Northern Lower Peninsula runs from October to May. The snowstorm season for the Upper Peninsula runs from late September to May. This does not mean that all of these months necessarily receive significant snowfall each year. Instead, the "season" denotes the part of each year when a significant snowstorm may occur. A significant snowstorm is here defined as at least several inches of snow accumulation in a single event.

By observing winter storm watches and warnings, adequate preparation can usually be made to reduce the impact of snowstorms on Michigan communities. Providing for the mass care and sheltering of residents left without heat or electricity, and mobilizing sufficient resources to clear blocked roads, are the primary challenges facing community officials. Severe snowstorms can affect every Michigan community. Therefore, every community should plan and prepare for severe snowstorm emergencies. That planning and preparedness effort should include the identification of mass care facilities and necessary resources such as cots, blankets, food supplies and generators, as well as snow clearance and removal equipment and services. Pre-planning for snow storage areas will be helpful. In addition, communities should develop debris management procedures (to include the identification of multiple debris storage, processing and disposal sites) so that the tree and other storm-related debris can be handled in the most expedient, efficient, and environmentally safe manner possible.

Michigan sees a major regional or statewide snowstorm approximately every 5 years. Local events are more frequent. Casualties are difficult to assess because many deaths are caused by automobile accidents, heart attacks from overexertion, and other secondary impacts that may be difficult to distinguish as weather-related.

Heavy snows can shut down towns and cities for a period of a few days if snow is persistent and cannot be cleared in a timely fashion. Roof failures may occur as the weight and volume of snow cause damage to homes and buildings. Urban areas are especially susceptible to outages and problems with snow removal, while rural areas may have inaccessible roads for some time but have residents that are more prepared to handle power outages and temporary isolation. Motorists and passengers in cars can be stranded in rural areas and die of exposure because of inadequate preparation for conditions.

Impact on the Public

Snowstorms present hazards that are similar to ice storms, but occur much more frequently. Transportation impairments tend to be of longer duration and require the clearance of snowy "debris" out of the areas needed for transportation or other useful functions. The work required to move accumulated snow (which may "drift" to significant heights or be blown back in place by wintry winds) can often overwhelm the capacities of both individual residents as well as public workers and local budgets.

Impact on Public Confidence in State Governance

For this hazard, the main issues regarding public confidence in government predominantly involve: (1) the ability of the infrastructure of the impacted area to withstand the winter storm event and continue to serve area residents, and (2) the ability of the government(s) to efficiently clear away snow and ice from areas that are most vitally needed for transportation and other shared public uses (e.g. schools, hospitals). If any shortcomings or failures in one or both of these functions are too evident to citizens (or mass media providers), then the capacity, efficiency, and adequacy of government(s) may be called into question. In many areas, the State and different forms of local governments and agencies will have different types of responsibilities, and where problems arise in the coordination or clarity of these governments' actions and responsibilities, discontent can reasonably be expected to be expressed by citizens.

Impact on Responders

Responders are asked to be outdoors during winter weather events in which most citizens prefer to take shelter. In addition to the risks from winds, obscured vision, impaired control of vehicles, power failures and blocked roadways, winter storm events also expose responders to extremely cold temperatures for long periods of time, and may thus compound the difficulties, risks, and expenses of response. Fatigue can more easily become a problem under extreme temperature conditions, either during winter weather emergencies or during extreme summer heat and humidity. Snow can impede facility access and make travel and outdoor activities treacherously slippery.

Impact on the Environment

Heavy snowstorms and severe blizzards can cause environmental impacts. Snowstorms can damage trees, with the weight of heavy snow accumulations bringing down limbs, branches, or entire trees. Dried dead trees more readily catch fire, contributing to wildfires in other seasons if not removed properly. Dead trees can become a breeding ground for beetles or other pests that can harm healthy green trees in non winter seasons. Animal deaths can occur as a result of immobility, injury, infections, frost bite, hypothermia, etc. Floods often occur when snow melts, and can cause environmental effects (as described in the flooding section). Erosion from melted snow can occur, affecting beaches and soils, and harming vegetation.

Snow can function as a significant source of water pollution since it accumulates a variety of contaminants from the atmosphere and roadways. The removal of snow from roadways can damage the physical and biological environment with contaminants that include salts and salt additives, sediments, metals/emissions, asbestos, petroleum products, bacteria, organic chemicals, soil materials and litter. Those materials that accumulate in roadway-removed snow affect streams, rivers, ground water resources, and lakes, causing harm to fish species and destruction of bottom-dwelling fish fodder. The contamination of soil and groundwater can also result in vegetative stress and decreased productivity. The contamination in sediments can accumulate in the tissues of plants and animals and cause harm.

Climate Change Considerations

According to meteorologist Paul Gross, author of "Extreme Michigan Weather" (2010), the likely effects of climate change upon Michigan's winters will involve more severe snowfall events, even though the length of Michigan's winter season may shrink.

Recent Significant Snowstorms in Michigan

January 26-28, 1967 – Mid-Michigan

From January 26-28, 1967 a snowstorm dumped 24 inches of snow in Mid-Michigan, causing Lansing and other area communities to virtually come to a standstill. The storm contributed to 17 deaths across the region. Hundreds of motorists were stranded in their cars and had to be rescued by the National Guard and local law enforcement. The heavy snowfall caused the collapse of roofs on numerous homes and businesses, and shut down public transportation services. Several public shelters were opened to accommodate those stranded by the snow or without heat or electricity due to downed power lines.

January 26, 1977 – Southern Michigan

Beginning on January 26, 1977, a major snowstorm occurred that affected vast portions of southern Michigan. Winds of blizzard proportions resulted in extensive drifting of snow, blocking many roads. Many residents were isolated in rural residences or stranded in public shelters. This storm resulted in a Presidential Emergency Declaration for 15 counties in the southern part of the state.

January 26-27, 1978 – Statewide

On January 26-27, 1978 a severe snowstorm struck the Midwest, and Michigan was at the center of the storm. Dubbed a "white hurricane" by some meteorologists, the storm measured 2,000 miles by 800 miles and produced winds with the same strength as a small hurricane and tremendous amounts of snow. In Michigan, up to 34 inches of snow fell in some areas, and winds of 50-70 miles per hour piled the snow into huge drifts. At the height of the storm, it was estimated that over 50,000 miles of roadway were blocked, 104,000 vehicles were abandoned on the highways, 15,000 people were being cared for in mass care shelters, and over 390,000 homes were without electric power. In addition, 38 buildings suffered partial or total roof collapse. Two days after the storm, over 90% of the state's road system was still blocked with snow, 8,000 people were still being cared for in shelters, 70,000 vehicles were stranded, and 52,000 homes were still without electricity. This storm resulted in a Presidential Emergency Declaration for the entire state, to provide assistance with snow clearance and removal operations.

December 9-12, 1995 – Sault Ste. Marie (Chippewa County)

On December 9, 1995 a snowstorm moved across the Upper Peninsula and stalled near Sault Ste. Marie for nearly 24 hours, dumping a record 28 inches of snow on the city. That eclipsed the city's previous 24-hour snowfall record (15.2 inches, in 1988) by more than one foot. By the time the storm system passed on December 12, Sault Ste. Marie had received a total of 61.7 inches of snow. The excessive snowfall presented a great threat to public safety. Most city streets were impassable to emergency vehicles, and snowdrifts and piles restricted visibility at intersections and buried hundreds of fire hydrants. Schools and most businesses were closed due to the difficult conditions.

A Governor's Emergency Declaration was granted on December 13 to provide assistance with snow clearance and removal activities. The Michigan National Guard was activated, along with work crews from the Michigan Department of Transportation and the Michigan Department of Corrections, to clear and remove snow. (The Guard alone removed more than 150,000 cubic yards of snow in five days.) The Michigan Family Independence Agency and Michigan Office of Services to the Aging provided assistance to senior citizens and other homebound individuals. The Michigan Department of Environmental Quality waived regulations to allow the disposal of clean snow into the St. Mary's River. Other areas that received heavy snowfall in this storm event included Munising with 53 inches, Ontonagon with 43 inches, and Silver City and Houghton with 34 inches.

December 20, 1996 – Southwestern Lower Michigan

On December 20, 1996 heavy snow rapidly became lake enhanced and dumped storm totals up to 20 inches in the southwestern Lower Peninsula. Schools were closed for up to two days in some areas. Some secondary roads were blocked until road crews could get control of the situation.

January 10-12, 1997 – Western Lower Peninsula

During a three day period from January 10- 12, 1997 heavy snow was reported in Ottawa and Kent County for all areas of snowfall of at least 12 inches or more. In neighboring Allegan County the snow was measured at 28 inches on Friday evening and 40 inches by Saturday afternoon. In the northern portion of the Lower Peninsula, Grand Traverse County received 12 to 18 inches. Schools were used as emergency shelters for stranded motorists throughout the affected area. Secondary roads across all of the area were blocked from Friday night into Saturday and interstates were also closed for a few hours late Friday into Saturday. Accidents occurred at the rate of 50 to 100 per county per day from the 10th through the 12th.

March 13-15, 1997 – Upper Peninsula

Beginning on the afternoon of March 13, 1997 and continuing until the morning of March 15, a snowstorm moved across the Upper Peninsula, dumping 20-30 inches of heavy snow in many communities. Although the Upper Peninsula is accustomed to heavy snows throughout the winter, this storm produced snowfall totals that were significant even for that region. In Marquette, nearly 33 inches of new snow fell. In a 24-hour period between March 13-14, Marquette received 28 inches of snow, breaking the 24-hour snowfall record set back in March 1986. The storm also produced a record snow depth of 63 inches at Marquette County Airport, eclipsing the previous record of 59 inches recorded in March 1976. The storm dropped 29 inches of snow at Phoenix in Keweenaw County, 25 inches at Herman in Baraga County, and 21 inches at Shingleton in Alger County. Numerous other communities across the region received between 16 and 20 inches of new snow.

October 26, 1997 – Southern Lower Michigan

An early season snowstorm crossed southern Lower Michigan on October 26, 1997, dumping 2-8 inches of heavy, wet snow. Because of the significant amount of foliage still left on the trees, the added weight of the heavy snow caused many trees and tree branches to break, resulting in numerous power outages and reports of property damage from downed trees. At the height of the storm, over 330,000 electrical customers statewide were left without power – 195,000 in the Grand Rapids area alone. Total property damage was estimated at $1.2 million. Because of the widespread power outages (some of which lasted 36-72 hours), shelters were established in several communities to care for senior citizens and others vulnerable to the cold. The storm forced the closure of many schools and businesses throughout the impacted area.

January 2-3, 1999 – Southern Lower Michigan

In the early morning hours of January 2, 1999 a severe winter storm moved across the western and southern portions of Michigan. The storm grew in intensity and size, producing record or near-record snowfall that affected much of the southern two-thirds of the Lower Peninsula by the late evening hours of January 3. High winds and frigid temperatures created blizzard conditions that lasted until late in the day on January 4 in some areas. Subsequent storms over the next several days dumped an additional foot of snow in many areas of the state, resulting in snowfall of historic proportions in several Michigan communities. Combined, these winter storms produced the worst winter conditions to hit Michigan since the statewide blizzard that occurred in January 1978 (see description above).

The effects of the blizzard on the city of Detroit were the focus of national media attention. Detroit and surrounding communities received nearly two feet of snow during the blizzard. The unusually intense snowfall, coupled with the frigid temperatures and blowing and drifting snow, severely hampered snow removal operations within Detroit. The City's inability to plow residential streets created public health and safety concerns in many areas due to lack of access for police, fire, and other emergency vehicles. The unplowed streets and sidewalks also forced the Detroit school system to close for several days, idling more than 180,000 students. The heavy snowfall collapsed numerous commercial building roofs in Detroit and throughout southeast Michigan. In addition, ice dams on residential roofs were a widespread problem, damaging tens of thousands of structures. The record snowfall also hampered mail delivery, affected the ability of residents to travel to and from work, and negatively impacted business activity and tourism.

At Detroit Metropolitan Airport, the severe winter conditions forced the cancellation of hundreds of flights over the three-day period from January 2-4, stranding thousands of travelers without adequate accommodations. Numerous planes landed at the airport, only to sit on the runway apron for hours at a time – unable to

unload passengers because the snow could not be cleared from the gates fast enough or there simply were not enough open gates or personnel to handle the large influx of planes. This situation also drew the attention of the national media and cast a negative shadow over the airline and airport operations. A Presidential Emergency Declaration was granted for the 31 Michigan counties that received record or near-record snowfall, making available Federal snow removal assistance under the Federal Emergency Management Agency's (FEMA) Public Assistance Grant Program.

November 20, 2000 – Southwestern Lower Michigan

On November 20, 2000 the first snow storm of the season for the Grand Rapids area produced a record 24 hour snowfall of 11.5 inches at the National Weather Service in Grand Rapids, breaking the old record of 10.4 inches. Lake effect snow continued through the night and during the morning hours of the 21st, and 1 to 2 feet of snow fell across parts of Ottawa County. Allegan County also received 24 inches.

December 11-31, 2000 – Central and Southern Lower Michigan

In the early morning hours of December 11, 2000 a severe winter storm moved through the state, inflicting its heaviest effects on the southern two-thirds of the Lower Peninsula before moving out of the state on the morning of December 12. That storm produced record or near-record 24-hour snowfall levels in 31 counties, paralyzing the entire region. High winds and frigid temperatures created blizzard conditions that lasted until late in the day on December 13 in some areas. The storm produced great hardships for many Michigan communities. Schools across much of southern Lower Michigan were closed for several days, idling hundreds of thousands of school children. The storm also forced the cancellation of hundreds of airline flights in and out of Detroit Metro Airport and at other airports across the region, and forced many businesses to close at the height of the Christmas shopping season (the most profitable shopping period of the year).

Another series of winter storms the following week dumped an additional foot or more of snow across southern Lower Michigan, increasing snow depths in many counties to two feet or more. The tremendous snow depths caused a host of public health and safety concerns across the region. The snow fell at such a steady rate in many areas that public works crews worked at maximum capacity – often around the clock – for two weeks just to keep pace. The weight of the accumulated snow caused numerous collapsed roofs on homes and businesses, and ice dams and water seepage damaged thousands of structures well into January 2001. In addition, several house fires erupted when water from melting snow and ice seeped into electric meter boxes.

The cumulative effects of the heavy snowfall, high winds, and severe cold temperatures that began on December 11 caused problems across the region for the next several weeks. The sheer volume of snow made it difficult to handle, and the process of clearing it out of the way became difficult and expensive, as there was almost no place to put it. Many communities used the majority of their annual snow-removal budget and their road salt supply to combat these storms. The winter storms of December 2000 produced the worst winter conditions to hit Michigan since the statewide blizzards that occurred in January 1978 and January 1999. In Flint and Saginaw, the December 2000 snowfall set an all-time record for ANY month. In many other areas, it set all-time records for the month of December.

A Presidential Emergency Declaration was granted for the 39 Michigan counties that received record or near-record snowfall or incurred significant cumulative effects, making available Federal snow removal assistance under the Federal Emergency Management Agency's (FEMA) Public Assistance Grant Program.

December 23-29, 2001 – Southwestern and Northern Lower Peninsula

From December 23-29, 2001, Grandville (in Kent County) received 26 inches of snow. Up to 15 inches of snow fell in Grandville in less than 24 hours and around 24 to 26 inches of snow fell total in a band from Ottawa County southwest to Allegan County. Even more lake effect snow redeveloped on the 28th and continued through the 29th, producing additional snowfall of 8 to as much as 22 inches across the area. 12 to 18 inches of snow was common across the Grand Rapids area. There was also a narrow strip of around a foot of snow that fell about 25 miles inland from Ottawa county.

Storm total snowfalls broke all previous records for snowfall in one week in several locations across southwest Michigan. Grandville (Kent County) ended up with 70.2 inches of snow for the week, which was the greatest reported snowfall total across the area. The National Weather Service Forecast Office in Grand Rapids (Kent County) had a storm total snowfall of 50.6 inches for the week. Generally speaking, the heaviest snow accumulations for the week occurred along the US-131 corridor from Grand Rapids down through Allegan County, where two to four feet of snow fell. The cities of Petoskey and Charlevoix broke their 2 and 3 day snowfall total records with amounts of 44 and 60 inches and 27 and 39 inches, respectively. Traverse City tied their 2 day snowfall record with 20.5 inches from the 28th through the 29th. Many other areas saw snowfall totals of a foot or more during the last week of December.

January 29-30, 2002 – Southern Lower Michigan

Severe winter weather battered much of the Lower Peninsula for two days during the end of January 2002, bringing a foot or more of snow, mixed with sleet and ice. Schools were closed, roads were flooded, and over 152,000 were left without power. Four people were killed in weather-related traffic accidents in Kent, Saginaw, Midland, and St. Joseph Counties. AAA Michigan served more than 2,850 motorists by the late afternoon on January 30. Detroit Metropolitan Airport cancelled more than 170 departures and 183 arrivals due to weather conditions.

March 2, 2002 – Lower Michigan Peninsula

On March 2, 2002 a winter storm produced heavy snow across most of the Lower Peninsula, producing 12 to 18 inches of snow. The maximum snowfall reported was in Ludington (Mason County), where 18 inches of snow fell. The snow was particularly wet and heavy, and numerous tree limbs and power lines were downed in the area.

February 7 and 12, 2003 – Southwestern Lower Michigan

On February 7, 2003, blizzard conditions caused a 72-car accident on I-94 in Benton Township (Berrien County). The accident began when a car slid under the back of a semi-tractor trailer during whiteout conditions. Those involved in the crash stated that the heavy lake-effect snow had reduced visibility and caused poor road conditions. When the motorists approached the I-94 and I-196 interchange, the weather changed from bad to worse, causing zero visibility. These conditions caused cars to slow at different rates, and thus a chain collision ensued.

Only five days later, on February 12, 2003 an Alberta clipper moved through and produced heavy snow across western Lower Michigan. The heaviest snowfall report was received from Walker (Kent County), where 14 inches of snow fell. A large swath of anywhere from 6 to 10 inches of snow fell across other parts of Ottawa County as well as Kent County. There were also localized reports of a foot or more of snow received in the two counties.

January 19-20, 2004 – Northwestern Lower Peninsula

Heavy lake effect snow came in off of Lake Michigan, accompanied by gusty northwest winds and blowing and drifting. The most persistent band of snow settled in from central Leelanau County to western Grand Traverse County. Around 20 inches of snow fell near Interlochen, with drifts of 5 to 6 feet across M-72 in Leelanau County.

January 27, 2004 – Central Lower Michigan

On January 27, 2004, six to ten inches of snowfall occurred across much of central Lower Michigan. Up to 14 inches of snow accumulated northeast of Grand Rapids, in Montcalm County. Visibility was near zero when a pileup involving about 50 cars and trucks occurred on I-96 near Portland, shutting down both sides of the highway. There was only one injury reported and the highway was reopened about three hours later. Police in the tri-county area had responded to more than 200 accidents during the day.

November 24-25, 2005 – Northern Lower Peninsula

Lake effect snow quickly developed and became intense by the afternoon of Thanksgiving Day throughout much of the northern portions of the Lower Peninsula. Near-blizzard conditions developed, with wind gusts of 25 to 35 mph inland and 50 mph near the coastlines, lowering visibilities to near zero at times. Total snowfall amounts of 12 to 18 inches were common in the prime snow belts regions around Gaylord, Kalkaska, and Mancelona. Holiday travel was impacted severely by the falling, blowing, and drifting snow. Numerous accidents occurred on area highways.

February 3-4, 2007 – Southwest Lower Michigan

The combination of lake-effect snow (and snow already on the ground) with very strong winds resulted in blizzard conditions across western Lower Michigan on February 3rd. The maximum snowfall total for a twelve hour period was eight inches, and the maximum snowfall total for a 24-hour period was 12 inches. The highest snowfall total for the entire event was 17 inches, in Grandville. The Gerald R. Ford International Airport in Grand Rapids reported visibility at or under a quarter-mile from 9:30 a.m. through 8 p.m. on Saturday February 3rd. Numerous other observation sites across far western Lower Michigan also reported blizzard conditions. Many locations reported sustained winds of 20 to 30 mph, with gusts to around 40 mph, during the late morning and afternoon hours of the 3rd. The blizzard conditions resulted in numerous road closures, power outages, and car accidents.

February 25-26, 2007 – Northern Lower Peninsula

A low pressure system stalled out over the Southwest Great Lakes region resulting in a fairly extensive period of accumulating snowfall and gusty east winds in much of Northern Lower Michigan. The axis of heaviest snowfall stretched from Cadillac to Lake Ann, with total of 12 to 15 inches. Blustery winds produced considerable blowing and drifting snow. Wexford County officials reported that more than 50 vehicles slid off of area roads. Numerous schools were closed on the 26th.

February 6-7, 2008 – Saginaw County

Widespread heavy snowfall of 8 to 12 inches occurred along and north of the I-69 corridor in eastern Michigan. The heaviest snow total of 16 to 18 inches occurred in Saginaw County. This snowstorm total in Saginaw County was the biggest amount since the Blizzard of 1978. Strong northeast winds off of Saginaw Bay also led to near blizzard conditions. Road crews in Saginaw County could not keep up with the snow, which fell at a rate of 2-4 inches per hour. Two to three foot snow drifts left at least 50 cars stranded. Snowfall amounts tapered off south of I-69, as sleet mixed in, cutting down accumulations quickly, with less than 3 inches across Wayne County and points to its south.

February 10, 2008 – Southwest Michigan

A blizzard event involved a combination of extreme cold, frequent wind gusts up to 40 mph, whiteout conditions, heavy snow, and blowing snow. There was a fifty-car pileup on I-196 in Ottawa County, causing 20 persons to receive treatment for minor injuries. Snowfall totals were the greatest over Allegan and Van Buren Counties. Snow drifts of 3 to 5 feet deep were common in rural areas. Property damage was estimated at $250,000 in Ottawa County.

December 21-22, 2008 – Western Lower Peninsula

From December 21-22, 2008 six to 12 inches of snow fell in Kent and Ottawa Counties, accompanied by wind gusts up to 45 mph. This resulted in two to three foot snow drifts across portions of the area. In conjunction with the blizzard to near-blizzard conditions, this produced dangerous travel conditions. Farther north, Wellston ended up with 23 inches of snow in 24 hours, and many Northern Lower Peninsula areas received similar amounts. At the height of the storm, several stretches of highway were shut down due to multiple vehicle accidents.

December 3-4, 2009 – Grand Rapids Area

From December 3-4, 2009 over a foot of snow was reported across portions of Ottawa County, where 15 inches fell in Marne and 14 inches fell in Coopersville. Several inches of slushy snow accumulated on roads from Muskegon to Grand Rapids. The following week, four to eight more inches of snow, in conjunction with wind gusts to 40 mph, created near-blizzard conditions at times, resulting in very hazardous travel conditions. Numerous accidents were reported, due to slippery roads and reduced visibility in the blowing snow.

December 9-11, 2009 – Northern Lower Peninsula

From December 9-11, 2009 heavy snowfall totals and blizzard conditions were common across all of Northern Michigan. The snow transitioned to lake effect snow that night, and lasted into the 11th in some of the snow belts. Gaylord had its 2nd largest three-day snowfall since 1950, with 21.8 inches. There was a considerable amount of wind, with some gusts over 50 mph, causing blowing and drifting snow. Almost all school districts were closed on the 9th, and some schools called off classes for three consecutive days. Numerous accidents were reported, due to slippery roads and reduced visibility in the blowing snow.

February 9-10, 2010 – Ottawa County

From February 9-10, 2010 six to ten inches of snow fell across Ottawa County. The storm coincided with Michigan's winter "Count Day," used to determine base funding for local public school systems. Many school systems closed due to the snowstorm. Several significant accidents occurred on the region's primary arteries. I-94 was closed for several hours, due to jackknifed trucks. There was also a multiple vehicle pileup on I-196.

February 1-2, 2011 – Southern Lower Michigan

From February 1-2, 2011 a major winter storm occurred throughout much of Lower Michigan. The storm brought 10 to 15 inches of snow and blizzard conditions to much of southern Lower Michigan. Wind gusts in excess of 40 mph combined with heavy snow to produce whiteout conditions and snowdrifts of 3 to 5 feet. Thunder accompanied the snow in some areas with snowfall rates exceeding two inches per hour. Many businesses, schools (including major universities), and some government offices were closed the next day. Most main roads were plowed by the next day but some side streets were not cleared for a couple more days.

Other Significant Snowstorms of General Interest in Michigan and Across the United States

Winter 1888 - Northern U. S.

The fabled Winter of 1888 was devastating to much of the northern United States, with snow, freezing temperatures, and severe winds responsible for the deaths of hundreds of people and thousands of cattle across the Dakota Territory, Minnesota, Wisconsin, and Michigan's Upper Peninsula. As bad as conditions were in the Midwest, however, one single snowstorm will forever characterize that brutal winter. The famous Blizzard of 1888 struck the eastern seaboard on March 12, 1888, dumping 40-50 inches of snow in New York and creating 30-40 foot snowdrifts in parts of southern New England. Snowdrifts were reported over the tops of houses from New York to New England, including some three-story houses. One town in New York had a snowdrift that measured 52 feet in height. Over 400 people died in the blizzard, including 200 in New York City alone. Wind gusts up to 80 miles per hour were reported, which contributed greatly to the tremendous drifting and high number of deaths.

November 7-12, 1913 - Eastern Great Lakes (primarily Lake Huron)

Although severe winter storms on the Great Lakes are common in November, the fall storm of November 7-12, 1913 is considered the greatest ever to strike the Great Lakes. No other Great Lakes storm in modern history compares to the November 1913 storm in terms of death and destruction. The November 1913 storm development was similar to the monster storm that struck Michigan on January 26-27, 1978 (see previous description). Like the 1978 storm, the November 1913 storm was also dubbed a "white hurricane" because of its tremendous size and strength. Winds up to 62 miles per hour and blizzard-like snow struck Port Huron on November 8-9, while in Detroit wind gusts of 70 miles per hour were reported. Port Huron was buried with heavy snow and snow squalls, creating four to five-foot drifts that immobilized the city. The heavy snow pummeled many other shoreline communities as well. On Lake Huron, sailors reported continuous, battering waves at least 35 feet high. The constant barrage of water severely punished various ships and eventually led to their demise. Forty ships were believed to have sunk in that storm, with at least 235 sailors lost. Of the 40 vessels, eight were large lake freighters that went down with all aboard.

March 12-14, 1993 - Eastern U. S. ("Storm of the Century")

On March 12-15, 1993 a snowstorm now called the "Storm of the Century" struck the eastern United States with a vengeance, dumping up to 56 inches of snow in some areas and causing more than $2 billion in property damage. This storm was among the worst non-tropical weather events in U.S. history. The storm impacted 26 states and approximately 50% of the nation's population. (Fortunately, Michigan was not one of those states severely affected.) A total of 270 deaths

and over 600 injuries were attributed to the storm. All interstate highways from Atlanta northward were closed, some for several days. In addition, every major airport on the East Coast was closed at one time or another during the storm. Over three million electrical customers lost power due to fallen trees and high winds, and hundreds of roofs collapsed due to the weight of the heavy, wet snow. Wind gusts up to 144 miles per hour were recorded, and the temperature dipped to minus 12 degrees Fahrenheit in some localities. In Daytona Beach, Florida the temperature dipped to 31 degrees Fahrenheit. The National Weather Service (NWS) estimated the volume of water that fell as snow to be a staggering 44 million acre-feet, which is comparable to 40 days' flow on the Mississippi River at New Orleans.

December 3-5, 2002 - Southern and Eastern United States

Severe winter weather hit several states from New Mexico to the Carolinas and then spread along the Atlantic Coast. Twenty-two people were killed, mostly from traffic accidents. More than 1.6 million homes and businesses were without electricity in the Carolinas. Schools closed in parts of 13 different states and travelers faced cancellations and delays at airports near New York City and Newark, N.J. Some 3,000 travelers were stranded overnight at a North Carolina airport. The storm was compared to recent hurricanes in the area for its scale of destruction.

February 17-18, 2003 - Eastern United States

A severe winter storm plagued the northeast United States for two days in February 2003. Heavy snow blown by northeast winds of 20 to 30 miles per hour caused near-blizzard conditions throughout the area. The storm was blamed for 44 deaths and it also exhausted many of the states' snow removal budgets. The snow removal cost in New York was estimated at $20 million—about $1 million for each inch of snow. Many states, such as Maryland, Massachusetts, Connecticut, and New Jersey, were already over their snow removal budget before the storm occurred.

Programs and Initiatives

Note: Many of the programs and initiatives designed to mitigate, prepare for, respond to, and recover from ice and sleet storms have the dual purpose of also protecting against snowstorms. As a result, there is some overlap in the narrative programs and initiatives descriptions for each respective hazard. This redundancy allows each hazard section to stand alone, eliminating the need to refer to other hazard sections for basic information.

National Weather Service Doppler Radar

The National Weather Service has completed a major modernization program designed to improve the quality and reliability of weather forecasting. The keystone of this improvement is Doppler Weather Surveillance Radar, which can more easily detect severe weather events that threaten life and property – including severe winter weather events such as snowstorms. Most importantly, the lead time and specificity of warnings for severe weather have improved significantly.

National Weather Service Watches, Warnings and Advisories

The National Weather Service issues winter storm watches and winter weather warnings to notify the public of severe winter weather conditions. A winter storm watch indicates that severe winter weather conditions (freezing rain, sleet, or heavy snow) may affect an area, while a winter weather warning indicates that severe winter weather conditions are imminent.

Winter storm warnings can be issued for snow alone, but they can also take on different varieties. For example, a blizzard warning signifies that blizzard conditions are imminent or occurring. Blizzard conditions mean that the visibility will frequently be one-quarter mile or less in falling or blowing snow, with wind speeds of at least 35 miles per hour. A wind chill warning is issued when wind chills drop below -30 degrees Fahrenheit, with winds equal to or greater than 10 miles per hour. Finally, an ice storm warning is issued for a significant accumulation of ice, normally a coating of at least one-quarter inch.

The National Weather Service also issues a number of different advisories for winter weather. These advisories can be issued for snow, freezing rain, blowing snow, and wind chill, among other things. Advisories mean that conditions are expected to cause significant inconveniences and may be hazardous. However, if caution is exercised, the situation should not become life threatening.

The State and local government agencies are warned via the Law Enforcement Information Network (LEIN), National Oceanic and Atmospheric Administration (NOAA) weather radio, and the Emergency Managers Weather Information Network (EMWIN). Public warning is provided through the Emergency Alert System (EAS). The National Weather Service stations in Michigan transmit information directly to radio and television stations, which in turn pass the warning on to the public. The National Weather Service also provides detailed warning information on the Internet, through the Interactive Weather Information Network (IWIN).

Winter Hazards Awareness Week

Each fall, the Emergency Management and Homeland Security Division, Department of State Police, in conjunction with the Michigan Committee for Severe Weather Awareness, sponsors Winter Hazards Awareness Week. This annual public information and education campaign focuses on winter weather hazard events such as snowstorms,

blizzards, extreme cold, and ice and sleet storms. Informational materials on winter weather hazards and safety are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public.

Electrical Infrastructure Reliability

One of the major problems associated with any winter weather hazard (including snowstorms) is the loss of electric power. Although the problem is not quite as chronic in Michigan as it is with ice storms, snowstorms have nonetheless caused several widespread and severe electrical power outages. Weather-related damage to electric power facilities and systems is a concern that is being actively addressed by utility companies across the state. Detroit Edison, Consumers Energy and other major electric utility companies have active, ongoing programs to improve system reliability and protect facilities from damage by snow, ice, severe winds, and other hazards. Typically, these programs focus on trimming trees to prevent encroachment of overhead lines, strengthening vulnerable system components, protecting equipment from lightning strikes, and placing new distribution lines underground. The Michigan Public Service Commission (MPSC) monitors power system reliability to help minimize the scope and duration of power outages.

Urban Forestry/Tree Maintenance Programs

Urban forestry programs can be very effective in minimizing snowstorm damage caused by falling trees or tree branches. In almost every severe snowstorm, falling trees and branches cause power outages and clog public roadways with debris. However, a properly designed, managed and implemented urban forestry program can help keep tree-related damage and impact to a minimum. To be most effective, an urban forestry program should address tree maintenance in a comprehensive manner, from proper tree selection, to proper placement, to proper tree trimming and long-term care.

Every power company in Michigan has a tree trimming program, and numerous local communities have some type of tree maintenance program. The electrical utility tree trimming programs are aimed at preventing encroachment of trees and tree limbs within power line rights-of-way. Typically, professional tree management companies and utility work crews perform the trimming operations. At the local government level, only a handful of Michigan communities have actual urban forestry departments or agencies. Rather, crews from the public works agency or county road commission perform the bulk of the tree trimming work.

When proper pruning methods are employed, and when the work is done on a regular basis with the aim of reducing potential storm-related damage, these programs can be quite effective. Often, however, tree trimming work is deferred when budgets get tight or other work is deemed a higher priority. When that occurs, the problem usually manifests itself in greater storm-related tree debris management problems down the line.

Severe Winds

Non-tornadic winds of 58 miles per hour or greater.

Hazard Description
Severe winds spawned by thunderstorms or other storm events have had devastating effects on Michigan, resulting in 122 deaths, nearly 700 injuries, and hundreds of millions of dollars in damage to public and private property and agricultural crops since 1970. Severe wind events are characterized by wind velocities of 58 miles per hour or greater, with gusts sometimes exceeding 74 miles per hour (hurricane velocity), but do not include tornadoes. (Please refer to the Tornadoes section which follows, for more information on that hazard.)

Hazard Analysis
Figures from the National Weather Service indicate that severe winds occur more frequently in the southern-half of the Lower Peninsula than any other area of the state. On average, severe wind events can be expected 2-3 times per year in the Upper Peninsula, 3-4 times per year in the northern Lower Peninsula, and 5-7 times per year in the southern Lower Peninsula. It must be emphasized that this refers to winds from thunderstorms and other forms of severe weather, but **not** tornadoes.

The property damage from straight line winds can be just as extreme as that of a tornado, since the damage from straight line winds is more widespread and usually affects multiple counties. In addition to property damage to buildings (especially less sturdy structures such as storage sheds, outbuildings, etc.), there is a risk for infrastructure damage from downed power lines due to falling limbs and trees. Large-scale power failures, with hundreds of thousands of customers affected, are common during straight-line wind events.

Another dangerous aspect of straight line winds is that they occur more frequently beyond the April to September time frame than is seen with the other thunderstorm hazards. It is not rare to see severe winds ravage parts of the state in October and November. Stark temperature contrasts seen in colliding air masses along swift-moving cold fronts occur regularly during those months.

National Weather Service forecasts of severe winds usually give sufficient warning time to allow residents to take appropriate action to reduce, at least to some degree, the effects of wind on structures and property. Little can be done to prevent damage from flying objects. However, proper structural bracing techniques can help minimize or even eliminate major damage due to the loss of a roof or movement of a building off its foundation.

In terms of response to a severe wind event, providing for the mass care and sheltering of residents left without heat or electricity, and mobilizing sufficient resources to clear and dispose of downed tree limbs and other debris from roadways, are the primary challenges facing Michigan communities. In addition, downed power lines present a public safety threat that requires close coordination of response efforts between local agencies and utility companies. Thunderstorms and severe winds can affect every Michigan community. Therefore, every community should adequately plan and prepare for this type of emergency. That planning and preparedness effort should include the identification of necessary resources such as cots, blankets, food supplies, generators, and debris removal equipment and services. In addition, each community should develop debris management procedures (to include the identification of multiple debris storage, processing and disposal sites) so that the stream of tree and construction debris can be handled in the most expedient, efficient, and environmentally safe manner possible.

To mitigate the effects of severe winds, communities can: 1) institute a comprehensive urban forestry program, 2) properly brace and strengthen vulnerable public facilities, 3) ensure compliance with manufactured home anchoring regulations, 4) coordinate with utility companies on local restoration priorities and procedures, 5) improve local warning systems, and 6) amend local codes to require structural bracing, where appropriate, in all new residential and commercial construction.

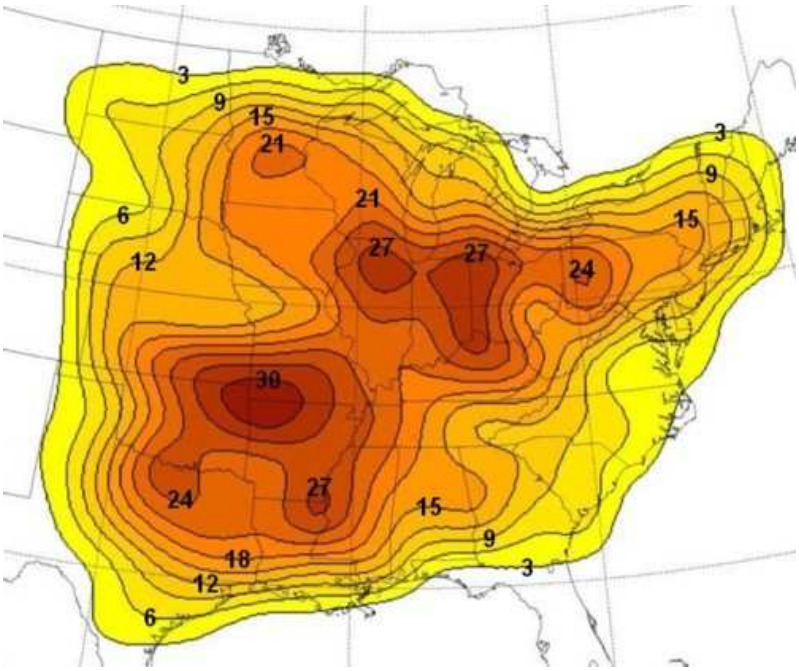
<u>Derecho</u>
A Derecho, also called a bow echo, is a widespread and long-lived windstorm that is associated with a fast-moving band of severe thunderstorms. Derechos are usually not associated with a cold front, but instead with a stationary

front. They occur mostly in July, but can occur at anytime during the spring or summer. The following map gives an indication of the pattern of Derecho frequency across the Midwest.

There are three types of Derechos:

- Serial Derecho - Multiple bow echoes embedded in a massive line typically around 250 miles long. This type of Derecho is usually associated with a very deep low pressure system. Also because of embedded supercells, tornadoes can easily spin out of these types of Derechos.
- Progressive Derecho - A small line of thunderstorms take a bow-shape and can travel for hundreds of miles.
- Hybrid Derecho - Has characteristics of a serial and progressive Derecho. These types of Derechos are associated with a deep low pressure system like serial Derechos, but are relatively small in size like progressive Derechos.

Moderate and High Intensity Derechos
1980-2001



Note: Numbers on map indicate the number of Derechos that occurred during the period.
Source: National Oceanic and Atmospheric Administration

On average, severe wind events can be expected 2 to 3 times per year in the Upper Peninsula, 3 to 4 times per year in the northern Lower Peninsula, and 5 to 7 times per year in the southern Lower Peninsula. Based upon an analysis of NCDC records (kept since 1990), an average of two deaths and 20 injuries occur each year from severe winds. Property damage from major events averages about $25 million per year.

Impact on the Public

Severe winds tend to impede transportation, causing slowed traffic and impaired control on roadways, and delays in the flight schedules for airlines. In addition, their physical impact can be comparable to that of a weak tornado, judged in terms of the severity of the resulting property damage, but with a more widespread area of effect. Structural collapse, and damages caused by falling trees/limbs, can cause injury and impairment of the residential and commercial use of the affected properties. It is very common for winds to cause trees and their limbs to break communication and power lines, causing the types of impacts described for the lightning hazard (and in the section on infrastructure failures).

Impact on Public Confidence in State Governance

When winds cause infrastructure failures, a question may be raised about the adequacy of that infrastructure, its maintenance, and its design and regulation. In events that require mass sheltering, such as schools or large gatherings (e.g. a county fair or community-sponsored event), the ability of local and state government to adequately plan for severe weather is often vital to the success of such events, which themselves are often important for various sectors of the local and state economy. Citizen discontent and media-exacerbated controversies have arisen from situations in which inadequate planning was evident, or provisions for public sheltering were inadequate.

Impact on Responders

Responders tend to be working outdoors in conditions from which most residents are taking shelter. Although special training and safety precautions have usually been taken (e.g. for line-repair workers), nevertheless, responders are more exposed to and at-risk from the impacts of severe winds. Some winds, such as the most extreme gusts from severe straight-line winds (microbursts), can be brief, but can still be surprising and harmful to those caught in them. Strong winds can also persist for many hours and exacerbate the existing difficulties and challenges involved in emergency response—impeding traffic, causing power loss and road closures, and making the use of equipment more difficult.

Impact on the Environment

Non-tornadic winds of at least 58 mph are classified as severe winds and/or derechos. Some of the harmful effects of wind on the environment include full-grown trees being completely uprooted and knocked down, or large acreage of forest land being destroyed. Large amounts of debris, elements from collapsed structures, and destroyed natural vegetation can result from severe winds. Wildlife species can be harmed. Collapsed structures can contain combustible building materials, debris, chemicals, machinery, smoke, sewage, or other elements that can damage the environment. Lakeshore beach erosion can occur, along with rip currents in the water, as a result of severe winds. Winds can stir up sediments in waterways that can also disrupt the ecosystem.

Recent Significant Severe Wind Events in Michigan

Various Dates – Lake Michigan (Oceana and Mason Counties)

The twenty-mile span of Lake Michigan between Little Point Sable, at Silver Lake, and Big Point Sable, north of Ludington, has earned a reputation as the "Graveyard of Ships." Beginning with the loss of the Neptune in 1848, through the Armistice (now Veterans') Day Storm of 1940, nearly seventy vessels have gone down in these treacherous waters. Gales and November snow storms have made navigation of this part of the lake a sailor's nightmare. Significant among the losses near Pentwater Harbor were the schooner Wright in 1854, the Minnie Corlett and the Souvenior in 1875, the Lamont in 1879 and the tug Two Brothers in 1912. The freighters William B. Davock, Anna C. Minch and Novadoc were all lost on November 11, 1940.

November 18, 1958 – Lake Michigan

The November 18, 1958 sinking of the 615-foot Carl D. Bradley limestone carrier in Lake Michigan, 60 miles west of the Mackinac Bridge, was due to excessive waves caused by winds up to 100 miles per hour. Mariners theorized that the “working” of the steel hull by 20-foot waves popped the rivets that held the ship’s plates together, causing the large vessel to split in two and sink. Thirty-three of the 35 crewmen onboard died in the accident.

November 10, 1975 – Lake Superior

The November 10, 1975 sinking of the freighter Edmund Fitzgerald in Lake Superior was due to excessive waves caused by severe winds exceeding 60 miles per hour. A total of 29 crewmen died in the accident.

July 15-20, 1980 – Southern Lower Michigan

Wind-related damages were so severe in the southern Lower Peninsula from July 15-20, 1980 that a Presidential Major Disaster Declaration was granted for 10 counties. Over 300,000 electrical customers were left without power, some for several days. During the recovery process, almost $6.8 million in public and private assistance was made available to affected local jurisdictions and to residents in the affected areas. Four million dollars in low-interest disaster loans were made available through the Small Business Administration.

April 30, 1984 – Lower Michigan

On April 30, 1984 a windstorm struck the entire Lower Peninsula, resulting in widely scattered damage, 1 death, and several injuries. Wind gusts measured up to 91 miles per hour in some areas. Damage was widely scattered, but extensive, with 6,500 buildings, 300 mobile homes, and 5,000 vehicles being damaged. Over 500,000 electrical customers lost power. In addition, 10-16 foot waves on Lake Michigan caused severe shore erosion, collapsing some cottages and driving many boats aground.

March 27, 1991 – Central and Southern Lower Michigan

On March 27, 1991 severe thunderstorms and accompanying high winds caused considerable damage across a large portion of central and southern Lower Michigan, damaging homes, businesses, farms, and some public facilities. A total of three deaths and 27 injuries were attributed to the storms, and power was lost to 450,000 electrical customers (many for up to one week). The storms also spawned tornadoes and hail in some areas. Damage to homes and businesses was estimated at over $30 million, with almost all of those losses covered by private insurance.

July 7, 1991 – Southern Lower Michigan

On July 7, 1991 a line of severe thunderstorms with very high winds crossed the southern Lower Peninsula. The National Weather Service recorded wind speeds of 60-70 miles per hour, with gusts in several locations exceeding 80 miles per hour. Several million dollars in damage occurred, and over one million electrical customers (more than 10% of the State’s population) were left without power, some for several days. In addition, thousands of downed power lines caused significant public safety concerns and burdened an already difficult restoration process.

July 13-15, 1995 – Statewide

From July 13-15, 1995 severe thunderstorms damaged numerous areas of Michigan. These storms, which produced winds up to 100 miles per hour with damaging golf ball-sized hail and severe lightning, damaged hundreds of structures and downed thousands of trees and power lines statewide. Damage was widespread, but the impacts were not severe or extensive enough in any one location to require supplemental disaster assistance. The strong winds produced widespread power outages. More than 400,000 electrical customers in southeast Michigan lost power due to the storms. In Roscommon County, over 100,000 trees were toppled by the winds. Wind gusts in that area were estimated in the 85-100 miles per hour range. One person was killed when her pontoon boat flipped over while attempting to return to its dock. One person was killed in Huron County when a barn collapsed between Bad Axe and Harbor Beach.

April 6-7, 1997 – West Michigan

On April 6-7, 1997, an intense early spring low pressure system moving across the Great Lakes brought gale force winds to much of Lower Michigan. Wind gusts of 50-70 miles per hour created 10-15 foot waves on the Lake Michigan shoreline, causing widespread wind damage and lakeshore beach erosion. Private damage was estimated at $5 million, most of that occurring in a handful of West Michigan counties. The winds downed numerous trees and power lines across the region, causing roof damage to many structures and power outages for nearly 200,000 Consumers Energy electrical customers. The U.S. Army Corps of Engineers estimated that the severe beach erosion resulted in as much as 20 feet of beach loss in some areas. The beach erosion was due in part to the unusually high Great Lakes water levels, nearly 38 inches above average. No deaths or injuries were reported in this severe wind event.

July 2, 1997 – South-Central and Southeast Michigan

On July 2, 1997 a series of intense thunderstorms went through south-central and southeast Michigan, spawning severe straight-line winds, several tornadoes, and heavy rainfall. In some areas, the straight-line winds reached speeds of 70-100 miles per hour, causing significant structural damage and massive amounts of debris. The severe storms and the associated impacts caused a total of 16 deaths and 120 injuries. The tornadoes and straight-line winds downed thousands of trees and power lines, which knocked out power to 350,000 electrical customers. A Presidential Major Disaster Declaration was granted for the five county area most severely impacted by the storm event. (See the Tornadoes section for additional details on the tornadoes associated with these severe thunderstorms.)

October 5, 1997 – Delta and Schoolcraft Counties

Severe thunderstorms out of Canada pushed their way through the Upper Peninsula on October 5, 1997, creating numerous microbursts (small, powerful downdrafts) that caused significant damage in Delta and Schoolcraft counties. Winds estimated in excess of 100 miles per hour cut a 12-mile wide swath of destruction in the two counties, downing thousands of trees and damaging 600 buildings and numerous vehicles. Total property, tree and agricultural losses were estimated at $3 million. The U.S. Forest Service reported damage to 9,000 acres of forest. The Michigan Department of Natural Resources suffered 500 acres of tree loss, and 200 acres of corporate forest were also heavily damaged. Fortunately, these microbursts occurred in lightly populated areas, or the threat to life and property might have been much greater.

May 31, 1998 – Southern Lower Peninsula

On May 31, 1998 a derecho raced across the Lower Peninsula around 4:30am, producing widespread 60 to 90 mph wind gusts that caused extensive tree and structural damage and left over 861,000 homes and businesses without electricity. Consumers Energy reported the derecho as the most destructive weather event in its history, leaving over 600,000 of its customers without power. There were four storm-related fatalities and 146 injuries (mostly minor) reported in the state. Statewide, approximately 250 homes and 34 businesses were destroyed and 12,250 homes and 829 businesses were damaged. Damage estimates totaled over $166 million. The highest wind gusts reached 120 to 130 mph in Spring Lake (Ottawa County) and Walker (Kent County), 100 mph in portions of Montcalm County (including Cody Lake and Stanton), and 90 mph in Rockford (Kent County) and Zeeland (Ottawa County). It took up to 10 days to fully restore power to certain areas, including the City of Walker and portions of Montcalm and Gratiot Counties. A Presidential Disaster Declaration was declared for 13 counties.

September 26-27, 1998 – Northern Lower Michigan

During the weekend of September 26-27, 1998, severe thunderstorms ravaged northern Lower Michigan, producing strong winds that damaged or destroyed homes, businesses and public facilities, and downed trees and power lines. Otsego County, specifically the city of Gaylord, was hardest hit, although damage was also reported in Crawford and Charlevoix counties as well. The storm front, which ran along and north of the M-32 corridor from East Jordan to Alpena, was approximately 12 miles wide and 15 miles long. When the front slammed into Gaylord, wind speeds had reached hurricane force of 80-100 miles per hour. The wind was accompanied by brief heavy rainfall and golf ball sized hail. The storm lasted only a few minutes in Gaylord, but the damage was tremendous. Thousands of trees were snapped off at waist level, homes and businesses were torn apart, power lines were downed, and several public facilities were substantially damaged – including the Otsego County Courthouse, which lost half of its roof. Approximately 818 homes were damaged throughout Otsego County, including 47 that were destroyed and 92 that incurred major damage. In addition, the storm injured 11 persons – none seriously. Region-wide, about 12,000 electrical customers lost power. A Governor's Disaster Declaration was granted to the county, to provide state assistance in the debris cleanup effort.

November 10-11, 1998 – Statewide

One of the strongest storms ever recorded in the Great Lakes moved across Michigan on the 10th and 11th of November, 1998, producing strong, persistent winds that damaged buildings, downed trees and power lines, killed one person, and left over 500,000 electrical customers in the Lower Peninsula without power. Wind gusts of 50-80 miles per hour were common, and a peak gust of 95 miles per hour was reported on Mackinac Island. Damage was widespread but relatively minor for a storm of that intensity. However, there were several pockets of significant damage across the state. In Troy, the walls of a church under construction were destroyed. In Flint, a warehouse lost its roof to the wind, and another had its roof damaged. In Mt. Clemens, a boat storage rack collapsed, causing about $500,000 in damage to 20 boats. In Frankfort, on the Lake Michigan shoreline, 80-90 mile per hour wind gusts destroyed a hangar at the City-County Airport ($500,000 in damage) and damaged six private planes. In Lake City, the roof was blown off a hardware store. The U.S. Forest Service reported that at least $10 million worth of timber was lost in the Ottawa and Hiawatha National Forests. The strong winds generated 15-20 foot waves on Lake Michigan, while 8-15 foot waves were reported along the western Lake Superior shoreline. The waves caused considerable beach erosion in both locations.

The extended period of strong winds even affected the water level in Saginaw Bay. By the morning of November 11, the winds had pushed so much water out into Lake Huron that the water level on Saginaw Bay bottomed out 50" below chart datum – over 5 feet below the recent average. The temporary loss of over 5 feet of water in the shallow bay exposed up to one-half of the bay bed, which briefly became dry land during the storm. As the wind died down later in the day, the water level rose again to its more normal level.

Coincidentally, this storm system occurred on the 23rd anniversary of the storm system that sunk the freighter Edmund Fitzgerald in Lake Superior in 1975 (see description below).

May 17, 1999 – Central and Southern Lower Michigan

On May 17, 1999 a strong storm system raced through central and southern Lower Michigan, bringing with it severe winds, heavy rain, and large hail. Wind gusts of 60-70 miles per hour downed numerous trees and power lines, leaving 150,000 homes and businesses without power. Peak wind gusts of 115 miles per hour were recorded near Wyoming, Lansing, and Battle Creek. A wind gust caused a home under construction to collapse in Wyoming, killing one person and injuring another. In Lansing, utility poles along I-496, built to withstand 100 mile per hour winds, were snapped off like twigs, closing parts of the freeway for 26 hours and causing rush hour traffic tie-ups. Response and recovery costs for Lansing city agencies (including the municipal power company) were pegged at $1.5 million.

July 4-5, 1999 – Several Northern States

The Boundary Waters-Canadian Derecho, also commonly called the Boundary Waters Blowdown, was an international Derecho that occurred during the afternoon and evening hours of July 4 and the early morning hours of July 5, 1999. It was classified as a progressive Derecho and it traveled over 1300 miles in 22 hours through Minnesota, Wisconsin, Michigan, Ontario, Quebec and Maine. There was also a tremendous amount of lightning associated with this Derecho, around

6,000 lightning strikes per hour. This event was one of the northernmost progressive Derechos to have ever been recorded. It caused $100 million in damage, killed 2 people and injured 70. Over 700,000 homes and businesses lost power from the event.

July 24-25 and 31, 1999 – Southern Lower Michigan

During the last two weekends of July 1999, a series of severe thunderstorms, fueled by high temperatures and extreme humidity, moved across southern Lower Michigan. The storms produced strong wind gusts (estimated at 60-70 miles per hour), heavy rainfall, and hail in some areas. Most of the damage caused by the wind involved downed trees and power lines. A total of 430,000 electrical customers were left without power after the two weekend storms, many for more than 24 hours. Unfortunately, the outages occurred at a time when temperatures were soaring past 90 degrees and humidity was unbearably high. Many electrical customers lost large amounts of perishable food to spoilage. Restoration efforts after the July 24 storms were further complicated when another series of storms struck on the 25th, forcing utility crews to temporarily halt their restoration efforts. Damage to homes, businesses, vehicles, and boats was reported in southeast Michigan and the Saginaw Bay area. In Detroit, heavy rainfall flooded freeway underpasses with up to two feet of water, while golf ball sized hail was reported in Kawkawlin, Bay City, Zilwaukee, Goodrich, and Southfield.

May 9, 2000 – Southeast Michigan

During the afternoon and evening hours of May 9, 2000, an outbreak of severe thunderstorms (with winds gusting to 70 miles per hour) struck southeast Michigan, causing considerable damage across the region. The storm front produced a combination of straight-line winds and some reported tornadoes, accompanied by large, damaging hail in many locations. In Lenawee County, strong winds destroyed several barns, flipped over a mobile home and recreational vehicle, caused numerous trees to fall on homes, destroyed grain bins, and destroyed one airport hangar and damaged two others. In Monroe County, dozens of trees were downed and a railroad depot was destroyed. In Washtenaw County, hundreds of trees were downed and a church and a grocery store were damaged. In Wayne County, a hangar at Detroit Metropolitan Airport collapsed, damaging the plane inside. Numerous other localities within Wayne County suffered damage to homes and businesses. All totaled, the storms left more than 200,000 electrical customers without power, injured at least six persons, and caused several million dollars in property damage.

October 24, 2001 – Southern Lower Michigan

On October 24, 2001, much of Michigan began experiencing severe weather as the result of a strong cold front colliding with warm, moist air. The result was widespread strong winds (in excess of 50 miles per hour) and severe weather throughout the state, but particularly so in southern Lower Michigan where severe thunderstorm warnings were issued for 13 counties, and tornado warnings were issued for seven counties. Although numerous funnel clouds were sighted across the region, only two actually touched down – one affecting Livingston and Oakland Counties along a 15-mile path, and the other affecting Saginaw County. The vast majority of the damage produced by this storm system was from straight-line winds, the strongest of which were reported in Lansing and estimated at 120 miles per hour.

Region-wide, the storms killed two persons and injured at least 20 others, caused extensive flooding of roads and streets, downed thousands of trees and power lines (leaving 195,000 electrical customers without power), closed schools and businesses, and damaged hundreds of cars, homes and businesses, and public buildings. The areas most heavily impacted by this storm system included the counties of Berrien, Cass, and Kalamazoo, and the cities of Lansing and East Lansing. A Governor's Disaster Declaration was issued for Kalamazoo County to provide supplemental state assistance for debris removal and cleanup.

July 31-August 2, 2002 – Central Michigan and Upper Peninsula

During the last day in July, severe weather hit central Michigan and the Upper Peninsula. The National Weather Service issued tornado warnings for seven counties in central Michigan. Funnel clouds were reported along a 120-mile stretch extending from Howard City to Onaway. Golf ball-size hail fell in Escanaba and thunderstorms soaked Houghton with 1.25" of rain in a two-hour period. About 14,000 Upper Peninsula Power Company customers lost electricity for several days due to 70 mile per hour winds that toppled trees and power lines in the western Upper Peninsula. Some Houghton customers were blacked out when high winds tore the metal roof off a Frito-Lay warehouse and it sliced through nearby power lines. From Tuesday night through midday Thursday, the National Weather Service issued 44 severe weather warnings for various parts of the Upper Peninsula.

May 11, 2003 – Southeast Michigan

A strong cold front moved through the Great Lakes region during the morning of the May 11, 2003. Wind gusts of 55 to 60 mph were estimated across much of Wayne and Washtenaw counties. The rest of Southeastern Michigan generally had estimated wind gusts of 45 to 50 mph. The winds caused several trees to blow down across the area and several thousand homes and businesses across the area to lose power. The strong winds were also blamed for a hydrochloric acid leak from a plant in Ypsilanti. Investigators concluded that the high winds ripped a chunk of the plant's roof loose, smashing it into a distribution pipe, which caused roughly 100 gallons of acid to leak out.

July 4-6, 2003 – Southern Lower Michigan

A line of thunderstorms that developed over Wisconsin made its way across Lake Michigan over the Independence Day weekend, bringing wind gusts of more than 60 miles per hour, knocking down trees and leaving more than 200,000 customers without electricity. Power went out during one of the warmest weeks of the summer, causing many citizens to lose large amounts of perishable foods. In Brighton Township, residents of a subdivision were without running water for several days because they relied on electricity to operate wells. A small stretch of beaches in southwest Michigan turned deadly over the weekend, as 10 swimmers drowned from the storm-powered undercurrents. On July 4, more swimmers drowned in one day than drown all summer, on average, in southwest Michigan. Nine fatal car accidents also occurred over the holiday weekend due to the severe weather.

August 1, 2003 – Southern Lower Michigan

Severe thunderstorms and winds up to 77 miles per hour swept through southern Lower Michigan on August 1, 2003, killing two persons. One man was killed while he was walking when high winds snapped off a tree limb, hitting him on the head. A woman was pronounced dead at a local hospital after being struck by lightning. A young boy survived a lightning strike the same day. The high winds caused about 127,000 electrical customers to lose power - most of whom had it restored within a couple of days.

November 11, 2003 – Southeast Lower Michigan

Wind gusts up to 74 miles per hour knocked down trees and power lines, causing a loss of power for more than 370,000 electrical customers in southeast Michigan. The harsh weather conditions forced many school districts to cancel classes. A live power line fell across eastbound Interstate 94 near Monroe, forcing the closure of the highway and causing a major traffic jam near Detroit Metropolitan Airport. Detroit's Department of Public Works received 73 telephone calls reporting trees down and other damage.

November 6, 2005 – Southeast Michigan

On November 6, 2005 a deep and rapidly intensifying storm system moved through Southeast Lower Michigan during the morning. High winds along the associated cold front knocked down trees, leading to approximately 200,000 power outages. Winds were sustained out of the southwest at 30 to 40 mph, with gusts as high as 60 mph from mid to late morning. Street signs were toppled, traffic lights were sent spinning, and power lines were split. Many streets and roads had to be temporarily closed until trees blocking the way could be cleared. Property damage was estimated at $4.2 million.

May 15, 2007 – Southern Lower Michigan

Severe thunderstorm winds affected many counties and measured as high as 83 knots (at the Three Rivers Airport in St. Joseph County). Significant damages were caused at locations as diverse as Centreville, Schoolcraft, North Aurelius, and Howell. One mile north of Essexville (Bay County), a power plant's coal stacker was reported as having been destroyed when it was toppled over by strong winds, with damages estimated at $1.5 million.

June 6, 2008 – Southern Lower Michigan

Numerous thunderstorms produced damaging winds of up to 65 knots. The strongest winds were reported at Howell and Saginaw. The greatest damages occurred in the Saginaw area, where 12,000 residents lost electricity. Two miles north of Carrollton, dozens of trees were blown down, some knocking down power lines, some falling onto houses, some blocking roads, and one falling onto a car and injuring its two occupants. An entire roof was blown off a commercial building near the intersection of Stevens and Hamilton.

June 8, 2008 – Southern Lower Michigan

A derecho swept across many counties in the southern Lower Peninsula, involving winds as high as 74 knots (at Marine City). There were also tornadoes associated with this system. Along with an estimated $100 million in total damages, several casualties were caused by the storm systems, and more than 10,000 persons were without power for a week or more. This was the worst such wind event of the decade. Thousands of trees were lost, and great property damage was caused as they toppled onto houses and cars. One mile west of Spring Lake, a car was struck by a tree while it was being driven, killing the driver and injuring the passenger. A pedestrian was also killed by a falling tree, a mile southeast of Harrisburg. Numerous power lines were down, and boats were overturned in the water.

August 9, 2009 – Ottawa and Kent Counties

On August 9, 2009 severe thunderstorms developed across Ottawa and Kent Counties, resulting in hundreds of trees being blown down and numerous utility poles and wires taken down by 60 to 80 mph winds. Fruitport took the brunt of the storm, with wind gusts of 70 to 80 mph lasting for about 10 minutes. Numerous homes were heavily damaged by falling trees. Significant damage to apple orchards occurred west of Sparta. The storm complex also produced an EF-0 tornado path 35 miles long, and up to 9 miles wide.

July 18, 2010 – Kent County

On July 18, 2010 a NWS storm survey team concluded that a series of wet micro bursts across southwestern Kent County had produced wind gusts ranging from 60 up to 80 mph, brought down several trees and power lines in the Wyoming and Cutlerville areas, and flipped over and destroyed 8 wood and metal sheds at a store near Cutlerville. A tornado damaged a home and broke or uprooted several trees just northeast of Wayland. A roof was lifted off of a garage in Wyoming, a shed was destroyed, and some structural damage occurred to one home, due to wind gusts estimated to be as much as 80 mph.

Programs and Initiatives

Note: Many of the programs and initiatives designed to mitigate, prepare for, respond to, and recover from tornado effects have the dual purpose of also protecting against severe straight-line winds. As a result, there is some overlap in the narrative programs and initiatives descriptions for each respective hazard. This redundancy allows each hazard section to stand alone, eliminating the need to refer to other hazard sections for basic information.

National Weather Service Doppler Radar

The National Weather Service (NWS) has completed a major modernization program designed to improve the quality and reliability of weather forecasting. The keystone of this improvement is Doppler Weather Surveillance Radar, which can more easily detect severe weather events that threaten life and property – including severe winds. Most important, the lead time and specificity of warnings for severe weather have improved significantly.

Doppler technology calculates both the speed and the direction of motion of severe storms. By providing data on the wind patterns within developing storms, the new system allows forecasters to better identify the conditions leading to severe weather such as tornadoes and severe straight-line winds. This allows early detection of the precursors to severe storms, as well as information on the direction and speed of storms once they form.

National Weather Service Watches/Warnings

The National Weather Service issues severe thunderstorm watches for areas where the meteorological conditions are conducive to the development of severe thunderstorms. People in the watch area are instructed to stay tuned to National Oceanic and Atmospheric Administration (NOAA) weather radio and local radio or television stations for weather updates, and watch for developing storms. Once radar or a trained Skywarn spotter detects the existence of a severe thunderstorm, the National Weather Service will issue a severe thunderstorm warning. The warning will identify where the storm is located, the direction in which it is moving, and the time frame during which the storm is expected to be in the area. Persons in the warning area are instructed to seek shelter immediately.

The State and local government agencies are warned via the Law Enforcement Information Network (LEIN), NOAA weather radio, and the Emergency Managers Weather Information Network (EMWIN). Public warning is provided through the Emergency Alert System (EAS). The National Weather Service stations in Michigan transmit information directly to radio and television stations, which in turn pass the warning on to the public. The National Weather Service also provides detailed warning information on the Internet at www.weather.gov, where an interactive map can be used.

Public Warning Systems

Numerous communities in Michigan have outdoor warning siren systems in place to warn the public about impending tornadoes and other hazards. Most of these systems were originally purchased to warn residents of a nuclear attack, but that purpose was expanded to include severe weather hazards as well. These systems can be very effective at saving lives in densely populated areas where the siren warning tone is most audible. In more sparsely populated areas

where warning sirens are not as effective, communities are turning to NOAA weather alert warning systems to supplement or supplant outdoor warning siren systems. Unfortunately, a large number of communities across the state do not have adequate public warning systems in place to warn their residents of severe weather or other hazards. Federal funding specifically allocated to assist communities in the purchase of public warning systems has effectively disappeared, leaving many communities unable to purchase adequate systems to warn their residents of impending danger.

Attempting to fill some of that funding void, the State of Michigan has used federal Hazard Mitigation Grant Program (HMGP) funds to assist local communities in purchasing public warning systems. To date, HMGP funds have been used to purchase and install more than 80 outdoor warning sirens, over 1,000 NOAA weather alert monitors for schools, hospitals and places of public assembly, four NOAA weather radio transmitters, and several other early warning systems. Communities that received funding for these projects were encouraged to implement a warning education program to ensure that residents know what to do once they receive warning of an impending hazardous event. Because HMGP funds must be used to fund a wide variety of mitigation projects, the amount of funds available to fund warning systems is limited to a small percentage of the overall available grant funds allocated to the state. The HMGP funds are provided on a 75% federal, 25% local cost share. A Presidential major disaster declaration is required to activate the HMGP funding. As a result, the funding stream may not always be available in the future. In addition, state mitigation priorities may change over time, putting public warning systems at a lower priority than other mitigation projects. However, the HMGP does provide at least one possible avenue for assisting communities in enhancing their local public warning capability.

Severe Weather Awareness Week

Each spring, the Emergency Management and Homeland Security Division, Department of State Police, in conjunction with the Michigan Committee for Severe Weather Awareness, sponsors Severe Weather Awareness Week. This annual public information and education campaign focuses on severe weather events such as tornadoes, thunderstorms, lightning, hail, flooding and high winds. Informational materials on severe winds and other weather hazards are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public.

Manufactured Home Anchoring

Manufactured homes are vulnerable to wind damage if they are not properly anchored down. As a result, a major national effort has been initiated to encourage the structural anchoring or “tie down” of manufactured homes. The Michigan Manufactured Housing Commission Administrative Rules (R 125.1602, Subsection 5) require new manufactured home installations in floodplains to be structurally anchored to a foundation. Through this requirement, the possibility of damage from wind is minimized. Unfortunately, structures outside designated floodplains do not have to comply with the anchoring provision, although many owners choose to comply voluntarily. It should also be noted that local communities have the option of adopting an ordinance that requires anchoring of manufactured home installations located outside a designated floodplain. State anchoring system standards are outlined in Administrative Rules R 125.1605 through R 125.1608.

Electrical Infrastructure Reliability

One of the major problems associated with severe winds is the loss of electric power. As mentioned previously, Michigan has had numerous widespread and severe electrical power outages caused by severe winds, and several of those outages have resulted in upwards of 500,000 electrical customers (more than 5% of the State’s population) being without power for several hours to several days at a time. Wind-related damage to electric power facilities and systems is a concern that is being actively addressed by utility companies across the state. Detroit Edison, Consumers Energy and other major electric utility companies have active, ongoing programs to improve system reliability and protect facilities from damage by severe winds and other hazards. Typically, these programs focus on trimming trees to prevent the encroachment of overhead lines, strengthening vulnerable system components, protecting equipment from lightning strikes, and placing new distribution lines underground. The Michigan Public Service Commission (MPSC) monitors power system reliability to help minimize the scope and duration of power outages.

Structural Bracing / Wind Engineering

One of the best ways to protect buildings from severe wind damage is to install structural bracing and metal connectors (commonly called hurricane clips) at critical connecting points in the frame of the structure. Typically, this involves

adding extra gable end bracing at each end of the structure, anchoring the roof rafters to the walls with metal connector straps, and properly anchoring the walls and sill plate to the foundation. This extra bracing helps ensure that the roof stays on the structure, and the structure stays anchored on its foundation. Experience in high wind events has shown that once the roof begins to peel away from the walls, or the building begins to move off its foundation due to extreme lateral wind forces, major structural damage occurs. If the damage continues unabated, the building can end up being a total loss.

Urban Forestry/Tree Maintenance Programs

Urban forestry programs can be very effective in minimizing storm damage caused by falling trees or tree branches. In almost every severe wind event, falling trees and branches cause power outages and clog public roadways with debris. However, a properly designed, managed and implemented urban forestry program can help keep tree-related damage and impact to a minimum. To be most effective, an urban forestry program should address tree maintenance in a comprehensive manner, from proper tree selection, to proper placement, to proper tree trimming and long-term care.

Every power company in Michigan has a tree trimming program, and numerous local communities have some type of tree maintenance program. The electrical utility tree trimming programs are aimed at preventing encroachment of trees and tree limbs within power line rights-of-way. Typically, professional tree management companies and utility work crews perform the trimming operations. At the local government level, only a handful of Michigan communities have actual urban forestry departments or agencies. Rather, crews from the public works agency or county road commission perform the bulk of the tree trimming work.

When proper pruning methods are employed, and when the work is done on a regular basis with the aim of reducing potential storm-related damage, these programs can be quite effective. Often, however, tree trimming work is deferred when budgets get tight or other work is deemed a higher priority. When that occurs, the problem usually manifests itself in greater storm-related tree debris management problems down the line.

Tornadoes

An intense rotating column of wind that extends from the base of a severe thunderstorm to the ground.

Hazard Description

Tornadoes in Michigan are most frequent in the spring and early summer when warm, moist air from the Gulf of Mexico collides with cold air from the polar regions to generate severe thunderstorms. These thunderstorms often produce the violently rotating columns of wind known as funnel clouds. Michigan lies at the northeastern edge of the nation's primary tornado belt, which extends from Texas and Oklahoma through Missouri, Illinois, Indiana, and Ohio. Most of a tornado's destructive force is exerted by the powerful winds that knock down walls and lift roofs from buildings in the storm's path. The violently rotating winds then carry debris aloft that can be blown through the air as dangerous missiles.

A tornado may have winds up to 300+ miles per hour and an interior air pressure that is 10-20% below that of the surrounding atmosphere. The typical length of a tornado path is approximately 16 miles, but tracks much longer than that – even up to 200 miles – have been reported. Tornado path widths are generally less than one-quarter mile wide. Typically, tornadoes last only a few minutes on the ground, but those few minutes can result in tremendous damage and devastation. Historically, tornadoes have resulted in tremendous loss of life, with the mean national annual death toll being 87 persons. Property damage from tornadoes is in the hundreds of millions of dollars every year.

Hazard Analysis

Tornado intensity is measured on the Enhanced Fujita Scale, which examines the damage caused by a tornado on homes, commercial buildings, and other man-made structures. The Enhanced Fujita Scale rates the intensity of a tornado based on damaged caused, not by its size. It is important to remember that the size of a tornado is not necessarily an indication of its intensity. Large tornadoes can be weak, and small tornadoes can be extremely strong, and vice versa. It is very difficult to judge the intensity and power of a tornado while it is occurring. Generally, that can only be done after the tornado has passed, using the Enhanced Fujita Scale as the measuring stick. The Enhanced Fujita Scale is presented in the table below.

The Enhanced Fujita Scale of Tornado Intensity

EF-Scale Number	Intensity Descriptor	Wind Speed (mph)	Type/Intensity of Damage
EF0	Gale tornado	65-85	Light damage. Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.
EF1	Weak tornado	86-110	Moderate damage. The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
EF2	Strong tornado	111-135	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
EF3	Severe tornado	136-165	Severe damage. Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off ground and thrown.
EF4	Devastating tornado	166-200	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
EF5	Incredible tornado	Over 200	Incredible damage. Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile-sized missiles fly through the air in excess of 100 meters; trees debarked; steel reinforced concrete structures badly damaged; incredible phenomena will occur.

NOTE: When describing tornadoes, meteorologists often classify the storms as follows:
EF0 and EF1 = weak tornado; EF2 and EF3 = strong tornado; EF4 and EF5 = violent tornado

(Source: The Tornado Project; Storm Data, National Climatic Data Center)

According to the National Weather Service (NWS), since 1950 the vast majority of tornadoes that occurred in the United States (approximately 74%) were classified as weak tornadoes (EF0 or EF1 intensity). Approximately 24% were classified as strong tornadoes (EF2 or EF3 intensity), and only 3% were classified as violent tornadoes (EF4 or EF5 intensity). Unfortunately, those violent tornadoes, while few in number, caused about 65% of all tornado-related deaths nationally. Strong tornadoes accounted for another 33% of tornado-related deaths, while weak tornadoes caused only 1% of tornado-related deaths. If the data prior to 1950 is examined, the percentage of deaths attributable to violent tornadoes climbs drastically. That is largely due to the fact that tornado forecasting and awareness programs were not yet established. As a result, it was much more likely for death tolls from a single tornado to reach several hundred.

The map and table at the end of this section show the breakdown of tornadoes by county for the period from 1950-2009. A close examination of the map indicates that tornadoes occur more frequently in the southern-half of the Lower Peninsula than any other area of the state. This area could be referred to as Michigan's "tornado alley." Most tornadoes in Michigan come from the southwest and travel northeast, with many passing through the most densely populated areas of the state.

Records indicate that tornadoes in Michigan have been more deadly than in many other tornado-prone states. Part of that is influenced by the high death toll associated with the June 8, 1953 and April 11, 1965 tornadoes. However, part is also due to the fact that several tornadoes have hit relatively densely populated areas of Michigan, increasing the fatalities. As for when those deaths occurred, the table below provides a good indicator, based upon about 55 years of events, and reveals that 96% of the state's tornado-related deaths have occurred in the months of April, May and June. June has been Michigan's most deadly tornado month, with 54% of all deaths. If the June 8, 1953 tornado death toll of 115 people is excluded, April becomes the most deadly tornado month with 77 deaths (32% of the total).

Tornado-Related Deaths in Michigan, by Month: 1950-May 2005

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
0	**0**	**3**	**77**	**23**	**130**	**3**	**1**	**1**	**0**	**1**	**0**	**239**

Source: National Climatic Data Center

Although tornadoes cannot be predicted, prevented or contained, their potential impacts on Michigan's citizens and communities can certainly be reduced. In general, improved surveillance and warning systems implemented by the National Weather Service and emergency management agencies, coupled with extensive public education campaigns, have been very effective in keeping the death toll down in recent years. However, this is not to say that a major death toll could not occur again if a strong tornado should strike a highly populated area. History has clearly shown that tornadoes must always be treated with the utmost respect and caution. Other initiatives, such as structural bracing, urban forestry practices, manufactured home anchoring, and strengthening electrical system components, can help to reduce public and private property damage.

Like severe straight-line wind events, tornado disasters require that communities plan and prepare for the mass care of residents left without electrical power and the clearance and disposal of tree and construction debris from roadways. Those are the two primary challenges facing Michigan communities. The planning and preparedness effort should include the identification of necessary mass care facilities and supplies, as well as debris removal equipment and services. In addition, communities should develop debris management procedures (to include the identification of multiple debris storage, processing and disposal sites) so that the debris stream can be handled in the most expedient, efficient, and environmentally safe manner possible.

National Weather Service data indicates that Michigan has experienced 923 tornadoes and 242 related deaths during the period from 1950 to 2009, an average of 15 tornadoes and 4 tornado-related deaths per year. The greatest number of tornadoes per year during that period occurred in 1974, with 39 tornadoes (8 of which occurred on April 3). The least number occurred in 1959, with only 2 tornadoes. From 1950 to March 2005,

Michigan experienced 508 "tornado days" (defined as days in which tornadoes are observed), an average of 9 days per year.

The map and table at the end of this section list the number of tornadoes experienced in each Michigan county for the period 1950-2009. (Note: these totals do not correct for boundary-crossing tornadoes; therefore, a tornado that crosses a county boundary will be "double counted" in the totals for each county.)

All counties south of Kent and Genesee Counties have had at least 14 tornadoes touch down in their boundaries from 1950-2009 (with the exception of St. Joseph County, having only 9 tornadoes). Genesee (41), Lenawee, Kent and Oakland Counties (31 each) have had the highest total of tornadoes in the state. When adjusting for the size of the county, the highest-risk counties on a per-land area basis become Genesee (10.5 tornadoes per 10,000 square miles), Monroe (8.4), and Ingham and Berrien (8.0 each). North of Flint and Grand Rapids, only Saginaw County has had a relatively high occurrence of tornadoes, with 21. The extreme northern portion of the Lower Peninsula and the Upper Peninsula overall have a lower risk of tornadoes, with almost all counties having 11 or fewer tornadoes (although Alpena and Ogemaw had 14) over the 60-year time span. Nevertheless, the tornado impact can be disastrous for any Michigan county.

In terms of intensity, Michigan's tornado experience since 1950 has essentially mirrored the national experience. Approximately 67% of all Michigan tornadoes have been weak tornadoes (EF0 or EF1 intensity), while 29% have been strong tornadoes (EF2 or EF3 intensity) and 4% have been classified as violent tornadoes (EF4 or EF5 intensity). However, those few violent tornadoes have been responsible for 88% of Michigan's tornado-related deaths. Strong tornadoes (EF2 or EF3 intensity) have accounted for approximately 11% of the deaths, while weak tornadoes (EF0 or EF1 intensity) have caused only 1% of all tornado-related deaths. Those patterns are fairly consistent with the national averages, although Michigan has had more strong and violent tornadoes (approximately 33% in Michigan vs. 27% nationally), and its death toll from violent tornadoes is slightly higher than the national average (67% in Michigan vs. 65% nationally). Michigan's higher than average death toll from violent tornadoes is largely due to the tragic storm events that occurred in Flint in 1953 and across southern Michigan in 1965 (see the Significant Tornadoes section for more details). Unfortunately, Michigan's tornado experience to date has been more deadly than in many other tornado-prone states across the country. Michigan's tornado events have earned it a top ten ranking in three national tornado statistical categories: (1) single killer tornadoes, (2) deaths per 10,000 square miles, and (3) killer tornadoes as a percent of all tornadoes.

Killer Tornadoes: Selected Top Ten Lists

Rank	Single Killer Tornadoes (Date, State, # Deaths, F-Scale)	Tornado Deaths Per 10,000 Sq. Miles	Killer Tornadoes as % of all Tornadoes
1	March 18, 1925, MO-IL-IN, 695 deaths, F5	Massachusetts	Tennessee
2	May 7, 1840, LA-MS, 317 deaths, F?	Mississippi	Kentucky
3	May 27, 1896, MO-IL, 255 deaths, F4	Indiana	Arkansas
4	April 5, 1936, MS, 216 deaths, F5	Alabama	Ohio
5	April 6, 1936, GA, 203 deaths, F4	Ohio	Alabama
6	April 9, 1947, TX-OK-KS, 181 deaths, F5	**Michigan**	Mississippi
7	May 22, 2011, MO, 161 deaths, F5	Arkansas	North Carolina
8	April 24, 1908, LA-MS, 143 deaths, F4	Illinois	**Michigan**
9	June 12, 1899, WI, 117 deaths, F5	Oklahoma	New York
10	**June 8, 1953, MI, 115 deaths, F5**	Kentucky	Massachusetts

Source: The Tornado Project / National Weather Service

Michigan's tornado death toll is significantly influenced by two disasters: one in Flint on June 8, 1953 that caused 115 deaths and $19 million in damage, and a series of tornadoes in southern Michigan on April 11, 1965 (Palm Sunday) that caused 53 deaths and $51 million in damage. (See the tables below and on the following pages for more information on these and other significant tornadoes in Michigan.) Fortunately, the trend over time has generally been toward a lesser number of tornado deaths. During the 1950s, 153 deaths occurred, when the total number of tornadoes recorded was 109. In the 1960s, the number of deaths dropped to 66 although the number of tornadoes went up a bit, to 123. In the 1970s, despite a whopping 251 tornadoes, only 8 deaths resulted, and the trend has stayed quite low ever since. The 1980s saw 10 tornado deaths and 212 tornado events, but the 1990s

saw only 2 deaths among 173 events. During the 2000s, a total of 3 deaths occurred, and the total number of events numbered 160.

According to the National Climatic Data Center, tornadoes in 2001 alone caused $28 million in property damage and $490,000 in crop damages in the state, while tornadoes in 1999 and 2000 only produced $2.4 million in property damage around the state.

Michigan has averaged about 17 tornadoes per year. At the end of this section are maps that provide information about each county's risks. An average of about 4 tornado deaths and 60 injuries takes place each year, in Michigan. Property damage averages more than $15 million per year. (NOTE: As with other weather events, these figures are conservative, actual totals are likely to be higher.) Higher-risk regions of Michigan are illustrated in the maps at the end of this section. Vulnerabilities tend to vary by the engineering of each particular type of structure.

Impact on the Public

Tornadoes are rightfully dreaded as the most severe windstorms to which most of Michigan is vulnerable. Ordinary public activities must be curtailed in order to avoid extreme danger of injury and death either from the force of the winds themselves (which have the capacity to lift persons, heavy objects, or even structures and throw them great distances), or from the impact of objects that are being thrown forcefully around by the storm. Sheltering needs are compounded by the danger of broken and flying glass—to best ensure residents' safety, it is necessary to find the most secure area possible within a structure or affected area. An underground or specially reinforced, window-free room is usually required to guarantee personal safety (sometimes at considerable economic expense). The effects of a strong tornado may disrupt normal community functions for some time, or even cause a small community to be practically destroyed. Tornadoes cause more annual injuries, on average, than any other Michigan hazard except for structural fires.

Impact on Public Confidence in State Governance

When infrastructure failures occur, as from the impact of tornadic winds, a question may be raised about the adequacy of that infrastructure, its maintenance, and its design and regulation. For example, an assumption might be made by some that the burying of power lines should be undertaken (or required by legislation), even if it involves considerable expense, whereas a full consideration of the tradeoffs involved in such burial (e.g. greater difficulty in locating and repairing a broken line) may not have been considered. In events that require mass sheltering, such as schools or large gatherings (e.g. a county fair or community-sponsored event), the ability of local and state government to adequately plan for severe weather is often vital to the success of such events, which themselves are often important for various sectors of the local and state economy. Citizen discontent and media-exacerbated controversies have arisen from situations in which inadequate planning was evident, or provisions for public sheltering were inadequate.

Impact on Responders

Responders tend to be working outdoors in conditions from which most residents are taking shelter. Although special training and safety precautions have usually been taken (e.g. for line-repair workers), nevertheless, responders are more exposed to and at-risk from the impact of winds. Fortunately, tornado events tend to be rather brief, but their unpredictability, and their difficulty of detection and avoidance, exacerbates the existing challenges involved in emergency response. Impeded traffic, power failures, debris, and road closures often make responses and the use of equipment much more difficult.

Impact on the Environment

Tornadoes are dangerous violent rotating columns of winds that can produce wind speeds from 73 to more than 300 miles per hour, and can cause severe environmental damage. Damage to the environment includes debris, fires, and chemicals from damaged and destroyed structures, vehicles, and infrastructure, which can be scattered for miles. Building materials, chemicals, smoke, sewage, and machinery can land in and cause harm to forests, valleys, streams, lakes, rivers, and wildlife species. Animals (including domesticated livestock) and other

organisms can be killed or injured in the event of a tornado. Trees can easily be uprooted, branches broken off, and entire woodlands can be destroyed by tornado impacts. Rural settings can be damaged and plants can be carried to different parts of land for seeding where they otherwise would not have been. There is also an increased threat of fire in areas where dead trees are not removed in a timely matter.

The most dangerous type of environmental impact would be when a tornado strikes a facility that contains potentially hazardous or toxic materials, farm chemicals, trash in a local landfill, medical waste awaiting disposal, or radioactive materials. Not only can material be spread around the immediate site where the tornado strikes, a small (but important) fraction can be carried aloft and transported a great distance down streams or rivers. There is also a possibility that tornadoes can cause the spread of diseases, or fungi found in certain soils. Gas lines can also be ruptured and harm local air quality as well as cause environmental damage by seeping into the soil, rivers, lakes, and streams.

Significant Tornadoes in Michigan

May 25, 1896 – Oakland and Lapeer Counties

One of the mere handful of F5 intensity tornado events to be recorded in Michigan's state history, this event resulted in 47 deaths and 100 injuries, as the communities of Ortonville, Oakwood, and North Oxford suffered from the touchdown of this monstrous storm.

June 5, 1905 – Sanilac and Tuscola Counties

This was the second of Michigan's few recorded tornadoes that were measured as a full F5 intensity level. Five persons were killed and 40 were injured.

June 6, 1917 – Kalamazoo County

A deadly tornado struck the Climax and Cass Lake areas very hard, resulting in 4 deaths and 50 injuries.

March 28, 1920 – Genesee County

Another deadly tornado event, this time impacting Fenton and Flint most heavily, caused 14 deaths.

May 21, 1953 – St. Clair County

Two persons were killed, and 68 injured, as an F4 tornado left a path 10 miles long and 1 mile wide. The total damage was estimated at $2.5 million.

June 8, 1953 – Flint (Genesee County)

The June 8, 1953 Flint tornado, Michigan's worst storm to date (and classified as F5), is ranked 10th on the top ten list of single killer tornadoes that have occurred in the United States. It was also the last single tornado, until the May 2011 Joplin, MO EF5 tornado, to cause over 100 deaths in the U.S. The storm began its destructive path approximately two miles north of Flushing, moved east-northeast and devastated the north part of Flint before ending two miles north of Lapeer. The tornado obliterated homes on both sides of Coldwater Road for about one mile. It was there that most of the deaths occurred and the damage swath was over one-half mile wide. There were multiple deaths in at least 20 families. The final death toll stood at 115 in Flint alone, along with 785 injuries and total damage estimated at $19 million. Several tornadoes touched down in other locations in Michigan on that day as well, resulting in an additional six deaths and 129 injuries statewide.

April 3, 1956 – Hudsonville/Standale (Ottawa and Kent Counties)

In 1956, a category F5 tornado struck first at Hudsonville, then traveled northeast and plowed through both Ottawa and Kent Counties, killing 14 and injuring 200. (Some sources cite 17 deaths and 300 injuries.) Over 700 homes were destroyed. Numerous other tornadoes classified as F4 took their toll on other counties such as Manistee (2 killed, 24 injured), Grand Traverse, Benzie, and Allegan.

May 12, 1956 – Flint

Three persons were killed and 116 were injured as a result of an F4 tornado. On the same day, an F4 tornado also touched down in Wayne County, injuring 22 persons.

July 4, 1957 – Livingston and Oakland Counties

Six persons were injured in Livingston County, when F4 tornadic activity took place around the dinner hour. Oakland County was also impacted.

May 8, 1964 – Macomb County

Although numerous tornadoes occurred throughout the Lower Peninsula on this date, the worst impact was in Macomb County, where 11 persons were killed, 224 were injured, and an estimated $2.5 million in property damage was caused.

April 11, 1965 - Southern and Central Michigan

The April 11, 1965 Palm Sunday tornado outbreak, which affected many other states in the Midwest, had a particularly devastating impact on Michigan. As the following table indicates, a total of 23 tornadoes touched down in 14 southern and central Michigan counties, resulting in 53 fatalities, 798 injuries, and $51 million in damage to public and private property. Many of the tornadoes were rated F3 and F4 in intensity (strong and violent tornadoes), which undoubtedly contributed to the high death and injury tolls. Across the Midwest, this storm system spawned over 50 tornadoes that collectively killed 256 people and caused an estimated $200 million in property damage. In addition to Michigan, the other states that were affected by the storms included Indiana, Illinois, Ohio and Wisconsin.

April 11, 1965 (Palm Sunday) Tornado Outbreak: Michigan Impacts

County	Number of Tornadoes	Deaths	Injuries	Tornado Intensity
Allegan	1	1	9	F1
Barry	2	0	5	F1 and F3
Branch	2	18	400	F3 and F4
Clinton	1	1	8	F4
Gratiot	4	0	1	all F2
Hillsdale	2	6	94	F3 and F4
Kalamazoo	1	0	17	F3
Kent	1	5	142	F4
Lenawee	2	9	83	F3 and F4
Monroe	3	13	39	F3 and F4
Montcalm	1	0	0	F2
Ottawa	1	0	0	F4
Shiawassee	1	0	0	F4
Tuscola	1	0	0	F2
STATEWIDE TOTALS:	**23**	**53**	**798**	**2 F1 tornadoes; 6 F2 tornadoes; 6 F3 tornadoes; 9 F4 tornadoes**

Source: The Tornado Project / National Weather Service

April 21, 1967 – Southwestern and South-Central Lower Peninsula

Numerous twisters caused many injuries and extensive property damage across more than a dozen counties. Fortunately, there were no known fatalities, but NCDC records indicate a total of 51 persons injured and more than $28 million in property damage. A touchdown in Clinton County was of F4 intensity.

July 4, 1969 – Southeastern Michigan

Numerous tornado events marred the 1969 Independence Day holiday in Michigan. Although no fatalities were reported, 65 persons were injured across Jackson, Washtenaw, and Wayne Counties. Damage estimates exceeded $5 million.

April 3, 1974 – Southeastern Michigan

After a number of years without any Michigan fatalities from tornadoes, disaster struck full force in 1974. Two persons were killed and 43 injured when numerous tornadoes touched down in Monroe, Hillsdale, Lenawee, and other counties. Damages totaled nearly $3 million. Although a downward trend in fatalities and injuries had been observed in each decade since the 1950s, Michigan residents were again reminded about the deadly severity of its tornado hazard, and the sheer number of tornadoes was very large at this time. This date is also notable, nationally. National Weather Service data reports a total of 239 tornadoes across the United States on this day—8 of which were in Michigan, 16 in Ohio, and 54 in Indiana! Nationally, 308 persons were killed by tornado impacts on this single day, 5,416 were injured, and property damages amounted to $1.5 billion. This "super outbreak" broke records as being the largest number of tornadoes to strike the United States in a single day.

March 20, 1976 – Southeastern Michigan

Most of the Lower Peninsula's residents were threatened by severe weather on this day, but as the dinner hour arrived in Oakland and Macomb Counties, a pair of tornadoes of F4 and F3 severity caused the weather impacts to turn deadly. Two persons were killed and 58 were injured. Nearly $26 million in property damage was also tabulated.

April 2, 1977 – Kalamazoo and Eaton Counties

Ten were injured in Kalamazoo, and then one person was killed and 44 injured in Eaton County. The tornado intensity was categorized as F4.

May 13, 1980 - Kalamazoo and Van Buren Counties

On May 13, 1980 two tornadoes occurred in southwest Michigan – one in Van Buren County and one in Kalamazoo. The Van Buren County tornado damaged over 500 structures and injured 15 persons. The Kalamazoo tornado damaged over 1,200 homes and caused five fatalities and 79 injuries. This was the greatest number of persons killed by a single tornado in Michigan since the April 11, 1965 occurrence. Damage in the two counties was so severe that a Presidential Major Disaster Declaration was granted to provide supplemental federal disaster assistance to those communities and individuals significantly affected by the storms.

July 4, 1986 – Menominee County

Another disastrous tornado event injured 12 and caused an estimated $2.5 million in property damage during the early evening on the Independence Day Holiday.

June 21, 1987 – Novi (Oakland County)

An F2 tornado caused 1 death, 6 injuries, and $250,000 in property damage.

October 4, 1990 - Genesee County

On October 4, 1990 an F2 intensity tornado touched down in Flint, Burton, and Davison Township in Genesee County, leaving a trail of destruction approximately 200 yards wide and four and one-half miles long. Over 30 homes and 20 businesses were severely damaged, and numerous roads and streets were blocked due to fallen trees and debris. One person was injured when his tractor-trailer was overturned by the strong winds while traveling on Interstate 69 in Burton. Total damage was estimated at $2 million. A Governor's Disaster Declaration was granted to provide supplemental state financial assistance to help pay for the cleanup costs associated with the storm.

March 27, 1991 – Entire Lower Peninsula

Severe weather events covered a wide area and produced numerous tornadoes across many Northern Lower Peninsula counties. Ogemaw, Iosco, and Alcona Counties were particularly hard-hit, and suffered a total of more than $5 million in property damage from F3 tornadoes that traveled dozens of miles. The Southern Lower Peninsula was also plagued by tornado impacts, including an F3 touchdown in Calhoun County that injured 18 persons, and an F3 tornado in Hillsdale County that caused $25 million in property damage.

April 16, 1992 - Plymouth (Wayne County)

On April 16, 1992 an F2 intensity tornado touched down in a mobile home park near Plymouth. The tornado destroyed 6 homes and damaged 14 others. Four residents of the mobile home park were injured. Total property damage was estimated at $2.5 million.

July 13, 1992 - Cass County

On July 13, 1992 an F2 intensity tornado touched down in northwest Cass County, leaving a trail of destruction one-half to one mile wide and six miles long. The tornado damaged or destroyed 40 homes, several agribusinesses, and one migrant labor camp. 25 persons were injured, and another 100 were left homeless by the tornado. Damage was estimated at $3.5 million, with nearly $2.7 million of that total being agricultural damage. A Governor's Disaster Declaration was granted to provide supplemental state assistance with security, sheltering and mass care.

July 2, 1997 - South-Central and Southeast Michigan

On July 2, 1997 a series of intense thunderstorms went through south-central and southeast Michigan. These storms spawned a total of 16 tornadoes, 13 of which occurred in the southeastern Michigan counties of Genesee, Lapeer, Livingston, Macomb, Oakland, Saginaw and Wayne. The total for southeast Michigan is the highest number for a single day since records have been kept from 1950. The tornadoes damaged or destroyed over 2,900 homes and nearly 200 businesses, and caused over $25 million in public damage and nearly $30 million in private damage. A total of 16 deaths were attributed to this storm front, but only 2 of those deaths were caused by the tornadoes. Another 120 persons were injured in the storm event (98 from tornadoes). The tornadoes and straight-line winds downed thousands of trees and power lines, which knocked out power to 350,000 electrical customers and caused significant public health and safety threats. Subsequent analysis by the National Weather Service indicated that the Wayne County tornado was F2 in intensity, while in Genesee County there were two F3 tornadoes and two F1 tornadoes. The remaining tornadoes were either F0 or F1 in intensity. A Presidential Major Disaster Declaration was granted for the five counties most severely impacted by the tornadoes and severe thunderstorms.

October 6, 1998 - Big Rapids (Mecosta County)

On October 6, 1998 a series of strong thunderstorms traveled through several counties in central Lower Michigan. The City of Big Rapids, in Mecosta County, was hardest hit by the storms. Officials from the National Weather Service determined that an "F-1 mini tornado," with winds reaching 80-90 miles per hour, had struck the Ferris State University campus, damaging several buildings and numerous surrounding residences and vehicles. The storm also downed trees and power lines in the area, and injured seven persons. The storm track was approximately 150 feet wide and one mile long. The storm dumped nearly 3 inches of rain in the Big Rapids area, flooding many streets and parking areas. In nearby Clare County, the storm destroyed one home, damaged ten others, and injured three persons.

July 3, 1999 - Comins (Oscoda County)

On July 3, 1999 a tornado touched down near Lewiston in Montmorency County and traveled southeast for twenty-one miles through Oscoda and Alcona Counties, causing damage to homes and businesses and injuring two persons. The hardest hit areas included the Village of Comins and Clinton Township in Oscoda County. The destruction was devastating – 80 percent of the Village of Comins was damaged or destroyed by the storm. Nine homes were destroyed, 46 homes sustained damage, and eight businesses were damaged or destroyed. The Clinton Township Hall and Fire Department buildings were also destroyed, and the Post Office sustained damage. Local roads were blocked by debris and downed power lines, leaving residents without power for several days. Only three buildings in town – a bar, a party store, and a senior center – were left standing intact. After striking Comins, the storm continued on its path and damaged another 20 residences at nearby Crooked Lake in Alcona County. A Governor's Disaster Declaration was granted to Oscoda County to provide supplemental state assistance with debris removal, clean up, and traffic control. Damage estimates approached $2 million.

May 21, 2001 - Southern and Central Michigan

On the afternoon of May 21, a line of severe thunderstorms moved across Michigan, spawning 21 tornadoes in 16 counties and causing damage in all but one of those counties. The hardest hit counties were Kalamazoo, Kent, Livingston and Oakland. Fortunately, no deaths or serious injuries occurred as a result of these storms. All totaled, the tornadoes caused about $5.5 million in property damage and $400,000 in agricultural crop damage. The largest share of the property damage – approximately $3 million – was caused by an F2 intensity tornado that struck Hartland and Tyrone Townships in Livingston County. The tornado tore through a golf course, destroying 12 vehicles and damaging 58 others, destroying 35 golf carts and a portion of the clubhouse, and injuring one person. The tornado also destroyed three nearby homes and two businesses, damaged another business, and downed hundreds of trees in the area. Several cars and semi-trailers were flipped and damaged when the tornado crossed U.S. 23.

September 9, 2001 - Delta Township (Eaton County)

In the late afternoon hours of September 9, 2001 an F1 intensity tornado carved an 8-mile long by 900-yard wide swath of destruction through Delta Township in Eaton County. The tornado – packing winds of up to 110 miles per hour – destroyed the cooling towers at a Lansing Board of Water and Light power plant, causing $4 million in damage and forcing the plant to shut down its operations. The tornado also destroyed a business and damaged several others in an industrial park, damaged dozens of homes and barns, and downed numerous trees and power lines. Even though the tornado crossed three Interstate Highways and passed several housing subdivisions along its path, it did not cause any deaths or serious injuries.

September 30, 2002 - Southeast Upper Peninsula

On September 30, 2002 a supercell produced three tornadoes and extensive downburst wind damage in southern Dickinson County. The majority of damage to the Iron Mountain, Kingsford and Quinnesec areas was caused by downburst winds, which knocked trees into homes, downed power lines, etc. The most significant damage was produced by the tornado that moved through Kingsford and Iron Mountain. An F1 intensity tornado developed in Florence County, Wisconsin and crossed the Menominee River just south of the Iron Mountain-Kingsford airport. Numerous trees and power lines were knocked down, blocking highway US-2 and disrupting electric power and telephone service. Gas lines were ruptured and several commercial buildings sustained substantial roof damage in Kingsford. Property damage due to all of the storms was estimated at around $7 million.

July 20, 2003 - Battle Creek (Calhoun County)

An F1 intensity tornado struck Calhoun County during the afternoon of July 20th, 2003. The tornado first touched down on the southeast side of Battle Creek. It lifted for several miles but eventually touched down again. It stayed on the ground for approximately three miles and intensified, causing a garage to be torn from a house and an older farm house to be rotated and pushed off its foundation. Three outbuildings and a barn were also destroyed. Roof shingle damage was also noted to other houses in the area. Hundreds of trees were uprooted or broken off. The tornado path was eight miles long from where it first touched down to where it lifted for the last time. The tornado width was nearly one half mile wide where the most severe damage occurred. The tornado caused nearly $1 million in property damage along with $200,000 in crop damage.

August 21, 2003 - Ingham County

On August 21, 2003 a tornado struck eastern Ingham County. The tornado's path length was 4.5 miles long and it was up to 1/2 mile wide. It was on the ground for 15 minutes and was rated as a lower F2 on the original Fujita scale. A severe thunderstorm warning was issued for Ingham County and that was soon upgraded to a tornado warning. Two homes were destroyed. One house collapsed and trapped two individuals inside, injuring both. At another location, a house was damaged and a barn was leveled, and a pickup truck was blown off the road. Tornado-related property damage was relatively low, but crop damage was estimated at $200,000.

August 24, 2007 – Eaton County

An EF3 tornado with wind speeds estimated at 140 mph produced its most severe damage along a path from M-50 just north of Kinsel Highway to just west of M-100 and Vermontville Highway near Potterville. A NWS storm survey indicated a tornado path which was 200 to 300 yards wide and 6.5 miles long. Fifteen homes were either destroyed or severely damaged. A roof was blown off a single-story home and windward-facing walls were blown in. The majority of the roof and garage from this home were not found. A roof was blown off a two-story home and the upper story front walls were blown in. Additional damage included the partial collapse of the upper story of a home, and another house was blown off its foundation. Two barns were destroyed and another incurred heavy damage just west of Potterville. Six persons were injured, and property damages totaled more than $25 million.

October 18, 2007 – Ingham County and Northern Lower Peninsula

A tornado occurred at night, and based on extensive damage to buildings and trees, it was classified EF2, with top winds estimated between 120 and 130 mph. The tornado began just northeast of Mason around 10:28 pm EDT and moved northeast at 40 to 45 mph through the City of Williamston between 10:40 and 10:45 pm. Approximately 100 structures were damaged in a subdivision on the south side of Williamston. Two fatalities occurred about 4 miles northeast of Williamston, where a modular home and its two occupants were flipped into a pond. The tornado then moved into Shiawassee County and dissipated shortly thereafter. Total property damages were estimated as nearly $20 million.

A historic tornado outbreak also rocked Northern Lower Michigan on the afternoon and evening of October 18, 2007. Northern Lower Michigan had a record six tornadoes on the day. The previous high was five, set on June 17, 1992. Unfortunately, a Kalkaska tornado produced a fatality. That was the first tornado fatality in Northern Lower Michigan since March 30 1976, when a single death had occurred in Ogemaw County.

June 6, 2010 – Monroe and Lenawee Counties

Two tornadoes struck Monroe County, one classified as EF2 and the other as EF1. The stronger tornado was up to 800 yards wide and tracked 13 miles across Monroe County, including movement through the Village of Dundee, which was the hardest-hit location (after which the tornado weakened to EF0 levels in its east-southeastern course). The weaker tornado was up to 500 yards wide and tracked 5 miles from the Woodland Beach area to the northeast, reaching Estral Beach and proceeding out into Lake Erie. The weaker tornado was especially significant for two reasons—it caused some damage at the Fermi nuclear power facility, and it also impacted an area that is a project site for flood mitigation activities (at Estral Beach). The tornado damaged more than 125 homes and 23 vehicles, and set back a significant amount of flood mitigation project work in the area. Estimated damages from the weaker tornado amounted to $10 million. Estimated damages from the stronger tornado were $50 million. A total of 311 buildings were damaged in Monroe County, and 5 houses were destroyed. A weaker F1 tornado also caused $500,000 in damage to property in adjacent Lenawee County.

June 27, 2010 – St. Clair County

Among the tornado damages this day was a disastrous strike at a campground just north of I-69 and west of Wadhams Road in Clyde Township. One person was killed and four were injured. The tornado was classified as EF1, with winds up to 95 mph. About 10 campers were damaged or destroyed, including being blown into the water of a large pond nearby. Total damages at that location were estimated at $700,000. Total tornado damages that day amounted to more than $1.25 million.

May 29, 2011 - Calhoun County

Three tornados produced wind gusts up to 100mph in the southern Lower Peninsula, resulting in several uprooted trees and downed power lines. 163,000 homes and businesses were without power. The Battle Creek area was hit the hardest, with straight line winds between 75 and 100mph, causing wide-spread damage. The event resulted in a Governor's disaster declaration for Calhoun County, no deaths or serious injuries were reported.

Other Recent Significant Tornado Outbreaks of General Interest in the United States

April 2011 – National Outbreak

April 2011 shattered the previous April tornado record of 267 tornadoes set in April 1974 by producing 677 confirmed tornadoes (875 were reported) across the United States. The previous record for any month was 552 tornadoes in May of 2003. In particular, from April 25-28, 2011 there were 362 tornadoes, breaking the previous single tornado outbreak record of 148 tornadoes on April 3-4, 1974. The 361 people killed during the April 2011 outbreak set a new record, with 322 of those deaths occurring during the April 25-28, 2011 time frame alone. There were four EF5 tornadoes during this particular outbreak. The biggest loss of life for a single tornado occurred in Tuscaloosa-Birmingham, Alabama, with at least 65 fatalities. This tornado, rated an EF5, had a maximum width of 1.5 miles and a track 80 miles long. Although the numbers with this single tornado are impressive, the deadliest single tornado on record in the United States still is the Tri-State tornado (Mo., Ill., Ind.) on March 18, 1925, when 695 died.

May 2011 – Joplin, MO

One month after the April 2011 national outbreak occurred, another deadly single tornado occurred in Joplin, Missouri, resulting in 161 fatalities and 990 injuries on May 22, 2011. This Joplin, Missouri tornado is only the second EF5 tornado to occur in Missouri since 1950. The tornado resulted in being the costliest disaster in Missouri history, at over $2.8 billion.

Programs and Initiatives

Note: Many of the programs and initiatives designed to mitigate, prepare for, respond to, and recover from severe straight-line winds have the dual purpose of also protecting against tornadoes. As a result, there is some overlap in the narrative programs and initiatives descriptions for each respective hazard. This redundancy allows each hazard section to stand alone, eliminating the need to refer to other hazard sections for basic information.

National Weather Service Doppler Radar

The National Weather Service has completed a major modernization program designed to improve the quality and reliability of weather forecasting. The keystone of this improvement is Doppler Weather Surveillance Radar, which can more easily detect severe weather events that threaten life and property – including tornadoes and the severe storms that spawn them. Most important, the lead time and specificity of warnings for severe weather have improved significantly.

Doppler technology calculates both the speed and the direction of motion of severe storms. By providing data on the wind patterns within developing storms, the new system allows forecasters to better identify the conditions leading to severe weather such as tornadoes and severe thunderstorms. This means early detection of the precursors to severe storms, as well as information on the direction and speed of storms once they form.

National Weather Service Watches/Warnings

The National Weather Service issues tornado watches for areas when the meteorological conditions are conducive to the development of a tornado. People in the watch area are instructed to stay tuned to NOAA weather radio and local radio or television stations for weather updates, and watch for developing storms. Once a tornado has been sighted and its existence is confirmed and reported, or Doppler Radar shows strong probability of the development or occurrence of a tornado, the National Weather Service will issue a tornado warning. The warning will identify where the tornado was sighted, the direction in which it is moving, and the time frame during which the tornado is expected to be in the area. Persons in the warning area are instructed to seek shelter immediately.

The State and local government agencies are warned via the Law Enforcement Information Network (LEIN), National Oceanic and Atmospheric Administration (NOAA) weather radio, and the Emergency Managers Weather Information Network (EMWIN). Public warning is provided through the Emergency Alert System (EAS). The National Weather Service stations in Michigan transmit information directly to radio and television stations, which in turn pass the warning on to the public. The National Weather Service also provides detailed warning information on the Internet at www.weather.gov, where an interactive map can be used.

Public Warning Systems

Numerous communities in Michigan have outdoor warning siren systems in place to warn the public about impending tornadoes and other hazards. Most of these systems were originally purchased to warn residents of a nuclear attack, but that purpose was expanded to include severe weather hazards as well. These systems can be very effective at saving lives in densely populated areas where the siren warning tone is most audible. In more sparsely populated areas where warning sirens are not as effective, communities are turning to NOAA weather alert warning systems to supplement or supplant outdoor warning siren systems. Unfortunately, a large number of communities across the state do not have adequate public warning systems in place to warn their residents of severe weather or other hazards. Federal funding specifically allocated to assist communities in the purchase of public warning systems has effectively disappeared, leaving many communities unable to purchase adequate systems to warn their residents of impending danger.

Attempting to fill some of that funding void, the State of Michigan has used federal Hazard Mitigation Grant Program (HMGP) funds to assist local communities in purchasing public warning systems. To date, HMGP funds have been used to purchase and install more than 80 outdoor warning sirens, over 1,000 NOAA weather alert monitors for schools, hospitals and places of public assembly, four NOAA weather radio transmitters, and several other early warning systems. Communities that received funding for these projects were encouraged to implement a warning education program to ensure that residents know what to do once they receive warning of an impending hazardous event. Because HMGP funds must be used to fund a wide variety of mitigation projects, the amount of funds available to fund warning systems is limited to a small percentage of the overall available grant funds allocated to the state. The HMGP funds are provided on a 75% federal, 25% local cost share. A Presidential major disaster declaration is required to activate the HMGP funding. As a result, the funding stream may not always be available in the future. In addition, state mitigation priorities may change over time, putting public warning systems at a lower priority than other mitigation projects. However, the HMGP does provide at least one possible avenue for assisting communities in enhancing their local public warning capability.

Severe Weather Awareness Week

Each spring, the Emergency Management and Homeland Security Division, Department of State Police, in conjunction with the Michigan Committee for Severe Weather Awareness, sponsors Severe Weather Awareness Week. This annual public information and education campaign focuses on severe weather events such as tornadoes, thunderstorms, lightning, hail, high winds and flooding. The purpose of the tornado portion of this

campaign is to inform the public about what tornadoes are and when they usually occur, what they should do if a tornado occurs, what community warning systems exist, and to provide other pertinent tornado-related information as appropriate. Informational materials are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public. Special educational programs are often conducted during this week.

Manufactured Home Anchoring

Manufactured homes are vulnerable to tornado damage if they are not properly anchored down. As a result, a major national effort has been initiated to encourage structural anchoring or "tie down" of manufactured homes. The Michigan Manufactured Housing Commission Administrative Rules (R 125.1602, Subsection 5) require new manufactured home installations in floodplains to be structurally anchored to a foundation. Through this requirement, the possibility of damage from wind is minimized. Although this will not protect a manufactured home from a direct hit by a tornado, it certainly will help prevent rollovers in most high-wind situations. Unfortunately, structures outside designated floodplains do not have to comply with the anchoring provision, although many owners choose to comply voluntarily. It should also be noted that local communities have the option of adopting an ordinance that requires anchoring of manufactured home installations located outside a designated floodplain. State anchoring system standards are outlined in Administrative Rules R 125.1605 through R 125.1608.

Electrical Infrastructure Reliability

One of the major problems associated with the severe winds from tornadoes and thunderstorms is the loss of electric power caused by trees falling on power lines. Michigan has had numerous widespread and severe electrical power outages caused by severe wind and other weather events. Several of those outages have resulted in upwards of 500,000 electrical customers (more than 5% of the State's population) being without power for several hours to several days at a time. Wind-related damage to electric power facilities and systems is a concern that is being actively addressed by utility companies across the state. Detroit Edison, Consumers Energy and other major electric utility companies have active, ongoing programs to improve system reliability and protect facilities from damage by tornadoes, severe straight-line winds, and other hazards. Typically, these programs focus on trimming trees to prevent encroachment of overhead lines, strengthening vulnerable system components, protecting equipment from lightning strikes, and placing new distribution lines underground. The Michigan Public Service Commission (MPSC) monitors power system reliability to help minimize the scope and duration of power outages.

Structural Bracing / Wind Engineering

One of the best ways to protect buildings from damage from severe winds associated with thunderstorms, tornadoes, or other high wind events is to install structural bracing and metal connectors (commonly called hurricane clips) at critical points of connection in the frame of the structure. Typically, this involves adding extra gable end bracing at each end of the structure, anchoring the roof rafters to the walls with metal connector straps, and properly anchoring the walls and sill plate to the foundation. This extra bracing helps ensure that the roof stays on the structure, and the structure stays anchored on its foundation. Experience in tornadoes and other high wind events has shown that once the roof begins to peel away from the walls, or the building begins to move off its foundation due to extreme lateral wind forces, major structural damage occurs. If the damage continues unabated, the building can end up being a total loss.

Urban Forestry/Tree Maintenance Programs

Urban forestry programs can be very effective in minimizing storm damage caused by falling trees or tree branches. In almost every tornado or other severe wind event, falling trees and branches cause power outages and clog public roadways with debris. However, a properly designed, managed and implemented urban forestry program can help keep tree-related damage and impact to a minimum. To be most effective, an urban forestry program should address tree maintenance in a comprehensive manner, from proper tree selection, to proper placement, to proper tree trimming and long-term care.

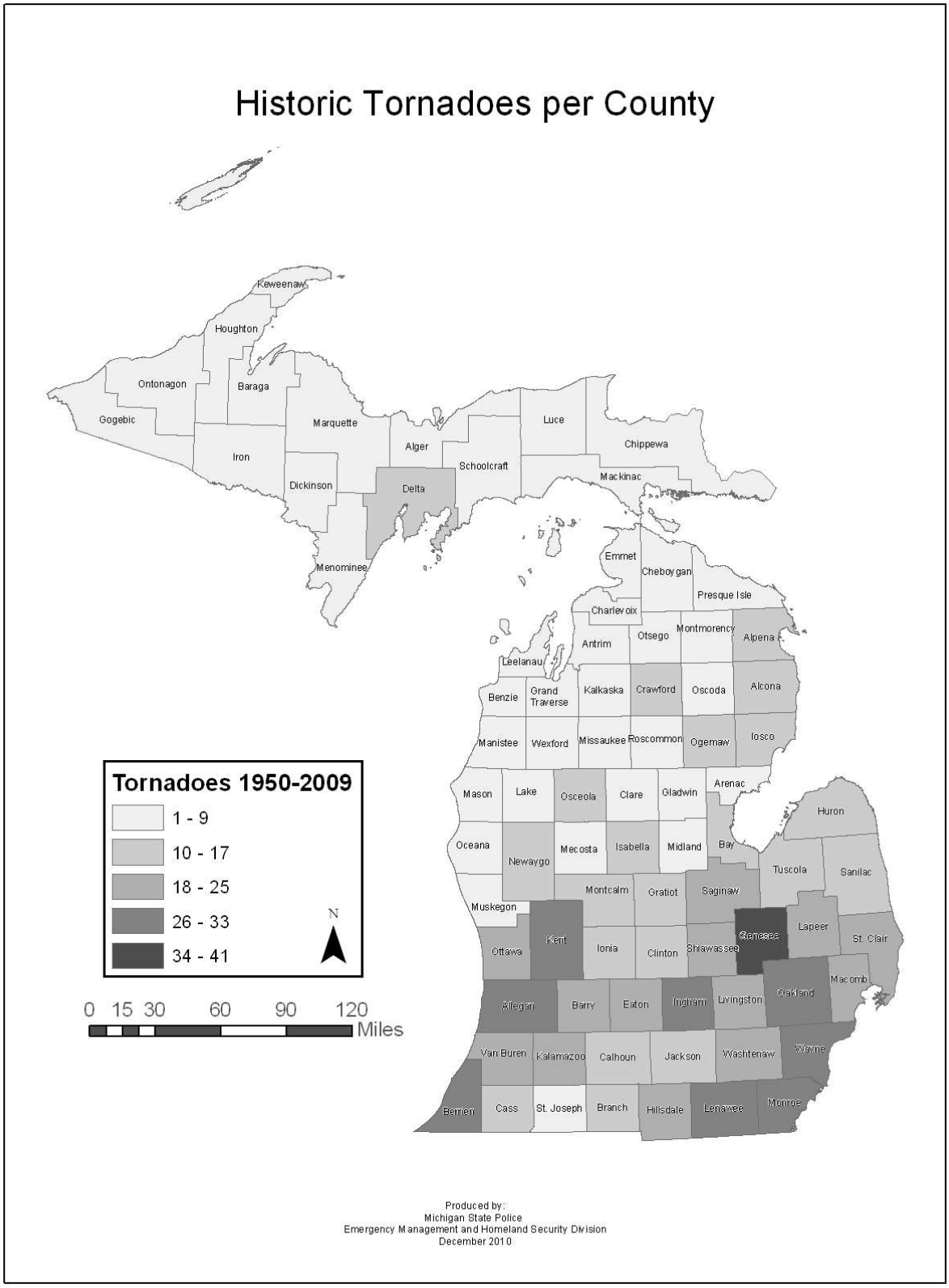
Every power company in Michigan has a tree trimming program, and numerous local communities have some type of tree maintenance program. The electrical utility tree trimming programs are aimed at preventing encroachment of trees and tree limbs within power line rights-of-way. Typically, professional tree management companies and utility work crews perform the trimming operations. At the local government level, only a handful of Michigan communities have actual urban forestry departments or agencies. Rather, crews from the public works agency or county road commission perform the bulk of the tree trimming work.

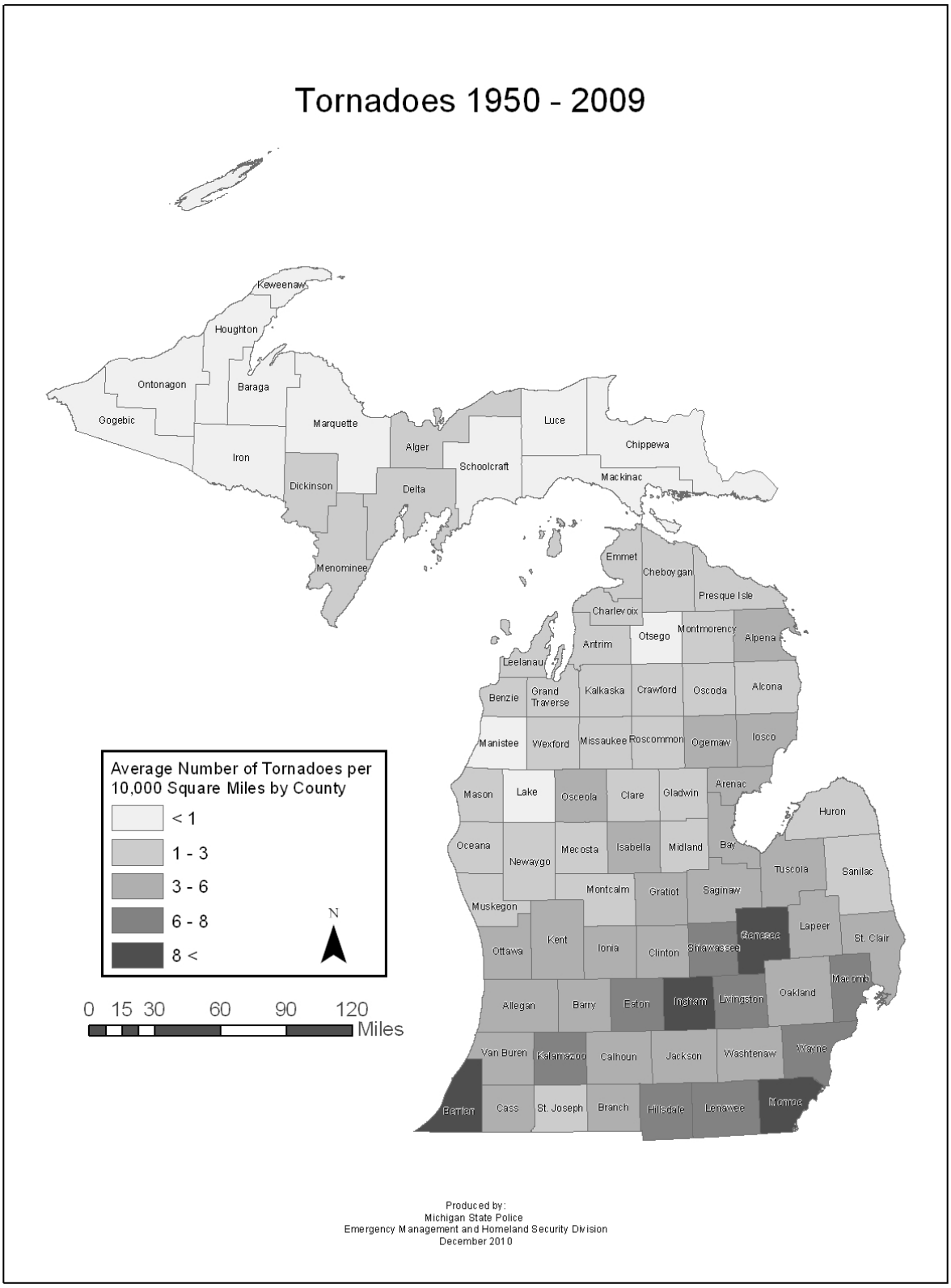
When proper pruning methods are employed, and when the work is done on a regular basis with the aim of reducing potential storm-related damage, these programs can be quite effective. Often, however, tree trimming work is deferred when budgets get tight or other work is deemed a higher priority. When that occurs, the problem usually manifests itself in greater storm-related tree debris management problems down the line. Although nothing will prevent tree damage from a direct tornado strike, a well planned, well managed urban forestry program can certainly reduce the scope and magnitude of the post-tornado tree debris problem.

Number of Tornadoes in Michigan, by County: 1950- 2009

County (A-K)	Tornadoes: 1950-2009	County (L-Z)	Tornadoes: 1950-2009
Alcona	11	**Lake**	2
Alger	6	**Lapeer**	20
Allegan	26	**Leelanau**	3
Alpena	14	**Lenawee**	31
Antrim	9	**Livingston**	24
Arenac	7	**Luce**	2
Baraga	2	**Mackinac**	5
Barry	18	**Macomb**	18
Bay	12	**Manistee**	2
Benzie	4	**Marquette**	6
Berrien	28	**Mason**	5
Branch	15	**Mecosta**	9
Calhoun	15	**Menominee**	7
Cass	14	**Midland**	8
Charlevoix	4	**Missaukee**	8
Cheboygan	6	**Monroe**	28
Chippewa	6	**Montcalm**	11
Clare	8	**Montmorency**	6
Clinton	17	**Muskegon**	7
Crawford	10	**Newaygo**	12
Delta	11	**Oakland**	31
Dickinson	7	**Oceana**	5
Eaton	25	**Ogemaw**	14
Emmet	5	**Ontonagon**	2
Genesee	41	**Osceola**	16
Gladwin	9	**Oscoda**	5
Gogebic	3	**Otsego**	3
Gd. Traverse	4	**Ottawa**	18
Gratiot	12	**Presque Isle**	6
Hillsdale	23	**Roscommon**	8
Houghton	1	**Saginaw**	21
Huron	12	**Sanilac**	14
Ingham	27	**Schoolcraft**	3
Ionia	17	**Shiawassee**	25
Iosco	11	**St. Clair**	20
Iron	5	**St. Joseph**	9
Isabella	13	**Tuscola**	17
Jackson	17	**Van Buren**	18
Kalamazoo	25	**Washtenaw**	24
Kalkaska	7	**Wayne**	28
Kent	31	**Wexford**	7
Keweenaw	2	**STATEWIDE:**	**923**

IMPORTANT NOTE: Tornadoes that crossed county lines are counted more than once in this table. Therefore, the statewide total is less than the sum of the individual county totals.
Source: National Weather Service


Historic Tornadoes per County
Keweenaw
Houghton
Ontonagon
Baraga
Gogebic
Marquette
Iron
Alger
Luce
Chippewa
Schoolcraft
Mackinac
Dickinson
Delta
Menominee
Emmet
Cheboygan
Presque Isle
Charlevoix
Antrim
Otsego
Montmorency
Alpena
Leelanau
Benzie
Grand Traverse
Kalkaska
Crawford
Oscoda
Alcona
Manistee
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Mason
Lake
Osceola
Clare
Gladwin
Arenac
Huron
Oceana
Newaygo
Mecosta
Isabella
Midland
Bay
Tuscola
Sanilac
Montcalm
Gratiot
Saginaw
Muskegon
Ottawa
Kent
Ionia
Clinton
Shiawassee
Genesee
Lapeer
St. Clair
Macomb
Allegan
Barry
Eaton
Ingham
Livingston
Oakland
Van Buren
Kalamazoo
Calhoun
Jackson
Washtenaw
Wayne
Berrien
Cass
St. Joseph
Branch
Hillsdale
Lenawee
Monroe
Tornadoes 1950-2009
1 - 9
10 - 17
18 - 25
26 - 33
34 - 41
N
0 15 30 60 90 120
Miles
Produced by:
Michigan State Police
Emergency Management and Homeland Security Division
December 2010



Tornado Frequency, by land area (per 10,000 square miles)

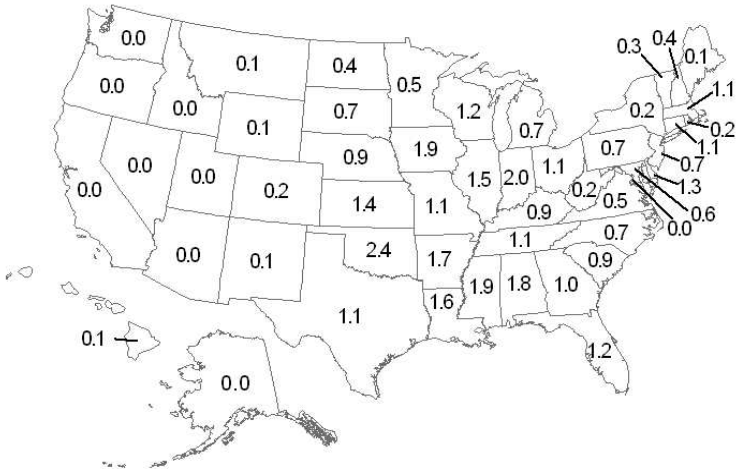
Comparative National Tornado Statistics

Source: National Weather Service

Annual Average Number of Strong-Violent (F2-F5) Tornadoes by State

* Theses maps use data for the years 1950 to 2009 for the State of Michigan only, but the rest of the states show data only for the years 1950 to 1995. Although updated national maps were not available from the National Weather Service for use in this plan, new information for Michigan was readily provided upon request, and these maps were then revised by MSP/EMHSD staff to reflect this new data

Average Annual Number of Strong-Violent (F2-F5) Tornadoes per 10,000 Square Miles by State



Michigan State Police
Emergency Management & Homeland Security Division
January 2011

Extreme Temperatures

Prolonged periods of very high or very low temperatures, often accompanied by other extreme meteorological conditions.

Hazard Description

Prolonged periods of extreme temperatures, whether extreme summer heat or extreme winter cold, can pose severe and life-threatening problems for Michigan's citizens. Although they differ in their initiating conditions, the two hazards share a commonality in that they both tend to have a special impact on the most vulnerable segments of the population—the elderly, young children and infants, impoverished individuals, and persons who are in poor health. Due to their different characteristics, extreme summer heat and extreme winter cold hazards will mostly be discussed separately in this section. For both types of temperature extremes, however, a longer hot or cold spell makes the temperature effects much more severe on vulnerable populations—a longer duration tends to produce more severe effects.

Hazard Analysis

Extreme Summer Heat is characterized by a combination of very high temperatures and humid conditions. When persisting over a long period of time, this phenomenon is commonly called a heat wave. The major threats of extreme summer heat are heat exhaustion and heatstroke (a major medical emergency). **Heat exhaustion** is a less severe condition than heatstroke, but it causes problems involving dizziness, weakness and fatigue. Heat exhaustion is often the result of fluid imbalance due to increased perspiration in response to the intense heat. Treatment generally consists of restoring fluids and staying indoors in a cooler environment until the body returns to normal. If heat exhaustion is not addressed and treated, it can advance to heatstroke, so medical attention should be sought immediately.

Heatstroke symptoms include a high body temperature (it can be 106 degrees or higher), dry skin, inadequate perspiration, paleness or reddening, confusion or irritability, and seizures. The victim may become delirious, stuporous, unconscious, or even comatose. Cooling is essential to preventing permanent neurological damage or death. Other, less serious risks associated with extreme summer heat are often exercise-related and include **heat cramps** (an imbalance of fluids that occurs when people unaccustomed to heat exercise outdoors) and **heat syncope** (a loss of consciousness by persons not acclimated to hot weather). Periods of hot weather also entail risks of dehydration, even for those who are not engaged in demanding physical activities. Non-caffeinated fluids should be consumed to maintain adequate hydration.

A useful set of general principles to recognize is that evaporation is a cooling mechanism for our bodies. Evaporation of moisture (i.e. perspiration) doesn't occur as rapidly when the surrounding air already has a relatively high moisture content (humidity). Thus, humidity inhibits evaporation and produces a feeling of greater heat, while winds assist the evaporation of perspiration from skin and thus tend to produce a feeling of greater coolness. It can therefore be difficult for the body to precisely gauge actual outdoor temperatures—it rather senses the potential for heat gain or loss. A period of extreme heat is more debilitating when the air humidity is high, and a period of extreme cold is similarly more dangerous when coupled with strong winds. For these reasons, temperature alone is usually only a limited indicator of the weather's likely threat to human health, and additional factors should also be considered. The additional factors of humidity and wind speed have provided the basis for two additional means of describing the extent of extreme temperatures' impact—the **Heat Index** (HI) and the **Wind Chill Temperature Index** (WCT).

The following tables indicate the way that temperature, humidity, and wind speed probably feels to the human body, and suggest the types of temperature effects relevant to Michigan's climate. Although some of the resulting heat numbers may at first seem outrageous to describe Michigan temperatures, some of the extremes are actually comparable to what is felt in a sauna, which is often set at more than 140 degrees. Like saunas, such heat should

not be felt by the body for more than brief periods of time, and since one of the body's cooling reactions is to increase the rate of blood circulation, this also adds to the burden placed on the heart muscle, and can be too much strain for some persons to bear.

HEAT INDEX	**Actual Temperature (degrees Fahrenheit)**									
Rel. Humidity	**90**	**92**	**94**	**96**	**98**	**100**	**102**	**104**	**106**	**108**
40%	91	94	97	101	105	109	114	119	124	130
45%	92	96	100	104	109	114	119	124	130	137
50%	95	99	103	108	113	118	124	131	137	144
55%	97	101	106	112	117	124	130	137	145	
60%	100	105	110	116	123	129	137	145		
65%	103	108	114	121	128	136	144			
70%	106	112	119	126	134	143				
75%	109	116	124	132	141					
80%	113	121	129	138						
85%	117	126	135	145						
90%	122	131	141							
95%	127	137								

Source: formulas obtained from the National Climatic Data Center

TECHNICAL NOTE: The two indices can also be summarized by the following mathematical formulas, in which T means temperature (in degrees Fahrenheit), H means relative humidity (%), W means wind speed (in miles per hour), and E denotes a shorthand for scientific notation (times 10 raised to the power of the number that follows the E):

$HI = -42.38 + 2.049T + 10.14H - 0.2248HT - (6.838E\text{-}3)T^2 - (5.482E\text{-}2)H^2 + (1.229E\text{-}3)HT^2 + (8.528E\text{-}4)H^2T - (1.99E\text{-}6)H^2T^2$

$WCT = 35.74 + 0.6215T - 35.75(W^{0.16}) + 0.4275T(W^{0.16})$

WIND CHILL	**Actual Temperature (degrees Fahrenheit)**									
Wind speed (mph)	**40**	**30**	**20**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**
5	36	25	13	1	-11	-22	-34	-46	-57	-69
10	34	21	9	-4	-16	-28	-41	-53	-66	-78
15	32	19	6	-7	-19	-32	-45	-58	-71	-83
20	30	17	4	-9	-22	-35	-48	-61	-74	-88
25	29	16	3	-11	-24	-37	-51	-64	-78	-91
30	28	15	1	-12	-26	-39	-53	-67	-80	-94
35	28	14	0	-14	-27	-41	-55	-69	-82	-96
40	27	13	-1	-15	-29	-43	-57	-71	-84	-98
45	26	12	-2	-16	-30	-44	-58	-72	-86	-100
50	26	12	-3	-17	-31	-45	-60	-74	-88	-102
55	25	11	-3	-18	-32	-46	-61	-75	-89	-104
60	25	10	-4	-19	-33	-48	-62	-76	-91	-105

Other tables and calculators can be found online, such as the tables for a heat index at http://www.ncdc.noaa.gov/oa/climate/conversion/heatindexchart.html, or the tables and calculator for wind chill at http://www.nws.noaa.gov/om/windchill/.

Although these indices involve a fairly straightforward means of expressing the "feel" of the weather in terms of a temperature equivalent, conditions for each individual will still vary with the duration and type of weather exposure, personal health, extent of acclimation, and the type of clothing worn. For example, exposure to full sunshine can increase heat index values by up to 15%. Also, cooler air holds less moisture, and dryer air readily allows the cooling evaporation of perspiration from skin. In other words, the heat index and wind chill index only

involve a consideration of two important factors, but they are still more useful than a consideration of temperature alone. The Heat Index table assumes shady conditions with a light wind. Actual indoor conditions may vary, trapping heat and/or humidity in some locations and making them potentially much more dangerous. Prolonged exposure, physical activity, and age all tend to increase the risks associated with heat. Conditions that might cause heat cramps in a teenager could be experienced as heat exhaustion by a middle-aged person, and as heat stroke by a senior citizen. Young infants, however, are also vulnerable to heat effects.

Extremely high numbers are not shown in the table, since there are limits on the extent to which both humidity and heat would be experienced as a part of Michigan's weather (shown on the map below). However, the following guidelines are recommended, to make better use of the raw numbers:

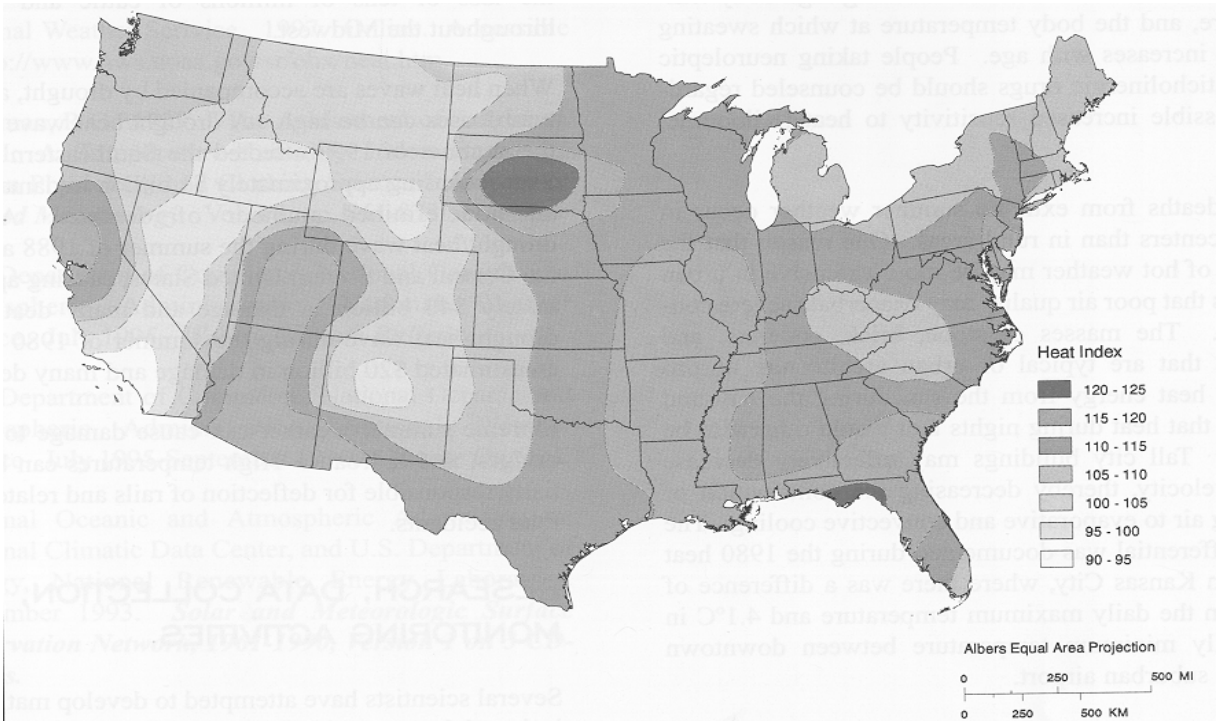
Heat Index above 130 degrees:
Extreme Danger (Heat stroke or sunstroke is highly likely with prolonged exposure and/or physical activity)

Heat Index in the 105 to 129 degree range:
Danger (Sunstroke, muscle cramps, heat exhaustion is likely with prolonged exposure and physical activity)

Heat Index in the 90 to 104 degree range:
Extreme Caution (Sunstroke, muscle cramps and/or heat exhaustion possible with prolonged exposure/activity)

Heat Index up through 89 degrees:
Caution (Fatigue possible with prolonged exposure and/or physical activity)

Severity and Extent of Extreme Summer Heat in the United States



Source: U.S. Department of Commerce; *Multi-Hazard Identification and Risk Assessment*, 1999, FEMA

In Michigan, heat advisories will tend to be announced when the heat index is calculated to exceed 105 degrees in an area for a period of at least 3 hours in duration. It should be noted, however, that the temperature inside of vehicles without air conditioning can be dozens of degrees hotter than the outdoor temperature—an outdoor temperature might be "only" 100 degrees Fahrenheit, but people may then get into a car that exceeds 130 degrees. People vary in the conditions in which they operate (and in their capacity to tolerate extreme temperatures), and can find themselves in circumstances that threaten their health even if no official temperature advisory has been issued.

Heat waves tend to have stagnant atmospheric conditions that trap pollutants in urban areas and thus compound the health effects faced by urban residents. Because the combined effects of high temperatures, high humidity, and trapped pollution are focused more intensely in urban centers, heatstroke and heat exhaustion are a greater problem in sizeable cities than in suburban or rural areas. Nationwide, approximately 135 deaths per year are attributable to extreme heat (a total of 3,311 over the 24 year period from 1986 to 2009, according to http://www.nws.noaa.gov/om/hazstats/images/70-years.pdf). Extreme summer heat is also hazardous to livestock and agricultural crops, and it can cause water shortages, exacerbate fire hazards, and prompt excessive demands for energy. Roads, bridges, railroad tracks and other infrastructure are susceptible to damage from extreme heat (due to the effects of thermal expansion of materials). Scorching weather also puts a strain on the energy demands for an area, as the use of air conditioning increases greatly. Possible shutdowns of schools, colleges, and industries can occur during these times.

Air conditioning is probably the most effective measure for mitigating the effects of extreme summer heat on people. Unfortunately, many of those most vulnerable to this hazard do not live or work in air-conditioned environments, especially in major urban centers where the vulnerability is highest. The use of fans to move air may help some persons feel more comfortable, but when the temperature reaches the high 90s, fans will not prevent heat-related illness. Bathing with cool water is more effective, but moving to a cooler environment (a basement or air-conditioned location) is most effective—even if only for a few hours per day.

To mitigate the extreme heat of summer, communities should have a contingency plan in place to protect those people who are most vulnerable to the heat. These contingency plans should include: setting up "cooling stations" where people can go to get out of the heat; a hierarchy of closings for industries, businesses, and schools during shutdown periods; and a means of explaining the dangers of heat conditions, such as pamphlets and local broadcast and print media. Monitoring of dangerous conditions can also be done through the National Weather Service website. A risk assessment should calculate the likelihood of such incidents and the number of days of extreme temperatures likely to be experienced in your community each year. It should also take account of past losses and harm caused by such events, and determine who or what is still vulnerable to such conditions today.

Heat waves severe enough to threaten health do not occur every year, and several relatively mild summers may intervene between major heat waves. The problem is complicated by the fact that long-term weather forecasts cannot reliably predict prolonged periods of extreme summer heat. Short-term forecasts of hot weather are more accurate, but often leave little time for mobilizing to effectively combat the hazard. Nevertheless, planning and preparedness activities can occur to mitigate the effects of this weather hazard.

Because of its geographic location in relation to the Great Lakes, Michigan is somewhat less susceptible to prolonged periods of extreme hot temperatures than are many other states. However, the Upper Midwest, in which Michigan is located, is definitely vulnerable to extreme temperature events. As a result, Michigan communities (and particularly urban centers) must always be prepared to respond to heat events in an organized, coordinated and expedient manner. Extreme summer heat poses the greatest danger to urban residents—especially the elderly, children, outdoor laborers, people with poor health, and people residing in homes without air conditioning. Michigan's urban communities must address extreme summer heat in their emergency preparedness efforts. Human service agencies, voluntary organizations, health departments, medical and health care facilities, and schools may have a role in response to a heat wave. The Michigan Department of Community

Health, together with local health departments, medical and health care facilities, may have to establish specialized medical surge facilities to assist in the care of a large number of persons who may be affected in such events. In addition, the local media could be tapped to assist in information dissemination and community outreach efforts.

In an average year, Michigan has many days above 90° Fahrenheit. MDCH and NWS estimate about 5 deaths per year, on average, due to extreme heat. Although larger cities have been noted as having more risk from extreme heat, it should also be noted that residents in isolated rural locations may have trouble accessing air-conditioned places, or reaching designated cooling shelters. Such access may be easier for urban residents.

Extreme Winter Cold periods can, like heat waves, result in a significant number of temperature-related deaths. Each year in the United States, approximately 700 persons die as a result of severe cold temperature-related causes. This is substantially higher than the average of 175 heat-related deaths each year. It should be noted that a significant number of cold-related deaths are not the direct result of "freezing" conditions. Rather, many deaths are the result of illnesses and diseases that are negatively impacted by severe cold weather, such as stroke, heart disease and pneumonia. It could convincingly be argued that, were it not for the extreme cold temperatures, death would not have occurred at the time that it did due to the illness or disease alone. There are, in various parts of Michigan, an average of between 3 and 50 (or more) days per year at or below 0° Fahrenheit. Michigan also tends to have between 90 and 180 (or more) days per year in which the temperature is below the freezing point.

Hypothermia (the unintentional lowering of core body temperature), and **frostbite** (damage from tissue being frozen) are probably the two conditions most closely associated with cold temperature-related injury and death. Hypothermia is usually the result of over-exposure to the cold, and is generally thought to be clinically significant when core body temperature reaches 95 degrees or less. As body temperature drops, the victim may slip in and out of consciousness, and appear confused or disoriented. Treatment normally involves warming the victim (preferably performed by trained medical personnel) but frostbitten areas should not be rubbed. Although frostbite damage itself rarely results in death (which may occur due to hypothermia instead), in extreme cases it can result in the amputation of the affected body tissue.

Periods of extreme cold are risky for those in both rural and in urban areas. Frostbite and hypothermia is common in rural areas where people are trapped outdoors and do not adjust properly to the temperatures. Even indoors, hypothermia is a concern for individuals living in inadequately heated apartments or rooms. Loss of life can occur with either of these situations. Damage to buildings and pipelines can also occur in bitter cold conditions, resulting in expensive repairs and potential days of business and school shutdowns.

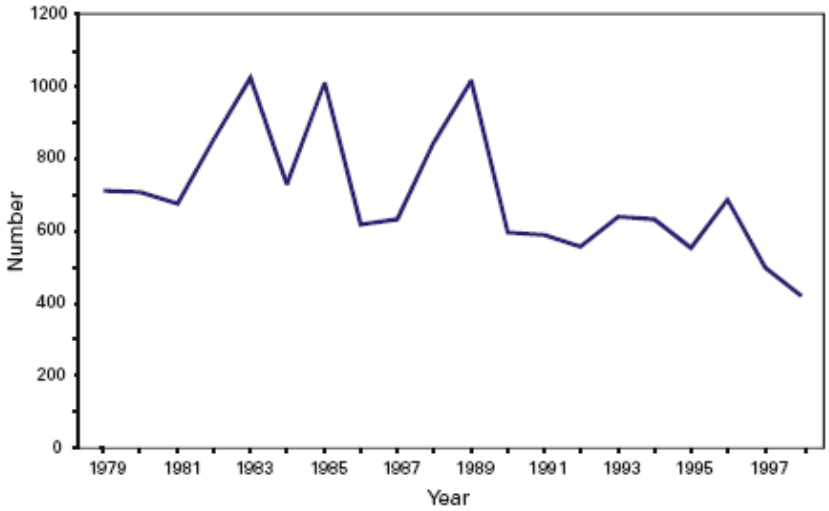
To mitigate the effects of the unfavorable cold temperatures, communities should make sure that housing codes are appropriate and that adequate furnaces are in place in apartment dwellings. Inspections of vulnerable and outdated infrastructure should be made in the fall season, before winter sets in. In addition, proper insulation of piped areas can prevent water main breaks.

In the wind chill chart, extremely low apparent temperatures can also be associated with an amount of exposure time that it takes to cause frostbite. Cells of the table that have darker shadings denote wind chill temperatures that can produce frostbite in 10 minutes or less. Cells with lighter shadings are associated with frostbite times of 30 minutes or less. Unshaded cells in the table should require longer exposure times to cause frostbite. Again, the chart displays only two factors that contribute heavily to risk, but risk can be increased for an individual in particular circumstances. For example, people should be aware that the drier air (common to winter weather) also allows a more rapid drop in temperature than is the case with warm summer air. As a cold front moves in, or as daytime high temperatures for the day change to nighttime low temperatures, the corresponding drop in temperature can be much greater when the humidity is low. Persons who are outdoors can rapidly find themselves in danger of hypothermia.

Hypothermia usually occurs in one of two sets of circumstances. One situation involves hypothermia associated with prolonged exposure to cold while participating in outdoor sports such as skiing, hiking or camping. Most victims of this form of hypothermia tend to be young, generally healthy individuals who may lack experience in dealing with extreme cold temperatures. The second situation involves a particularly vulnerable person who is subjected to only a moderate, indoor cold stress. A common example would be that of an elderly person living in an inadequately heated home. In such circumstances, hypothermia may not occur until days or perhaps weeks after the cold stress begins. Isolated rural locations may involve difficulties in reaching a heated space, or a designated warming shelter.

Deaths due to extreme winter cold are often not associated with a particular weather event. Rather, they are the result of a one-time over-exposure to severe cold weather (a hiker lost in the woods, or car failure in a rural area), or more commonly from continuous exposure to moderate cold temperatures by vulnerable persons (such as the elderly). In some cases, hypothermia deaths can be linked to severe winter weather such as snowstorms or blizzards, where the victim is caught unprepared for the extreme cold temperatures. As mentioned earlier, many cold temperature-related deaths involve the exacerbation of an existing, serious medical condition such as heart disease or pneumonia. In Michigan, approximately 70% of weather-related fatalities (about 40 deaths per year) are attributed to exposure to the cold (according to the Michigan Department of Community Health and the National Weather Service). The following 20-year table gives an indicator for the nation as a whole.

Number of Hypothermia-Related Deaths in U.S.: 1979-1998



Source: CDC Morbidity and Mortality Weekly Report

The special vulnerability of elderly persons to hypothermia has become apparent. Over half of the hundreds who die each year due to cold exposure are 60 years of age or older, even though this age group only represents about 20% of the country's population. This remarkable statistic may be due, in part, to an impaired perception of cold as well as the voluntarily setting of thermostats to relatively low temperatures. In addition, high energy costs and the relative poverty among some elderly people may discourage their setting thermostats high enough to maintain adequate warmth (just as it may cause others to limit their use of fans and air conditioning during summer heat waves). Because many elderly people live alone and do not have regular visitors, the cold conditions may persist for several days or weeks, thus allowing hypothermia to set in.

Babies and very young children are also very vulnerable to hypothermia. In addition, statistics indicate that death due to cold is more frequent among males than females in virtually all age groups. Part of that may be explained by differences in risk factors, and part may be due to different rates of cold exposure between activities performed by different sexes. Cold weather also increases blood viscosity, narrows small blood vessels, and increases blood pressure, all of which increase the risk of cardiovascular problems (e.g. a heart attack).

As explained in the general introduction to the weather hazards section of this plan, there should be no presumption made that temperatures will automatically be higher or lower in a southern or northern part of the state, despite the existence of certain trends and correlations. All parts of Michigan experience temperature extremes that threaten health. In fact, Michigan's two most extreme temperatures on record did not occur either in the extreme north of the Upper Peninsula or at the extreme south of the Lower Peninsula, but rather at locations in between – in the Northern part of the Lower Peninsula. The record low temperature of -51 was measured at Vanderbilt (located in Otsego County) and the record high of 112 was at Mio (located in Oscoda County).

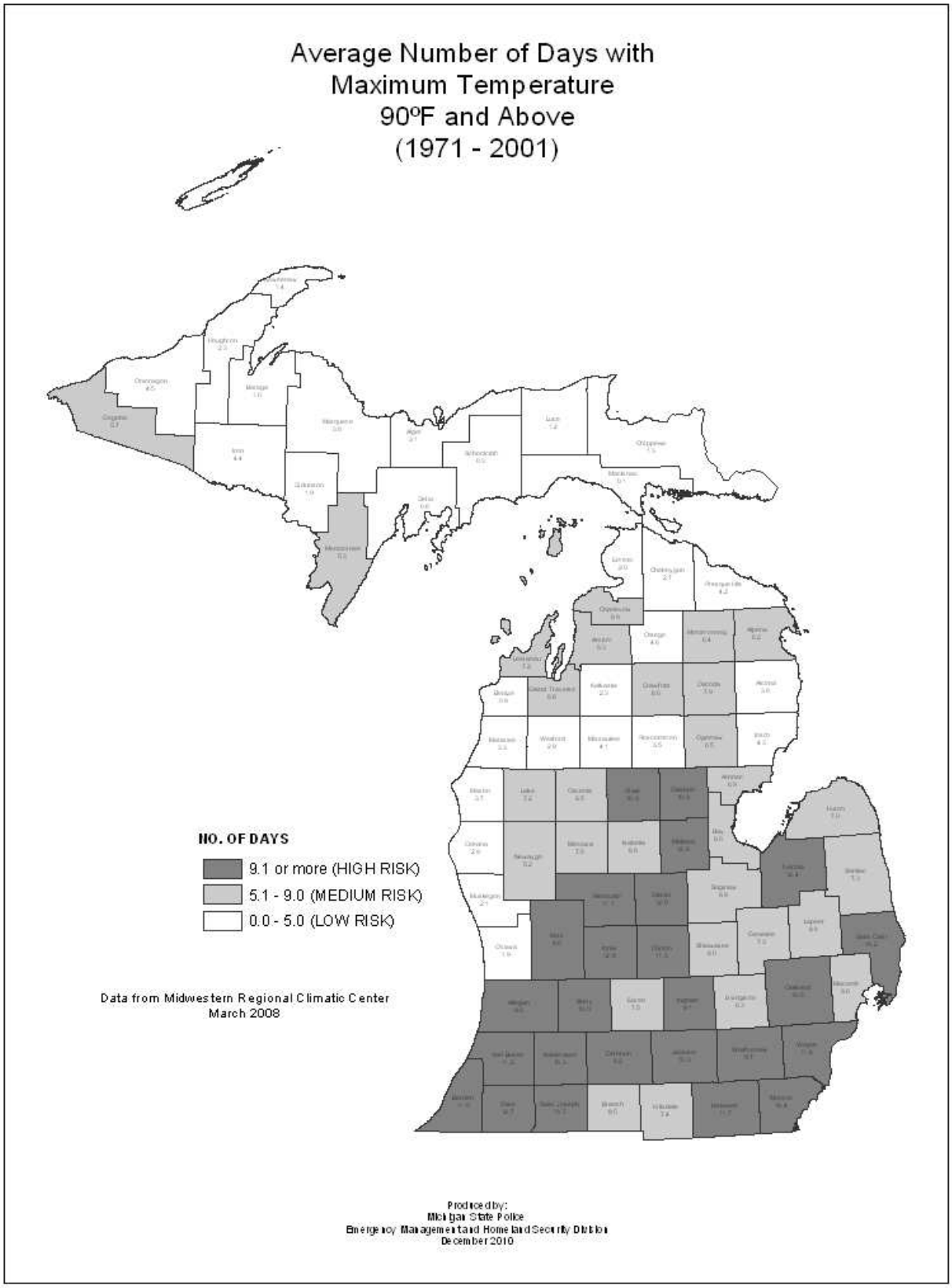
Nevertheless, there is some variation across Michigan in the conditions under which wind chill advisories are issued, since it is the case that the warm season is longer in the southern part of the Lower Peninsula and there is a different phase of that area's population becoming acclimated to each year's winter weather. For southern Michigan, wind chill advisories tend to be issued when the Wind Chill Temperature is within the -15 to -24 range. In northern Michigan and the Upper Peninsula, advisories tend to be issued when the WCT is within the -20 to -29 range. Wind chill warnings tend to be issued when the WCT gets down to -25 or below, in southern Michigan, or when it gets down to -30 or below, in northern Michigan.

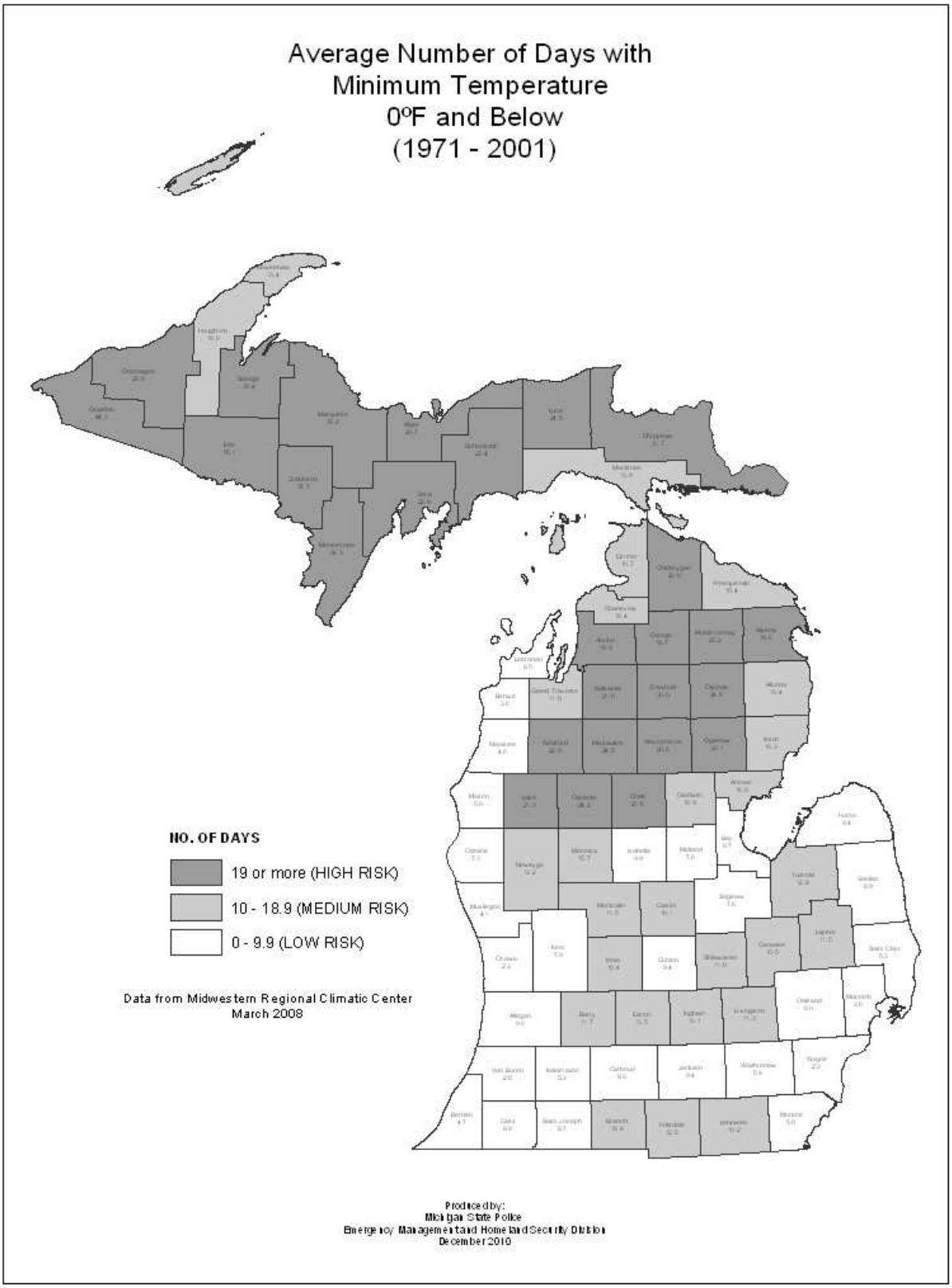
Maps on the following two pages illustrate the average number of days above 90 degrees and the average number of days below zero degrees, Fahrenheit. Although they are based on the three decades from 1971 to 2001, they give an excellent indication of the "typical" annual risk and exposure to Michigan summer and winter temperature extremes, for all of Michigan's counties.

A different type of risk indicator is provided in the subsequent table that lists record low and high temperatures for numerous weather stations across Michigan. For convenience, the listings are divided into three regions: the Southern Lower Peninsula, Northern Lower Peninsula, and Upper Peninsula. Note that these records are for specific stations, and do not necessarily represent all-time records for the counties or surrounding localities in that area. They should instead be taken as an indicator of the extremes to which various specific locations have experienced, across the state.

As already noted in the Introduction to the Weather Hazards section of this plan, although it makes sense to think in terms of three general Michigan regions for an analysis of trends and weather patterns, the extreme temperature hazard must be understood to be a significant one in every part of the state. This is true of both summer and winter temperature extremes. In general, however, "seasons" can be defined for these three regions, to denote when there is a serious risk of extreme temperature events. These "seasons" are based upon the historical occurrence of very high temperatures (above 90 degrees) and very low temperatures (near zero degrees, or below) and will here be generally defined:

	Extreme Heat Risk Season	**Extreme Cold Risk Season**
Southern Lower Peninsula	Early May to late September	Late November to early April
Northern Lower Peninsula	Late May to late September	Early November to April
Upper Peninsula	Late May to early September	Late September to May


Average Number of Days with
Maximum Temperature
90ºF and Above
(1971 - 2001)
NO. OF DAYS
9.1 or more (HIGH RISK)
5.1 - 9.0 (MEDIUM RISK)
0.0 - 5.0 (LOW RISK)
Data from Midwestern Regional Climatic Center
March 2008
Produced by:
Michigan State Police
Emergency Management and Homeland Security Division
December 2010


Average Number of Days with
Minimum Temperature
0ºF and Below
(1971 - 2001)
NO. OF DAYS
19 or more (HIGH RISK)
10 - 18.9 (MEDIUM RISK)
0 - 9.9 (LOW RISK)
Data from Midwestern Regional Climatic Center
March 2008
Produced by:
Michigan State Police
Emergency Management and Homeland Security Division
December 2010

Historic Temperature Records at Various Michigan Locations

Southern Lower Peninsula	Record Low Temperature	Record High Temperature
Adrian (Lenawee County)	-26° (Jan. 20)	108° (July 14 & 24)
Benton Harbor (Berrien County)	-21° (Jan. 12)	104° (June 1, July 21 & 30)
Coldwater (Branch County)	-23° (Jan. 4)	108° (July 24)
Ann Arbor (Washtenaw County)	-23° (Feb. 11)	105° (July 24)
Bloomingdale (Van Buren Co.)	-23° (Feb. 3)	105° (July 5 & 13)
Detroit (Wayne County)	-24° (Dec. 22)	105° (July 24)
Jackson (Jackson County)	-21° (Feb. 10)	105° (July 14)
Pontiac (Oakland County)	-22° (Feb. 5)	104° (July 6, 8, 16, 24)
Flint (Genesee County)	-25° (Jan. 18)	108° (July 8, 13)
Grand Rapids (Kent County)	-24° (Feb. 13 & 14)	108° (July 13)
Port Huron (St. Clair County)	-19° (Jan. 19)	103° (July 9)
Harbor Beach (Huron County)	-22° (Feb. 9)	105° (July 10)
Big Rapids (Mecosta County)	-36° (Feb. 11)	103° (July 13, 14 & 30)

The counties listed above start with the southernmost tier in Michigan, and proceed generally northward, tier by tier. Big Rapids is situated on the very edge of the southern and northern regions, and its record low fits the northern region.

Northern Lower Peninsula	Record Low Temperature	Record High Temperature
Alpena (Alpena County)	-37° (Feb. 17)	106° (July 13)
East Tawas (Iosco County)	-29° (Feb. 1 & 20)	106° (July 8 & 9)
Gaylord (Otsego County)	-39° (Jan. 6)	101° (July 11 & 30)
Gladwin (Gladwin County)	-39° (Feb. 20)	105° (July 13)
Traverse City	-37° (Feb. 17)	105° (July 7)
Upper Peninsula	**Record Low Temperature**	**Record High Temperature**
Hancock (Houghton County)	-30° (Feb. 9 & 10)	102° (July 7)
Ironwood (Gogebic County)	-41° (Jan. 17, Feb. 12)	104° (July 13)
Munising (Alger County)	-33° (Feb. 25)	103° (July 7, 8, 9, Aug. 6)
Sault Ste. Marie (Chippewa Co.)	-37° (Feb. 8 & 10)	98° (July 3, 30, Aug 5, 6)
Statewide all-time records	-51° (Feb. 9) Vanderbilt (Otsego County)	112° (July 13) Mio (Oscoda Co.)

Source: Extreme Michigan Weather, by Paul Gross (2010, University of Michigan Press, Ann Arbor)

These tables show all the record low and high temperatures at various weather stations across Michigan. It can be noted that the majority of record low temperatures occurred in January and February, and the majority of record high temperatures took place in July. This pattern holds true across all of Michigan's regions. It should also be noted that lower-lying areas often experience colder temperatures, since colder air is denser and heavier and thus tends to sink to lower areas. Local variations of that type help to explain why the absolute coldest and hottest temperature extremes ever recorded in Michigan are more extreme than the various records listed for specific weather stations.

The tempering effects of the Great Lakes also help moderate the impact of the severe cold weather normally prevalent in the Midwest during the winter months. Even so, Michigan still endures many days of extremely cold temperatures in an average winter, and prolonged periods of extreme cold are not uncommon during the months of January and February. During those months especially, increased outreach to elderly persons - particularly those living alone - is certainly warranted. In addition, communities should be particularly cognizant of the vulnerability of elderly as well as very young persons when power outages occur due to ice and snowstorms. When outages are expected to last for several hours or more, consideration should be given to opening warming

shelters. Once power is restored, outreach to the elderly may be necessary to ensure that furnaces have been re-started and are working properly.

Extreme cold temperatures are a universal hazard in Michigan. Whereas heat waves tend to impact urban centers more than suburban or rural areas, cold temperatures are an "equal opportunity" killer. Every community in Michigan is vulnerable, regardless of location or size. It must also be noted that many of the agricultural sectors of Michigan are vulnerable to crop losses because of extreme cold events.

Impact on the Public
Extreme temperatures can have direct impacts on personal health and productivity, which may collectively lead to reductions in economic activity and travel (e.g. tourism, shopping). Extreme temperature events tend to cause greater energy use, which can involve not only higher energy costs but can also result in infrastructure failures due to limitations in the capacity of the utility system. About 900 annual deaths nationwide have been attributed to extreme temperatures (mostly from extreme cold, involved in about 700 deaths), ranking this hazard as the second leading cause of fatalities (behind structural fires).

Impact on Public Confidence in State Governance
Questions may arise about the amount of utility assistance, provision/promotion of heating/cooling centers, etc. that governments are meant to provide, and whether there are identifiable and unjustified inequities in the extent and quality of resources and infrastructure provided to different groups and locations throughout the state. Inequities might be attributed to shortcomings in government efficacy and intentions, rather than to limited resources and the historical aspects of differential development patterns.

Impact on Responders
Heat and freezing conditions may directly impact the health and effectiveness of responders, including the potential for dealing with impacts on overwhelmed or failed infrastructure. Special clothing and equipment (and maintenance) tends to become necessary under conditions of extreme cold. Frozen pipes may inhibit or limit responders' access to water that is needed to fight fires, and extra activities and caution may be needed around wintry fire zones where water may have frozen and made footing treacherous for emergency workers (and others).

Impact on the Environment
Periods of extreme heat or cold can affect the environment in several ways. When the temperature rises, power consumption increases, as households and public buildings require more energy to run air conditioning. Agricultural areas also use more pumped water as irrigation is increased. More coal is burned to fulfill the rising demand and thus, more greenhouse gases and toxins are released into the air.

Long-term environmental damage includes greenhouse gas emissions that cause the earth's temperature to rise even further, in what may be described as a "vicious circle." The melting of glaciers in the arctic region will, along with the thermal expansion of ocean waters, increase the sea level, erode and flood coastal areas, and cause the extinction of many species.

Climate Change Considerations
Certain indicators of climate change in Michigan have already been observed. For example, in daily record temperature data, Michigan's new heat records outnumbered new cold records by 3 to 1 during the 1990s, and by 6 to 1 during the 2000s. Extreme heat problems are expected to increase in the future, and the MSP/EMHSD is coordinating with other agencies to assess the likely impacts of warming trends.

Significant Heat Waves Affecting Michigan

Following are brief synopses of some of the more significant heat waves that have affected Michigan in recent decades:

July 1936 – Michigan

During the second week of July 1936, a terrible heat wave struck Michigan, and particularly Detroit, with temperatures exceeding 100 degrees for up to seven days in a row (this varied by location—for example, Detroit had 7, West Branch and Alpena had 6, and Traverse City had 5). The temperature peaked at 112 degrees in Mio, setting a state record that still stands today. The extreme heat was an "equal opportunity" killer, causing many healthy adults to succumb to the heat at work or in the streets. Also, because most people relied on iceboxes to keep their food fresh, many heat-related deaths and illnesses occurred when the ice melted, causing the food to spoil. Statewide, 570 people died from heat-related causes, including 364 in Detroit. Nationally, the heat wave caused 5,000 deaths. Notice that these casualties disproportionately affected the large city of Detroit, and that Michigan was over-represented in terms of its population (11.4% of the national deaths were in Michigan).

August-September 1953 – Michigan

This summer included eleven days in a row with temperatures of 90 degrees or higher in Southeast Michigan, nine of which were 95 degrees or hotter, and also including two days that each hit 100 degrees.

July 1964 – Michigan

A heat wave lasted for twelve days, with temperatures all exceeding 90 degrees in Southeast Michigan. The highest such temperature was 95 degrees.

Summer 1988 – Central and Eastern U.S.

The 1988 drought/heat wave in the Central and Eastern U.S. also greatly impacted Michigan. Nationwide, the drought caused an estimated $40 billion in damages from agricultural losses, disruption of river transportation, water supply shortages, wildfires, and related economic impacts. The heat wave that accompanied the drought conditions was particularly long in Michigan – 39 days with 90 degree or better heat – eclipsing the previous record of 36 days recorded in the "dust bowl" days of 1934. During that 39-day stretch, the temperature in Southeast Michigan topped the 100 degree mark on 5 occasions, including a peak of 104 degrees on June 25. Nationwide, the 1988 drought/heat wave caused an estimated 5,000 to 10,000 deaths. (Again, the range of estimates is due largely to varying interpretations of "heat-related" death.)

July 1995 – Central and Eastern U.S.

During the period from July 11-27, 1995, the Central United States and many East Coast cities experienced a devastating heat wave. According to the National Oceanic and Atmospheric Administration, that heat wave caused 1,021 deaths - 465 of those occurring in the Chicago metropolitan area alone. Many of the deaths were low-income elderly persons living in residential units not equipped with air conditioning. Local utilities in Chicago were forced to impose controlled power outages because of excessive energy demands, and water suppliers reported very low levels of water in storage. In Milwaukee, Wisconsin, 85 heat-related deaths were reported during the July 11-27 period. Michigan experienced 28 heat-related fatalities in 1995, most of them occurring during the intense heat period in July. In addition to this tremendous human toll, the intense heat also caused the loss of tens of millions of cattle and poultry throughout the Midwest. This was the hottest summer on record for Southeast Michigan, in terms of having the highest average temperature in Detroit (74.5 degrees). The average August temperature was even higher, at 77.1 degrees, which also set a new record.

July 1999 – Midwest and East Coast

The July 1999 heat wave that struck the Midwest and East Coast resulted in an estimated 256 heat-related deaths in 20 states (including one in Kent County in Michigan). Most of the deaths occurred in urban areas in the Midwest, where temperatures soared above 90 degrees for much of the month and humidity levels were oppressively high. Numerous persons with heat-related problems (ranging from dehydration to heat stroke) were treated at hospitals in Detroit and other cities across the state throughout the heat wave.

June-August 2001 – Midwest and Central Plains

Extreme heat and humidity in the Midwest and Central Plains during parts of June, July and August sent heat stress index readings soaring well above 100 degrees Fahrenheit on many days. Communities across the region were forced to open "cooling centers" and take other steps in an attempt to avoid heat-related deaths among vulnerable segments of the population. Despite those efforts, heat-related deaths occurred in many areas – and unfortunately Michigan was no exception. In mid-June, three elderly residents of a Detroit-area nursing home died and five more were hospitalized due to heat-related stress. (Note: the deaths prompted a bill within the Michigan Legislature to require all nursing homes in Michigan to have air conditioning in resident rooms and common areas.) On August 1 and August 8, heat advisories were issued for many counties in the southern Lower Peninsula, with heat indices at 105 degrees for some jurisdictions on the former date, and 110 degrees for some jurisdictions on the latter date. The National Climatic Data Center reports one death and 200 "injured" during early August, from excessive heat.

June 2003 – Michigan

Summer heat was part of the reason that Red Flag warnings were issued for two counties in the Upper Peninsula, warning of extreme wildfire risk. This was the same summer that saw a massive heat wave strike Europe and cause an estimated 21,000 deaths there. Paris, France recorded its highest temperatures since records had begun in 1873. Fortunately, Michigan did not experience those sorts of extreme problems.

Summer, 2006 – Southeastern Michigan

The National Climatic Data Center reports that 315 "injuries" occurred as a result of heat in Michigan—75 occurring on May 29, and 240 in late July and early August, although most of the latter were mild cases involving dehydration, some heat exhaustion, and only 6 known cases of heat stroke. A 5 day period of temperatures at or above 90 degrees started on July 29 for Southeastern Michigan. The heat index averaged between 105 and 110 degrees, and various temperature records were tied. A large number of cooling centers were provided for residents in need, and preparedness was very good, perhaps because the earlier May 29 event had provided a milder warning event that alerted communities to the potential for heat problems. In that earlier case, on Memorial Day, temperatures went as high as the mid-90s (with a temperature of 98 reported at Midland), and outdoor parade events caused many to swoon and be treated for dehydration and heat exhaustion.

August 2007 – Michigan

Red Flag warnings were issued for many Upper Peninsula counties, with extreme heat one of the main causes of the wildfire risk.

(**NOTE:** Oftentimes, heat waves exacerbate drought conditions, resulting in significant agricultural losses. For example, the summer heat of 1980 worsened the effects of a drought that caused over $20 billion in agricultural damage. The drought / heat wave of the summer of 1999 caused a nationwide total of more than $1 billion in damage—mainly to agricultural crops in the Eastern U.S. The "dust bowl" conditions of the 1930s are widely known and described in practically any U.S. history text. The most damaging drought / heat wave in the past few

decades, however, was that of 1988, which affected the Central and Eastern United States. That event caused $40 billion in damage, in addition to contributing to many deaths. See the Drought section for more information.)

Significant Episodes of Extreme Cold Temperatures in Michigan

February 10 to 13, 1899 – Central and Western Lower Peninsula

Record low temperatures occurred multiple days in a row. At Baldwin (Lake County), four days in a row had record low temperatures: -36, -49, -48, and -37 degrees Fahrenheit. Grand Rapids also noted four days in a row that set all-time records: -21, -21, -23, and -24 degrees. At Big Rapids (Mecosta County), three days in a row set records: -33 degrees, -36 degrees, and -34 degrees. Similarly, Hastings and Muskegon also set records for three days in a row: the former with -26, -31, and -24, and the latter with -30, -29, and -22 degrees.

February 9, 1934 – Vanderbilt (Otsego County)

The coldest recorded temperature in Michigan was at this location in the northern Lower Peninsula—at 51 degrees below zero!

February 17, 1979 – Northern Michigan

This was one of the coldest days that ever occurred in Michigan, in terms of the widespread presence (across 14 monitoring locations) of top-ten coldest temperatures. At Trout Lake (Chippewa County), the low was -43 degrees. At Harrisville (Alcona County), it was -20 degrees. To the west, at Traverse City, the temperature went down to -37. At Standish (Arenac County), the low was -24 degrees, and at Houghton Lake, it was -34.

December 1993 to May 1994 – Upper Peninsula and Northern Lower Peninsula

This was the deep freeze disaster that was federally declared (#1028) and can be read about in the corresponding disaster report that appears in Attachment F of the 2011 Michigan Hazard Mitigation Plan. Ten counties (Gogebic, Ontonagon, Houghton, Marquette, Delta, Schoolcraft, Chippewa, Mackinac, Cheboygan, and Charlevoix) were declared disaster areas when record low temperatures caused the freezing and breakage of more than 3,200 water and sewer lines. Service to 18,700 homes was disrupted. Public costs were estimated at more than $12 million.

December 9, 1995 – Detroit

Winds averaged 20 to 25 mph and resulted in Wind Chill Temperatures of -30 to -35 degrees. Three deaths occurred from hypothermia in Detroit—two at street locations and one in a van. (The next morning, a man was also found frozen to death near his disabled vehicle 30 miles southeast of Ontonagon, where overnight low temperatures were -15 degrees and wind chill temperatures reached -60.)

February 3 to 5, 1996 – Stephenson (Menominee County)

There were three days in a row with record low temperatures in this area. The temperatures went down to -45, -44, and -41 at a spot 8 miles west-northwest of Stephenson, near the southern tip of the Upper Peninsula. On February 1, a few days before this event, a cold-related death was reported in Southeast Michigan, involving an elderly man who had wandered away from a nursing home in Detroit. That area of the state also experienced extreme cold, with Detroit's low on February 3 reaching -7 degrees. The temperature at Flint was zero degrees Fahrenheit, or below, for seven days in a row from January 31 to February 6.

January 17 to 19, 1997 – Southeast Michigan

The coldest weather of the winter occurred and resulted in two deaths from hypothermia—one in Bay City and the other (on January 12) in Warren. Low temperatures reached -6 at Detroit Metro Airport, and -9 at Flint's Bishop Airport.

January 1999 – Saginaw County

As a prelude, December 30, 1998 saw a damaging event at Saginaw Valley State University, when a sprinkler system pipe froze and burst, causing half a million dollars in damage at Brown Hall. Water was as deep as 3 to 4 inches in some offices by the time the break was discovered on New Year's Eve. Then, with January came more widespread events involving extreme cold. In Southeast Michigan, 3 persons died and 29 were confirmed as injured, as a cold blast crept around the sheltering Great Lakes and struck the southern Lower Peninsula. Temperatures went down to -13 at Ann Arbor and Tecumseh, and -10 in surrounding areas of Washtenaw, Lenawee, and Wayne Counties. The three deaths occurred in Oakland County on January 4. Confirmed injuries involved frostbite cases from a few hospitals in Oakland and Wayne Counties, and should be understood to represent only a small portion of the actual total from this event. On the early morning of January 11, a daily low temperature of -4 degrees was recorded, and on that day more than 120 water main breaks took place in the City of Detroit. A very large water main also ruptured in downtown Adrian, causing a shortage for 22,000 residents. Property damage was estimated at $1.3 million.

December 21 to 29, 2000 – Southeast Michigan (including the thumb area)

In late December 2000 after heavy snow had ended, extreme cold temperatures invaded southeast Michigan, including portions of the thumb region. Temperatures never got out of single digits on the 22nd, with Detroit seeing a high of only 4 degrees, after a morning low of -3. Flint wasn't much better, recovering from a low of -5 to reach 8 degrees in the afternoon. Christmas morning had a morning low of -13 degrees at Flint, setting an all-time record for the month of December. Three nights later, Flint would give the new record a run for its money, coming up just short with a low of -11 on the 28th. The arctic weather would take a toll on pipes. Both Ypsilanti High School and Chelsea High School had pipes burst over Christmas weekend, damaging classrooms. Several buildings on the University of Michigan campus in Ann Arbor had similar ruptures, including the School of Dentistry and Wolverine Tower. The cold also hampered shipping interests. Ice formation was extremely rapid on the Great Lakes and the connecting waterways. Several freighters got stuck in ice on both the Detroit River and Lake St Clair, blocking the shipping channel and bringing dozens of ships to a halt. Icebreaker assistance was needed to free the freighters. Ferry service on the St Clair River between Michigan and Canada was also interrupted due to ice jams. The end result was the 4th coldest December of all time in Detroit, and the 2nd coldest at both Flint and Saginaw. No other December on record comes close to this combination of heavy snow and brutal cold.

January 2003 – Lower Peninsula

Temperatures averaged well below normal across the Great Lakes region for much of January. For a three week period, the temperature never rose above freezing. Temperatures fell below zero for several nights during this period. Frozen pipes and water main breaks occurred in many areas of Detroit and its suburbs. The cities of Flint and Saginaw also had several reports of water main breaks. Several area schools had to cancel classes due to frozen pipes. Many homeless shelters were filled to capacity and area hospitals reported dozens of cases of frostbite. Three deaths were also attributed to this cold spell.

February 3 to 6, 2007 – Southeast Michigan

The worst cold wave event since the 1990s struck the region on February 3 and did not let up until February 6. Temperatures went as low as -7 at Saginaw and -5 at Flint, and winds of 15 to 25 mph included gusts of up to 35 mph. Wind Chill Temperatures ranged from -15 to -25 throughout almost the entire event, causing nearly every school district to cancel classes for one to two days. Hospitals reported numerous cold-related illnesses and frostbite cases. Area homeless shelters were filled to capacity. One death was attributed to the bad weather. Frozen pipes and water main breaks occurred throughout the area,

and flooding occurred in cases where these involved sprinkler system pipes. Total damages were estimated at $425,000. According to AAA, there were more than 20,000 vehicle service calls from Michigan due to the cold weather—more than had been seen for nearly 10 years.

February 9-11, 2008 – Upper Peninsula

Temperatures of 5 to 15 below zero combined with around 35 mph wind gusts drove bitterly cold wind chill values down to 25 to 40 below zero over much of Upper Michigan from the night of the 9th into the morning of the 11th. The powerful Arctic cold front pushed through the Upper Great Lakes on the afternoon and evening of the 9th and also produced blizzard conditions with lake effect snow and blowing snow over portions of Upper Michigan into the 10th. Many schools were either canceled or delayed on the 11th. AAA Michigan reportedly responded to numerous motorists' calls of dead batteries or fuel line freezes during the extreme cold.

January 14-18, 2009 – Southeastern Michigan

An arctic air mass become firmly established over the Great Lakes region on January 14th and persisted through the 18th, producing the winter season's coldest temperatures. Temperatures fell below zero all four days, with wind chill values in the 5 to 30 below range during the majority of the time. Detroit's low temperatures for January 14-18th were as follows: -3, -3, -15, -11. Wind chill values also plummeted to 20 to 40 below zero from late evening on the 13th through the morning of the 16th throughout much of the Upper Peninsula.

Programs and Initiatives

Extreme Summer Heat

Excessive Heat Events Guide Book – A product of the Environmental Protection Agency, in conjunction with FEMA, NOAA, and the Center for Disease Control and Prevention, this booklet can be obtained online at http://www.epa.gov/heatisland/about/heatguidebook.html. It provides an overview of heat impacts, sources of risk, notification and response programs, and recommendations.

Summer Heat Contingency Planning – In the aftermath of the extreme summer heat events of 1980 and the early 1990s, many major cities began to develop contingency plans for addressing heat-related hazards. The major elements of these plans include: 1) enhanced weather monitoring to better predict periods of extreme heat; 2) increased outreach to the elderly and other vulnerable individuals; 3) establishment of "cooling centers" for those most affected by the heat; and 4) enhanced public information campaigns to inform people of the perils of extreme summer heat and the resources available to them. In Michigan, cities such as Detroit and Lansing, among others, now address extreme summer heat contingencies in their emergency planning efforts.

Low Income Home Energy Assistance Program / State Emergency Relief Program – The LIHEAP is a federally-funded program to help eligible low income households meet their home heating or cooling needs. The money is used to help pay high utility bills or buy fans or air conditioners for persons considered at risk from extreme summer heat and it helps to pay for heat and weatherization during extreme winter cold. In 2003, about 4.6 million Americans received over $1.5 billion in assistance under the LIHEAP. Michigan received $40.8 million of that money to help aid low income citizens with heating expenses. In Michigan, the state Department of Human Services determines which families are eligible. In addition, the State Emergency Relief (SER) Program can also be used to alleviate the dangers of extreme heat and cold for Michigan families by providing financial assistance for home heating, electric and water bills.

Extreme Winter Cold

Since illness and death from hypothermia are not only seen in association with prolonged periods of cold temperatures, efforts to prevent hypothermia must be ongoing throughout periods of cooler weather. Because elderly persons are particularly vulnerable to hypothermia, prevention efforts must be primarily directed to them. Family, friends, neighbors, and local governmental and voluntary agencies can help ensure that all dwellings in which elderly persons reside are properly heated. This may require that a regular outreach program be established for this purpose. Local communities should also have adequate housing codes that require dwellings to have furnaces capable of maintaining sufficient room temperature for the winter conditions that will normally be expected. Governmental authorities, voluntary agencies and utilities can also assist those elderly persons that cannot pay all or part of their heating bills by providing financial assistance and/or making special arrangements for payment. Finally, governmental and voluntary agencies should, in conjunction with local media, continue to address the dangers associated with cold temperatures through regular public information and awareness campaigns. The combination of all these activities certainly will not prevent all cold temperature-related injuries and deaths, but it will go a long way toward preventing a large share.

FOG

Fog: Condensed water vapor in cloudlike masses lying close to the ground and limiting visibility.

Hazard Description

Fog forms near the ground when water vapor condenses into tiny liquid water droplets that remain suspended in the air. Many different processes can lead to the formation of fog, but the main factor is saturated air. Two ways that air can become saturated are by cooling it to its dew point temperature or by evaporating moisture into it to increase its water vapor content. Although most fog, by itself, is not a hazard because it does not actually apply destructive forces, the interaction between humans and fog can be a dangerous situation, sometimes resulting in disastrous consequences. It must be noted, however, that **freezing fog** (a hazard for which the National Weather Service does issue special statements) can cause direct harm by causing slickness on roadways and thus leading to serious transportation accidents (examples are provided later in this chapter).

Haze and Smog

Haze occurs when dust, smoke and other pollutant particles obscure the normal clarity of the sky. It occurs when dust and smoke particles accumulate in relatively dry air. When weather conditions block the dispersal of smoke and other pollutants, they concentrate and form a usually low-hanging shroud that impairs visibility and may become a respiratory health threat, as well as make safe driving more difficult. Dense haze caused by industrial pollution is also known as smog. This hazard may cause public health problems, so it is mentioned in this subsection but is not given particular emphasis since this plan has more of an emergency management focus. It is noted here as an area of potential overlap and future coordination with other agencies. The Michigan Department of Community Health and the Michigan Department of Natural Resources may do more with this issue in the future, if the effects become severe enough. Since it may be possible that climate change issues cause this to be a more frequent and ongoing concern in Michigan, it is mentioned here. In general, however, air quality has generally improved since the effects of the Clean Air Act, other legislation, regulatory measures, and shifts away from heavy industry in Michigan's economy.

Hazard Analysis

In considering severe and high-impact meteorological events, attention can easily become focused on the more dramatic storms. Tornadoes and hurricanes for example, are readily recognized by the general public and the meteorological community alike for their devastating consequences. Fog, on the other hand, does not lend itself as readily to this categorization. Yet, both in cost and casualties, fog has consistently impacted society, and in particular the transportation sector - sometimes with deadly consequences. Fog has played a contributing role in several multi-vehicle accidents over the past several years. While statistics suggest that highway accidents and fatalities, in general, have fallen, that trend is not evident with respect to accidents and fatalities caused by fog.

Fog can be very dangerous because it reduces visibility. Although some forms of transport can penetrate fog using radar, road vehicles have to travel slowly and use more lights. Localized fog is especially dangerous, as drivers can be caught by surprise. Fog is particularly hazardous at airports, where some attempts have been made to develop methods (such as using heating or spraying salt particles) to aid fog dispersal. These methods have seen some success at temperatures below freezing.

One major fog event is estimated to occur in Michigan approximately every two years. Property damage can be significant for vehicles, although real property and structures are usually unaffected. Fog has not yet been identified as one of the most significant hazards in any of Michigan's local hazard mitigation plans.

Impact on the Public

The primary risks from fog involve the dangers of traveling under conditions of limited visibility. Although some modes of transportation, such as aircraft, are well-regulated, other modes, including simple pedestrian travel, may involve risks that have not been properly accounted for by those who are focused merely on reaching their destination as quickly as possible. The most substantial impacts have recently involved drivers whose bad habits (primarily that of not maintaining safe speeds and following distances) proved to be simply unsustainable under

conditions of reduced visibility, resulting in severe crashes and subsequent roadway obstruction. In some circumstances, these conditions of reduced visibility can arise very quickly, although careless drivers, in their desire for fast travel conditions, may erroneously try to ignore the risks from reduced visibilities, in the hope that the condition will suddenly correct itself before any harm is caused.

Impact on Public Confidence in State Governance

This hazard is not expected to cause serious impacts upon public perception of the State's governance, so long as the cautionary messages issued by the National Weather Service and other agencies are received and understood. One reason for the estimated lack of impact on public confidence is that (1) the hazard is typically a localized one not presumed to be dealt with at a State level, (2) public announcements tend to be made when visibility gets too low, and (3) the airline industry operates under regulations (and also uses special equipment) to alleviate the risks from fog. The most serious incidents in Michigan, in which extensive chain-reaction car crashes have occurred on interstate highways, could arguably be connected with too lax of enforcement of fundamental traffic laws (primarily the infractions of following too closely and speeding), but a large proportion of the public, which persists in such unsafe and often unconscious driving habits, seems unlikely to perceive or understand any such hypothetical connection between these conditions.

Impact on Responders

In certain circumstances that require an emergency response, heavy fog may cause impediments and risks that would not normally be present. This is especially true in cases involving high-speed mechanized transportation that requires good visibility to maintain adequate and safe control and maneuvering ability, and for situations that involve search and rescue operations, for which visibility may be very important in locating and assisting victims. Response activities involving aircraft, for example, may be impaired or harmfully delayed by fog.

Impact on the Environment

Fog on its own does not directly impact the environment. However, fog may reduce visibility and can create dangerous traveling conditions. Transportation accidents involving a chemical release may cause great harm to the environment by releasing toxins into the soil, groundwater or air. (Please refer to the chapter on hazardous materials, in the Technological-Industrial Hazards section of this plan.)

Recent Significant Fog-Related Incidents in Michigan

January 11 to 13, 1995 – Michigan's Lower Peninsula

In January 1995, dense fog blanketed much of Lower Michigan from the evening of the 11th through the morning on the 13th. The fog caused numerous traffic accidents, which resulted in four fatalities. School openings were delayed in parts of southwest Michigan as visibilities dropped to near zero. Low visibilities caused most of the flights at Detroit's metro airport to be cancelled, delayed or diverted on the 12th. About seventy-five flights were also delayed or cancelled at Kent County International Airport in Grand Rapids.

October 25- 26, 2000 – Southeastern Metro Areas

On the morning of October 25, dense fog dropped visibilities to only about an eighth of a mile at the MBS International Airport (Saginaw County), causing most of the morning flights to be cancelled. In addition, several area school districts delayed the start of classes that morning. On the following morning, October 26, dense fog had a similar effect upon Metropolitan Detroit, causing dozens of flights to be delayed at the Detroit Metro Airport, and slowing the traffic of morning commuters on the area's roads and highways.

October 11 to 12, 2002 – Lapeer County

At certain times, dense fog reduced visibility to near zero in many locations. A 17 year old teenager was killed in Goodland Township when his pickup truck collided with a dump truck that was hauling a trailer. In a separate incident, a slightly older 19 year old driver failed to stop at a sign, and struck a school bus, resulting in one injury.

January 12, 2005 – Ingham County

Up to 200 cars collided on an expressway, in a chain of crashes blamed on heavy fog in Ingham County on January 12, 2005. Two people were killed and thirty-seven others were taken to local hospitals. It was the worst crash in mid-Michigan in recent years and shut down both lanes of Interstate 96 between Okemos and Webberville for several hours. The dense fog cut visibility to around ten feet during rush hour.

September 13, 2006 – Shiawassee County

Dense fog was reported to have caused three semi-trucks to roll over, a car crash and a separate car fire on I-69. As a result, that expressway had to be shut down in both directions between M-71 and the Grand River exit (a distance of about 4.5 miles), until the accidents could be cleared. A total of seven persons were injured in these crashes.

November 24, 2006 – Monroe County

In November, 2006 freezing fog caused zero visibility and created extremely dangerous driving conditions that led to numerous vehicle collisions. A semi-truck rollover accident resulted in the death of one man. Portions of I-275 were shut down for several hours due to the accident.

January 12, 2009 – Southern Lower Peninsula

The National Weather Service issued an advisory (for 17 counties) about freezing fog that would not only reduce visibility, as normal fog does, but would also freeze upon some roadways and "aggravate already slick conditions."

May 22, 2010 – Manistee County

Dense fog inhibited visibility in the area. At the entrance to Manistee Harbor, a fishing boat struck a pier, took on water, and submerged. Seven persons were rescued from the water, but there were two injuries and a death that still resulted (plus four persons who were less seriously harmed and merely required medical treatment on-site).

Programs and Initiatives

National Weather Service Detection Systems

The National Weather Service has completed a major modernization program designed to improve the quality and reliability of weather forecasting. The keystone of this improvement is Doppler Weather Surveillance Radar, which can more easily detect severe weather events that threaten life and property. Although the NWS Doppler Radar does not directly detect fog, the point of greatest importance is that the lead-time and specificity of warnings for severe weather have improved significantly, and a dense fog advisory is reported when widespread or localized fog reduces visibility to a quarter mile or less.

Weather satellites are useful tools in monitoring and detecting the formation of low stratus clouds and fog. Satellite images are obtained using two Geostational Operational Environmental Satellites (GOES) and NOAA polar satellites. Remote sensing with GOES and NOAA polar satellites allows for the continuous monitoring of weather across the Earth. Channels on these satellites allow the use of infrared images at night. During the daytime hours, visible satellite data can be used to locate areas of stratus clouds and fog, and water vapor imagery has also been found to be helpful.

Automated Surface Observation System (ASOS)

In the 1980s the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DOD) were faced with the need to find cost-effective ways to provide pilots with critical weather information. With NWS in the lead role, these federal agencies began development of automated sensors that were intended to eventually replace human weather observers. This automated sensor development culminated in the fielding of two systems: The Automated Weather Observation System (AWOS) and the Automated Surface Observation System (ASOS). AWOS and ASOS sensors provide continuous measurements of ceiling, visibility, temperature, dew point, wind speed and direction, and precipitation. All ASOS sites and some AWOS sites also have lightning detection and reporting, courtesy of the Automated Lightning Detection and Reporting System (ALDARS). Beginning in 1992, ASOS sites started to replace manual surface aviation observations. There are currently 882 federally sponsored ASOS sites around the country, and 24 of them are in Michigan. Fog is considered to be an obstruction to visibility when the temperature and dew points are within 5°F of each other. When the difference is more than five degrees, haze is reported.

Automated Weather Observing System (AWOS)

The Automated Weather Observing System (AWOS) is a suite of sensors, which measure, collect and disseminate weather data to help meteorologists, pilots and flight dispatchers prepare and monitor weather forecasts, plan flight routes, and provide necessary information for correct takeoffs and landings. An AWOS provides minute-to-minute updates that are usually provided to pilots by a VHF radio on a frequency between 118 and 136 MHz. An AWOS is categorized as either federal or non-federal. A federal AWOS was purchased and is currently maintained by the FAA. A non-federal AWOS is purchased and maintained by state, local, and private organizations. The sensors measure weather parameters such as wind speed and direction, temperature and dew point, visibility, cloud heights and types, precipitation, and barometric pressure. The AWOS does not predict weather, but may send current information to weather offices where forecasts are produced using this information along with computer model outputs, satellite photos and radar images. There are currently twenty-eight Automated Weather Observing Systems in Michigan.

Information Broadcast by an AWOS III

Airport Identifier	Zulu Time
Sky Conditions	Visibility
Wind Speed	Wind Direction
Temperature	Dew Point
Altimeter Setting	Remarks
Density Altitude	Wind Gusts

Advanced Weather Interactive Processing System (AWIPS)

The Advanced Interactive Processing System (AWIPS) is an interactive computer software system with a full suite of satellite imagery used to analyze meteorological and hydrological data. This system is used by the National Weather Service (NWS) to predict weather patterns, prepare forecasts, and issue weather-related warnings. AWIPS has been the foundation of the NWS operations for the past decade but was planned for update to AWIPS II in 2011. The newly updated software, which is being developed by the NWS and a private entity, will allow data to be processed more efficiently, resulting in greater accuracy of weather forecasting.

Lighthouses

Lighthouses are key parts of the infrastructure for water transportation, especially when dealing with the dangerous element of fog. Michigan has more lighthouses than any other U.S. state, by quite a large margin. In addition to traditional lighthouses, Michigan has many minor aids to navigation, in the form of cylindrical steel towers with navigation beacons at the top. These are known as D9 towers (named after the ninth Coast Guard district). Some of the D9 towers are regarded locally as being lighthouses, but most are not. Below is a list of lighthouses in Michigan that are still operational.

Operational Lighthouses in Michigan

Name	Lake	Name	Lake
Detroit River Light	Erie	Minneapolis Shoal Light	Michigan
Cheboygan River Range Front Light	Huron	Muskegon South Breakwater Lights	Michigan
Detour Reef Light	Huron	North Manitou Shoal Light	Michigan
Fort Gratiot Light	Huron	Escanaba Light	Michigan
Forty Mile Point Light	Huron	Fourteen Foot Shoal Light	Michigan
Harbor Beach Light	Huron	Point Betsie Light	Michigan
Martin Reef Light	Huron	Poverty Island Light	Michigan
Middle Island Light	Huron	Frankfort North Breakwater Light	Michigan
Poe Reef Light	Huron	Grand Haven South Pier Head Lights	Michigan
Pointe Aux Barques Light	Huron	Grays Reef Light	Michigan
Port Austin Reef Light	Huron	Seul Choix Pointe Light	Michigan
Port Sanilac Light	Huron	Skillagalee Light	Michigan
Presque Isle Lights	Huron	South Haven South Pierhead Light	Michigan
Round Island Passage Light	Huron	St. Helena Island Light	Michigan
Sturgeon Pointe Light	Huron	St. James Light	Michigan
Tawas Pointe Light	Huron	White Shoal Light	Michigan
Thunder Bay Island Light	Huron	Lake St. Clair Light	St. Clair
Alpean Light	Huron	St. Clair Flats South Channel Range	St. Clair
Spectacle Reef Light	Huron	Au Sable Light	Superior
Round Island Light	Mackinac Straits	Big Bay Point Light	Superior
Little Rapids Cut Range Light	St. Mary's River	Passage Island Light	Superior
Big Sauble Point Light	Michigan	Rock of Ages Light	Superior
Charlevoix Light	Michigan	Gull Rock Light	Superior
Charlevoix South Pier Light	Michigan	Huron Island Light	Superior
Holland Harbor (South Pier Head Light)	Michigan	Isle Royale Light	Superior
Lansing Shoal Light	Michigan	Keweenaw Waterway Entrance Light	Superior
Little Point Sable Light	Michigan	Manitou Island Light	Superior
Ludington North Breakwater Light	Michigan	Marquette Harbor Light	Superior
Manistee Light	Michigan	Mendota Light	Superior
Manistique (East Breakwater) Light	Michigan	Munising Range Lights	Superior
Menominee Light	Michigan	Eagle Harbor Light	Superior
		Whitefish Pointe Light	Superior

Michigan Lighthouse Assistance Program Grants

The Michigan Lighthouse Assistance Program was established by the Michigan legislature in 1999 to assist local groups in preserving and protecting lighthouses. The program arose from the efforts of the Michigan Lighthouse Project, out of concern for the disposal of some 70 lighthouses by the U.S. Coast Guard. Two-thirds of Michigan's lighthouses currently under federal ownership are scheduled for disposal within the next decade.

I. Natural Hazards
B. Hydrological Hazards

The following outline summarizes the significant hydrological hazards covered in this section:

1. Flooding
    - a. Riverine flooding
    - b. Great Lakes Shoreline Hazards
    - c. Dam failures
2. Drought

Most of the apparent impacts upon Michigan residents come from flooding. The section entitled Riverine flooding focuses upon inland areas and mapped floodplains, but consideration also needs to be given (where information allows) to urban flood hazards. Not all flooding occurs within recognized floodplain areas, or adjacent to rivers and lakes. In some cases, melting snow or other runoff waters pool in low-lying areas, damaging structures and inhibiting the function of roads and infrastructure. In other cases, some type of breakdown in an area's pumping or drainage infrastructure may result in a damaging flood. This type of flooding typically occurs in well-developed urban or suburban areas, and therefore is often called urban flooding. It tends to occur due to either (1) a breakdown in infrastructure or (2) inadequate planning and design standards on the part of builders, developers, engineers, architects, and planners.

One of Michigan's most heavily damaging federally-declared disasters (#1346) was the result of urban flooding, in September of 2000. A tremendous amount of damage had been caused by the entrance of water into basements throughout the densely developed central areas of the Metropolitan Detroit area. A historical problem with the development of many urban areas has involved the use of infrastructure whose original design was appropriate for the expected functions of the central city, but that has become overburdened with the effects of considerable "suburban" developments upstream, which send extra runoff into the system. In other cases, inadequate or deteriorating components exist at the connections between the drainage/sewage system and the structures they serve. Leaks, inadequate backflow preventers, drain openings clogged with leaves or other debris, the inadequacies of combined storm/sanitary sewer systems, and other problems can all cause water and sewer systems to experience problems under certain circumstances.

Fortunately, many important flood mitigation activities have taken place in recent decades, including the separation of combined sewer systems, the installation of backflow preventers in houses, and the dredging, expansion, and re-design of drainage systems. Numerous activities have demonstrated that municipalities and their utility providers have been able to learn from the hard lessons of the past. Nevertheless, a consideration of the types of flood events that have occurred in the past will help to keep such events from recurring in the future. Whether the urban flooding of September 2000, the basement flooding near Lake St. Clair in the early 1970s, or the channel changes and ice jams that caused flood problems to emerge in various other areas (such as Robinson Township, Ottawa County) over the past few decades, Michigan and its communities have learned lessons and taken many steps to mitigate flood impacts in the future. More importance is now placed on the preventive role of planners in coordinating their land development plans with the existing knowledge of local floodplains, wetlands, sewer capacity, and upstream development and hydrology. There has been an increased use of stormwater detention and retention areas, and a great deal of progress in the separation of combined sewer systems. However, drainage systems will always need to be maintained—to dredge out the sediment that would otherwise reduce stream capacities, to upgrade components of the infrastructure that have become worn or had their capacity exceeded, to identify and upgrade bridges that act as barriers to water flows, to remove dams that no longer provide a net benefit to nearby lands, to clear away clogging debris such as leaves and branches and logs, and to efficiently clear away ice jams that would similarly block and divert draining waters away from their intended, safe course.

Progress has also been made in collecting information that will help to identify and prioritize areas that are in need of flood mitigation activities. A system of stream gauges exists across Michigan and is linked with a real-time remote monitoring system through the internet (www.waterwatch.usgs.gov), allowing the assessment of risks and responses to both local flooding and regional drought conditions. A program of updated floodplain maps has also been proceeding (http://www.fema.gov/plan/prevent/fhm/mm_main.shtm), to not only update the boundaries of these maps, but also to

enable these maps to be readily used in digital information processing. A developing database of natural hazard events has been online for several years now (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms). Detailed aerial photos are now available at various sites on the internet, theoretically allowing a comparison between the identified at-risk areas and the actual structures and infrastructure that exist there. However, it will take years, plus adequate funding and staffing, for all of this new information to start to be adequately processed and incorporated into state and local plans.

Overlap Between Hydrological Hazards and Other Sections of the Hazard Analysis

Hydrological hazards stem from precipitation patterns, which are affected by the types of events described in the **Weather Hazards** sections on thunderstorms, severe winter weather, and extreme temperatures. Thunderstorms, snowstorms, and ice/sleet storms produce precipitation that can cause or exacerbate flooding—either immediately or when the frozen precipitation melts. In addition, ice can build up and block critical parts of drainage-ways and thus cause flooding. In the case of extreme temperatures, freeze events have caused flooding when pipes and water mains have broken, while heat waves may worsen the impacts of a drought. Severe winds and tornadoes tend to produce woody debris from the damage they do to trees, utility poles, etc., and this debris can, like ice, build up and jam streams or drains and thus cause flooding to occur. The same sort of debris might also arise from the **Ecological Hazards** of wildfires and invasive species (which can weaken and kill trees and thus cause them to fall).

Technological Hazards that inhibit the smooth functioning of drainage or water supply infrastructure may cause or exacerbate either the flooding or drought hazards. For example, sewer pumping and lift stations can go out of operation during a power failure (unless supplied with power by a back-up system or generators), and cause flooding to occur, or a reduction in water supply—especially in heavily developed urban areas. Transportation accidents also have the potential to cause power failures or even water main breaks, and thus produce flooding or exacerbate drought impacts.

Human-Related Hazards such as terrorism, sabotage, or civil disturbances, may cause water-related infrastructure to be disabled and thus cause or worsen flood or drought events. Public health emergencies may involve the contamination of already-limited water supplies during a drought and thus compound the human impacts of that hazard.

Examining the issue from a different direction, in terms of the effects that can be produced by flood or drought hazards, it can be seen that both flood and drought may, in their own different ways, reduce the quality of an area's water supply—possibly to the point of creating the risk of a public health emergency. Civil disturbances might result from a drought that involves a very limited supply of water for human consumption, or from some form of mismanagement, negligence, or culpability (real or imagined) on the part of some specific agency or actor. An example might be a damaging flood caused by a city's public works department, which might result in hostile protests and the destruction or sabotage of property.

It is also known that floods can cause hazardous materials incidents and transportation accidents, when facilities and transportation infrastructure is in the flooded area. Flood waters in urban or polluted areas tend to be contaminated with chemicals, debris from roadways and cars, and industrial residues. Flood waters can also carry the bodies of animals and humans, and exacerbate insect, snake, rodent, mold, and mildew problems that affect the public health of the area. Floods may hinder the response to emergency events (such as fires, accidents, or utility failures). Floodwaters may cause infrastructure failures, either due to physical impacts and erosion of roads and facilities, or by interfering with the functioning of equipment, electrical supply, etc. in the flooded area. Droughts increase the likelihood of wildfire events, and may also cause land subsidence.

Flood Hazards

Flood hazards in Michigan include dam failures, riverine flooding, and Great Lakes shoreline flooding and erosion. Flooding in Michigan can cause extensive property damage, reduced quality of life, and even injuries and deaths. The National Flood Insurance Program offers one form of security to communities that have flood-prone areas. As of December 2010, Michigan had 25,555 flood insurance policies in place. More information about this topic is provided in the Riverine Flooding section. Every year, flooding causes more than $2 billion of property damage in the U.S. In a high risk area, a home has at least a 26% chance of being damaged by a flood during the course of a 30-year mortgage, compared to a 9% chance of being damaged by fire. The map below shows the major rivers in Michigan and their watersheds (the area in which water runs off into the river and is then carried to one of the Great Lakes).

Riverine Flooding

The overflowing of rivers, streams, drains and lakes due to excessive rainfall, rapid snowmelt or ice.

Hazard Description

Flooding of land adjoining the normal course of a stream or river has been a natural occurrence since the beginning of recorded history. If these floodplain areas were left in their natural state, floods would not cause significant damage. Development has increased the potential for serious flooding because rainfall that used to soak into the ground or take several days to reach a river or stream via a natural drainage basin now quickly runs off streets, parking lots, and rooftops, and through man-made channels and pipes. Some developments have also encroached into flood plain areas and thus impeded the carrying capacity of the drainage area.

Hazard Analysis

Floods can damage or destroy public and private property, disable utilities, make roads and bridges impassable, destroy crops and agricultural lands, cause disruption to emergency services, and result in fatalities. People may be stranded in their homes for several days without power or heat, or they may be unable to reach their homes at all. Long-term collateral dangers include the outbreak of disease, widespread animal death, broken sewer lines causing water supply pollution, downed power lines, broken gas lines, fires, and the release of hazardous materials.

Floodprone areas are found throughout the state, as every lake, river, stream and open drain has a floodplain. The type of development that exists within the floodplain will determine whether or not flooding will cause damage. The Michigan Department of Environmental Quality (MDEQ) estimates that about 6% of Michigan's land – roughly the size of the southeast Michigan counties of Wayne, Oakland, Macomb, Washtenaw, and Monroe combined – is flood-prone, including about 200,000 buildings. The southern half of the Lower Peninsula contains the areas with the most flood damage potential.

The primary flooding sources include the Great Lakes and connecting waters (Detroit River, St. Clair River, and St. Marys River), thousands of miles of rivers and streams, and hundreds of inland lakes. Michigan is divided into 63 major watersheds, as shown in the map at the end of this section. All of these watersheds experience flooding, although the following watersheds have experienced the most extensive flooding problems or have significant damage potential: 1) Clinton River; 2) Ecorse River; 3) Grand River; 4) Huron River; 5) Kalamazoo River; 6) Muskegon River; 7) Saginaw River; 8) Rifle River; 9) River Raisin; 10) Rouge River; 11) St. Joseph River; and 12) Whitefish River. The flooding is not restricted to the main branches of these rivers.

Most riverine flooding occurs in early spring and is the result of excessive rainfall and/or the combination of rainfall and snowmelt. Ice jams are also a cause of flooding in winter and early spring. Log jams can also cause streams and rivers to be clogged up, and the backed-up waters to overflow the stream's banks. Either ice jams or log jams can cause dangerous flash flooding to occur if the makeshift dam-effect caused by the ice or logs suddenly gives way. Severe thunderstorms may cause flooding during the summer or fall, although these are normally localized and have more impact on watercourses with smaller drainage areas.

The map at the end of this section illustrates the major rivers and watersheds in the state. All of these rivers are susceptible to flooding. Although the flood hazard areas are spread throughout the state, the highest risk zones are in the populated areas of the southern two-thirds of the Lower Peninsula, including the glacial lake bed areas along Lake Erie, Lake St. Clair, and Saginaw Bay. As indicated earlier, the Michigan Department of Environmental Quality estimates that 6% of Michigan's land area, encompassing more than 200,000 buildings, is considered prone to flooding. Nationwide, annual flood losses amount to several billion dollars per year, along with over 140 fatalities on average. The monetary losses continue to rise. Michigan reflects this upward trend, with annual flood-related damages estimated to be between $60 and $100 million.

It is widely known that controlling floodplain development is the key to reducing flood-related damages. Although there are state and local programs to regulate new development or substantial improvements in flood-prone areas, floodplain development in many communities continues to increase, resulting in corresponding increases in potential future flood-related damages. The opportunity to mitigate flood hazards rests primarily with local government, since it

controls the regulation or direction of land development. Proper land use management and strict enforcement of building codes can make communities safer from flood hazards and help reduce the high costs of flood losses.

Urban and Other Flooding

Flooding may not always be directly attributable to a river, stream or lake overflowing its banks. Rather, it may simply be the combination of excessive rainfall and/or snowmelt, saturated ground, and inadequate drainage. With no place to go, the water will find the lowest elevations – areas that are often not in a floodplain. That type of flooding is becoming increasingly common in Michigan, as development outstrips the ability of the drainage infrastructure to properly carry and disperse the water flow. Flooding also occurs due to combined storm and sanitary sewers that cannot handle the tremendous flow of water that often accompanies storm events. Typically, the result is water backing into basements, which damages mechanical systems and can create serious public health and safety concerns. Other cases involve the ponding of waters across roads or in other low-lying areas. These additional types of flooding have not been given a separate chapter in this plan, but instead have been included in the descriptions of the Riverine flood hazards within this section.

In Michigan, there tends to be a major flood event about every two years. (A long list of flood events that resulted in disaster declarations follows in this section.) Every year, there are various local flood events that do not rise to the level of a state or federally declared disaster. Occasional deaths and injuries are reported in connection with these events—about one death every two years (not counting shoreline and Great Lakes deaths, which are covered in a separate section that follows) and a slightly larger number of injuries. Property damage is extensive, averaging at least 60 to 100 million dollars per year from major events.

Impact on the Public

Riverine flooding has caused displacement, property damage, and impacts on the health of residents. In some cases, utility providers have had facilities located in floodplain areas, and these facilities have been negatively impacted by flooding. Floodwaters can also prevent normal access to structures and facilities. Flooding is a hazard whose risks are routinely underestimated by the public, who may be inclined to attempt to walk or drive through shallow waters, or to allow their children and pets to play in the water as if it were part of a beach or swimming pool. Public education is vital so that there is widespread knowledge of the contaminants and germs that floodwaters contain, and a greater awareness of the risks that floodwaters pose to drivers and pedestrians. Drivers need to know that roads and bridges are often weakened and degraded by flood impacts, and that the road they assume is still there under shallow waters may no longer be intact. Less than a foot of flowing water can cause travelers to end up in a ditch or sinkhole, where persons may find that it is impossible to escape from a submerged vehicle under the pressures exerted by flowing water. Those who are tempted to walk through floodwaters should be informed that the waters tend to conceal the presence of open manholes and dangerous debris, such as rusty nails and metal, or live electrical wires that can cause harmful shocks.

Impact on Public Confidence in State Governance

In cases where any type of flood impact causes negative effects on structures, utilities, or the ability to access them, doubts can arise about the appropriateness of the planning and development mechanisms that may have allowed these flood impacts to occur. Doubts may also arise about the adequacy of the area's drainage infrastructure, whether in the form of channels/drains at the surface or storm sewer systems underneath the ground. Especially controversial are cases in which sewer systems are perceived to have caused basement flooding, and when the original designs of some sewer systems have had their capacities exceeded because of subsequent urban development trends, or when outmoded designs have caused waters to be contaminated with sewage. Public health issues in these cases can thus compound the problems caused by flooding itself, in ways that can seem to be attributable to government.

Impact on Responders

"Ordinary" flood waters in known floodplain areas and riparian lands often contain "hidden" hazards that may not be evident at first. Roads and bridges are often weakened and degraded by flood impacts, and a previously intact roadway area may have been eroded away under a seemingly shallow water surface. Floodwaters tend to conceal the presence of open manholes, dangerous debris (such as rusty nails and metal), and live electrical wires that can cause harmful shocks. Responders in a large flood event therefore deal with numerous hidden hazards as well as floodwaters that are often unclean (containing carcasses, garbage, and filth) and contaminated with chemicals (from area roads, cars, industrial sites, storage facilities, etc.).

Impact on the Environment

Flooding is generally part of a natural cycle that has many important and beneficial functions for the environment. Flooding raises the water table in wetlands, maintains biodiversity, and replenishes nutrients back into the soil. Additionally, higher water tables allow fish and water plants to recolonize and may also help to control some invasive species. Flooding, however, becomes a problem in the built environment. Drainage systems and city sewers can become overwhelmed, causing raw sewage to back up in basements and onto roadways. Flooding in urban areas can also cause increased runoff, which may carry pollutants through storm sewers into rivers and lakes. Urban runoff can be toxic, as it may contain garbage, fertilizers, oil and other residues from city streets.

Significant Riverine Floods

From 1975 to 2010, Michigan experienced 11 flood disasters that resulted in both a Presidential Major Disaster Declaration and a Governor's Disaster Declaration, and nine that resulted only in a Governor's Disaster Declaration. Combined, these flood disasters have caused hundreds of millions of dollars in damage to homes, businesses, personal property, and agriculture. Following are brief synopses of these flood events:

Flood disasters that resulted in Presidential and Governor's Disaster Declarations (opening up the full-range of federal and state supplemental disaster assistance):

April 1975 – Southern Lower Michigan

A series of intense thunderstorms struck southern Lower Michigan in the last two weeks of April 1975, spawning several tornadoes and causing widespread flooding over a 21 county area. Total public and private damage was nearly $58 million. A Presidential Major Disaster Declaration was granted for the 21 affected counties.

September 1975 – West Central / Central Lower Michigan

During the last week of August and first week of September 1975, intense thunderstorms and severe winds pounded a 16 county area in west-central and central Lower Michigan. Intense rainfall accompanying these storms caused widespread flooding, resulting in nearly $3 million in public and private damage. A Presidential Major Disaster Declaration was granted for the 16 affected counties.

March 1982 – Berrien and Monroe Counties

In March 1982 a combination of heavy rainfall and melting snow resulted in a flood disaster in Berrien and Monroe counties. Damage from that event was estimated at $12 million. One death was directly attributed to the flood conditions. A Presidential Major Disaster Declaration was granted for the two affected counties.

September 1985 – East Central Michigan

A year earlier, on September 5, 1985 severe thunderstorms struck east central Michigan, resulting in flooding in a six county area. As much as 7.45 inches of rain fell in Genesee County, which was hardest hit. The heavy rainfall caused flash flooding in many areas. Damage occurred primarily from overbank flooding on major rivers and streams. In addition, widespread flooding occurred in residential areas due to overburdened stormwater drainage systems. Over 2,500 homes were damaged, many roads were washed out and bridges damaged, and extensive agricultural damage occurred. Total public and private damage was estimated at $63 million. A Presidential Major Disaster Declaration was granted for the six counties.

September 1986 – Central Lower Michigan

Beginning on September 10, 1986 a slow moving low-pressure system moved across the middle of the Lower Peninsula. In a 24-hour period, the intense rainstorm produced rainfall ranging from 8 to 17 inches over an area 60 miles wide and 180 miles long. In Big Rapids, 19" of rain fell from September 9 to 12. The storm resulted in thousands of people being evacuated due to flooding. Five people were killed and 89 injured. (Up to ten were killed, if indirect effects are included.) About 30,000 homes suffered basement and structural damage and 3,600 miles of roadways were impassable as a result of the failure of four primary bridges and hundreds of secondary road bridges and culverts. The heavy rainfall resulted in 11 dam failures and 19 others that threatened with failure. Over $300 million in damage resulted from the flood. This was the worst flood in Michigan in 50 years. Thirty (30) counties were included in the Presidential Major Disaster Declaration granted for this flood.

June 1996 – Thumb Area

From June 21-23, 1996, intense thunderstorms producing heavy rainfall caused widespread and severe flooding in east central Michigan (the Thumb area). Some areas received over five inches of rain in a four to five hour period, which quickly outstripped the ability of the public drainage and sewer systems to handle the massive amounts of water runoff. The result was widespread flash flooding that caused numerous road and bridge washouts, culvert failures, damage to drainage channels, and damage to over 2,700 homes and 40 businesses. These storms also spawned a tornado that struck the city of Frankenmuth in Saginaw County, destroying six homes and one business, and damaging another 108 homes and nine businesses. The total public and private damage exceeded $25 million, most of which was flood-related. A Presidential Major Disaster Declaration was granted for the seven counties most heavily impacted by the storms and flooding.

July 1997 – Wayne and Macomb Counties

On July 2, 1997 a series of intense thunderstorms struck central and southeast Michigan, causing extensive wind damage. A Presidential Major Disaster Declaration was granted for five counties, primarily for the wind-related damage. However, the heavy rainfall produced by these storms caused flooding in Wayne and Macomb counties. Flood-related damage to the public water and sewer systems in those two counties totaled nearly $300,000. It should be noted that these flooding problems occurred at the same time the two counties were also faced with flooding problems associated with high water levels on the Great Lakes.

September 2000 – Wayne and Oakland Counties

A Presidential Major Disaster Declaration was granted to Wayne and Oakland Counties for urban flooding and sewer backups caused by intense rainfall on September 10 and 11, 2000. Although much damage took the form of basement flooding, which is not the type of flooding that is normally easy to see and broadcast through the mass media, this was one of the largest Michigan disasters ever to occur, in terms of the sheer amounts of documented damages to homes in Detroit and its surrounding cities. More details can be found in the report included as a part of the Michigan Hazard Mitigation Plan, in Attachment F. The event was denoted as federal disaster number 1346, and hazard mitigation funds made available to Michigan as a result of this disaster were instrumental in allowing local hazard mitigation plans to be developed in most areas of the state.

April 2002 – Western Upper Peninsula

In 2002, record-setting snowfall in February and March set the stage for flooding in April. During February and March of 2002, the north-central and western parts of Upper Michigan received over 100 inches of snowfall. The snow pack held over 11 inches of water. The snow quickly melted during a six day period (April 11-17), releasing all that water into creeks, streams, rivers and lakes. To heighten the situation, over two inches of rainfall occurred between April 10-12 over much of Upper Michigan, and record high temperatures in the 70s and 80s were recorded on the 15th and 16th. During those two days, a dramatic snow melt occurred with nearly two feet of snow melting away. To complicate matters further, moderate rain during the morning of the 18th and severe thunderstorms in the afternoon and evening dumped up to an additional 1½ inches of water over an already saturated and flooded Upper Peninsula. Following the rain and warm temperatures, streams and rivers began to rise and overflow. Many local and county roads were closed due to high water and several dams were in jeopardy of failing. Localized flooding of low-lying areas was common across the western and central Upper Peninsula. Major flooding on rivers and lakes occurred in eight Upper Michigan counties. Approximately 160 homes and businesses were affected by the rising waters. Major highways US-2, M-28, and M-64 were closed and 25 local and county roads were also closed due to high water. The Black, Montreal and Ontonagon Rivers all went above flood stage. A partial failure of the Presque Isle Wildlife Dam occurred on the Presque Isle River. Heavy rains and rapid melting of the snow pack contributed to the collapse of a 10 feet wide section of the earthen portion of the dam. The total cost of the flooding was estimated at $18.5 million. A Presidential Major Disaster Declaration was granted to six counties in the Upper Peninsula.

May-June 2004 – Southern Lower Michigan

In May 2004, a stationary front over Iowa, Wisconsin, and Michigan brought severe thunderstorms and heavy rains, which caused widespread flooding over Southern Lower Michigan. Much of the rainfall occurred in saturated areas that had experienced well-above average precipitation for the month of May. Over a 36 hour period (12 am May 22nd to 8 am May 23rd), 2 to 6 inches of rain fell across Southeast Michigan. Backyards were submerged under several feet of water. About 100 homes in Macomb County had damage of about $100,000 each. Road and bridge damage was expected to cost $10 million to repair. Total rainfall over the Grand River basin from May 20th through June 3rd varied from four to as much as seven inches. It was the biggest and longest duration flooding event in the past ten to twenty years across southwestern and south central Lower Michigan. It was the wettest May on record in Lansing and Muskegon and the third wettest May on record in Grand Rapids. A Presidential Major Disaster Declaration was granted to 23 counties in Southern Lower Michigan.

June 2008 – Lower Peninsula

Beginning on June 6, severe weather impacted twelve counties and two major population centers in the southwest and central Lower Peninsula. The National Weather Service reported two flash floods that exceeded the "100-year" threshold, confirmed three EF1 tornadoes, and also noted severe thunderstorms with winds exceeding 100 mph. Rainfall totals were estimated between 7 and 12 inches, exceeding the "100-year" rainfall values of 3.5 inches in less than 6 hours. Flash flooding washed out roads, flooded crops, and caused moderate flooding of rivers and streams. A large severe thunderstorm squall line affected Southwest Michigan on June 8, with four counties experiencing winds of 75 to 100 mph. Disaster declarations were requested and received in July, for 11 full counties.

Flood disasters that resulted in a Governor's Disaster Declaration only (activating state supplemental and limited federal disaster assistance):

June 1989 – Branch, St. Joseph, and Kalamazoo Counties

Heavy rainfall from May 31 to June 4, 1989 caused widespread flooding in Branch, St. Joseph and Kalamazoo counties. Over 400 homes incurred flood damage and many local roads washed out. (The storms also caused significant wind damage in some areas, particularly in the village of Manchester in Washtenaw County.) A Governor's Disaster Declaration was granted to provide assistance to the counties. In addition, SBA low-interest disaster loans were made available to home and business owners in the affected counties to help repair flood and wind-related damages.

July 1992 – Gogebic County

On July 2 and 3, 1992 severe storms struck Gogebic County, dumping over six inches of rain in a 24-hour period. The stormwater runoff caused creeks and rivers to overflow, causing severe damage to the road system throughout the county. Culverts were washed out, roads washed away, bridges were clogged with debris, and numerous residents were stranded because they could not use the road systems. Several road washouts were particularly severe – as much as 16-20 feet deep. The conditions were determined to be a serious threat to life safety and essential services. A Governor's Disaster Declaration was granted to provide assistance to the county in repairing the road washouts and clearing debris.

April 1993 – Shiawassee County

Flash flooding caused by heavy rains occurred in Rush and Hazelton Townships in Shiawassee County on April 21, 1993. The flooding caused widespread and severe washouts and structural damage to roads and bridges, greatly hampering the ability of emergency vehicles to provide timely emergency response to many parts of the county. As a result, the Governor granted a Disaster Declaration to the county to provide supplemental state assistance in repairing the damage and opening up the roads.

July 1994 – Lapeer, Sanilac, and Tuscola Counties

Heavy rains caused flash flooding in the counties of Lapeer, Sanilac and Tuscola on July 7-8, 1994. The flooding was widespread and caused severe damage to roads, drainage systems, and several homes. Saginaw County also suffered some storm-related damage, but to a lesser extent than the other three counties. Total public damage in Lapeer, Sanilac and Tuscola counties exceeded $1 million. Ninety-three homes incurred some level of damage. A Governor's Disaster Declaration was granted on July 8, 1994 to provide supplemental state assistance in the recovery.

May 1996 – Berrien County

On May 10, 1996 heavy rain in southern Berrien County caused widespread flash flooding that damaged nearly 100 miles of roadway (20 miles incurred severe damage) and numerous culverts, caused bridge washouts, collapsed basements, and undermined a railroad track. In addition, a dam in danger of overflowing had to be systematically drained by the Michigan Department of Environmental Quality and the U.S. Army Corps of Engineers. Public damage was estimated at $250,000. A Governor's Disaster Declaration was granted on May 22, 1996 to provide supplemental state assistance with the road, bridge, culvert and dam repairs. In addition, SBA low-interest disaster loans were made available to home and business owners that suffered uninsured damage from the flooding.

June 1997 – West Michigan

On June 20-21, 1997 a series of intense thunderstorms passed through West Michigan, spawning heavy rainfall that flooded many areas in Allegan, Ottawa, Barry, and Van Buren counties. Flood and wind damage was particularly severe in Allegan County, which reported four injuries, five homes destroyed and 234 damaged, and 37 businesses damaged. Damage to public facilities, roads and bridges, and culverts and drainage channels totaled nearly $1.5 million. Ottawa County officials reported damage to 111 homes and five businesses, in addition to nearly $700,000 in public damages. On June 27, 1997, a Governor's Disaster Declaration was granted to Allegan and Ottawa counties to provide supplemental state assistance for the public damage. The SBA provided low-interest disaster loans to those home and business owners that suffered uninsured damage from the flooding or wind.

April 1998 – Alpena County

Rapid snowmelt, combined with intense rainfall that began on March 30, 1998 and continued through April 2, resulted in severe flooding in the northeast portion of Alpena County. The flooding forced residents of 80 homes in one subdivision in the city of Alpena to be evacuated. A total of 221 homes and five businesses were damaged by the floodwaters. Public damage totaled over $700,000. A Governor's Emergency Declaration was granted to provide supplemental state

assistance to the county. In addition, a Small Business Administration (SBA) Declaration was also granted that provided low-interest disaster loans to the home and business owners impacted by the flooding.

February 2001 – Genesee County

Heavy rainfall and melting snow in parts of Southern Lower Michigan on February 9-10, 2001 caused flooding in many areas, but particularly in Genesee County. The worst flooding occurred in the southern half of Genesee County, where damage to roads, drains and other public facilities was extensive. Two major pumping stations were damaged by the flooding, resulting in estimated repair costs in excess of $7 million. Repair and floodfighting costs for the County Drain Commission totaled nearly $600,000, and the County Road Commission incurred an additional $1.8 million in flood-related damages and costs. The flooding also caused damage to dozens of homes and forced the evacuation of a 200-resident mobile home park. A Governor's Disaster Declaration was granted to provide supplemental state assistance to the county for public facility damages and costs. In addition, a Small Business Administration (SBA) Declaration was also granted that provided low-interest disaster loans to the home owners impacted by the flooding. (In addition to the damage in Genesee County, this flood event also caused damage to several hundred homes in Lansing and threatened to overtop the Shiawassee town Dam in Shiawassee County and the Peninsular Paper Dam in Ypsilanti. Fortunately, local and state officials were able to take steps to stabilize both dams and mitigate the threat of collapse.)

May 2003 – Marquette County

When the Mother's Day storm runoff from the Huron Mountains overwhelmed a dike holding back Silver Lake in northwest Marquette County, a wave of water inundated the Dead River basin all the way to Lake Superior in Marquette. A number of roads and bridges were washed out by the flood waters. An evacuation order was issued for about 1,800 people. The Presque Isle Power Plant at the Upper Harbor in Marquette was flooded and shut down for a number of days, resulting in shortages of electricity across western and central Upper Michigan. A Governor's Emergency Declaration was issued for Marquette County.

It is important to remember that the majority of riverine floods in Michigan do not result in a Governor's or Presidential Disaster Declaration.

An example was the flooding that occurred due to an ice jam on the Grand River in Robinson Township, Ottawa County, beginning on February 24, 1994 and continuing until the ice jam broke free on March 5. During that 10-day period, floodwaters damaged 45 homes and three businesses and caused the evacuation of 125 people from their homes until the waters receded. Sections of three county roads and a county park also sustained damage. The County formally requested a Governor's Disaster Declaration, but unfortunately there was little that could be done in the way of state assistance to help in the response and recovery to that particular event. However, the Governor did request, and receive, an SBA Disaster Declaration which made available low-interest disaster loans to those home and business owners that suffered uninsured losses in the flood.

This same area was affected by another ice jam in January 2005, causing the evacuation of about 50 homes. The area remained flooded for several days, as a prolonged cold spell slowed the flood water's retreat. The flooding, which occurred about 20 miles west of Grand Rapids, affected homes in two Robinson Township neighborhoods. At least one road was covered by three feet of water. The river usually runs about 10 feet in the area during that time of the year, but during the morning of the flood the water level had risen to 17.6 feet, which is 4.3 feet above flood stage. A state of emergency was declared in the township, but no Governor's or Presidential declaration was issued. However, the county did qualify again for the Small Business Administration's low interest disaster loans. Due to repeated flooding, the township is using Pre-Disaster Mitigation Program (PDMP) money to purchase up to 40 structures and 20 vacant parcels along the floodplain of the Grand River.

A similar example occurred on September 22-23, 2000 in Genesee County, when heavy rainfall caused the flooding of Thread Creek and inundated the city of Grand Blanc's storm and sanitary sewer systems as well as Genesee County's secondary sewer system. The flooding damaged nearly 50 homes and businesses. The Governor requested, and received, an SBA Disaster Declaration for this event, making low-interest disaster loans available to affected residents in Genesee County and the contiguous counties of Lapeer, Livingston, Oakland, Saginaw, Shiawassee, and Tuscola.

More recently, $11 million in flood damages were estimated from a September 2008 event around Comstock, in Kalamazoo County. An additional $5.25 million in flood damages were estimated in various statewide locations from the same September 2008 weather event. Part of the heavy rain was due to the remnants of Hurricane Ike. In December of 2008, about $3.6 million in flood damages occurred in Ottawa County. These events resulted in county emergency declarations. In March 2009, about $3 million in flood damages occurred along the River Raisin, in Monroe County. In June 2009, about $34 million in flood damages occurred to some 2,000 homes in Ottawa County, and $4 million in flood damages occurred in neighboring Allegan County. Both counties declared local states of emergency. August 2009, flooding took place in the southeastern part of Lapeer County, resulting in about $3 million in damage and the closure of M-53 for about 10 days, due to the highway being washed out. In August 2010, Mt. Pleasant experienced significant flooding and about $4 million in damages, including the partial flooding of the Central Michigan Community Hospital.

It is estimated that flood damages in Michigan average at least $60 million to $100 million per year. Only a fraction of those costs are covered under the flood insurance policies of the National Flood Insurance Program (over $1 million per year), and most of the rest seems to be absorbed out-of-pocket by individuals and communities. There are still no known sources of comprehensive flood information for Michigan. The NCDC database lists about $330 million in Michigan flood damages between 1993 and 2010 (an average of nearly $19 million per year), but it is known (from local planning efforts, project applications, and Michigan disaster declarations) that there are a great many local events that are not reported in that database. This plan has therefore focused upon disaster-level flood events. Much more study is needed to build a comprehensive understanding of all vulnerable areas within Michigan. Even the extensive flood mapping efforts do not cover all the possibilities that could arise from blocked drains, ice jams, low-lying areas, and infrastructure failures.

Significant Floods in Michigan Prior to 1975

March 24-27, 1904 - Central and Southern Lower Michigan

One of the most disastrous and extensive floods ever to occur in Michigan struck the central and southern Lower Peninsula during March 24-27, 1904. The flooding was caused by runoff resulting from intense rainfall, compounded by heavy snowpack and frozen soils. The flooding was most prevalent in the Grand, Kalamazoo, Saginaw and River Raisin basins, and to a lesser extent in the Huron and St. Joseph River basins. (The flood peaks from this flood are still the highest associated with spring flooding in the southern Lower Peninsula since recordkeeping began.) Damage was widespread and severe. In Grand Rapids, the flooding caused 14,000 persons to be homeless and damaged 2,500 homes and 30 businesses. Damage was estimated at $2 million. In Lansing, the flood was the most extensive in 135 years of local history. One fatality was reported, and damage was $200,000. In Bay City, numerous dams were undermined or washed away, and highway and railroad bridges were damaged – forcing a halt to railroad traffic. In Kalamazoo, a two square mile area was inundated, with damages estimated at $50,000.

April 4-11, 1947 - Central and Eastern Lower Michigan

The flood of April 4-11, 1947 was caused by a combination of snow and rainfall that began in late March of that year. In early April, two frontal systems dumped several inches of rain in many localities across central and eastern Lower Michigan. The areas primarily affected by the April, 1947 flood included the Clinton, Detroit, Grand, Kalamazoo, Saginaw and St. Clair Rivers, and the River Rouge. The city of Flint was particularly hard hit, with damage totaling $4 million. Damage was also significant in Northville, where floodwaters filled basements and inundated first floors of numerous residences.

April 24-26 and May 7-12, 1960 - Upper Peninsula

Record floods were widespread in the Upper Peninsula on April 24-26 and May 7-12, 1960. The April flood affected primarily the Montreal, Black and Presque Isle River basins in the western Upper Peninsula. The May flood affected the Manistique River basin in the central and eastern Upper Peninsula. Intense rainfall contributed to both flood events. Rainfall was 3-5 inches during April 24-26 and 4-6 inches during May 6-12. The size of the area covered by flooding was significant, but the damage was not. Because the area was neither densely populated nor developed, flood losses to residences, businesses, and public roadways and bridges were limited to $575,000.

Programs and Initiatives

USGS Water Watch

This web-based service provides real-time monitoring of stream gauge stations across the state. Each station can also be clicked on to obtain historical and statistical records. The web address is http://waterwatch.usgs.gov/new/.

The USGS "Water Alert" program

This service started in August of 2010 and is publicly available, with a website located at http://water.usgs.gov/wateralert/. The program enables users to elect to receive text messages and/or e-mails for any USGS stream gauge stations, when certain flow and water-quality conditions are observed. This program goes a bit beyond the services provided by the National Weather Service by allowing the user to set his or her own criteria for notification. This is useful for alerting users about the onset of a flood, or about a pre-flood stage that can allow advance actions to be taken to prepare and respond. It also offers some users the capacity to make inferences about stream locations beyond those in the existing list of official NWS flood forecast locations.

National Weather Service Doppler Radar

The National Weather Service has completed a major modernization program designed to improve the quality and reliability of weather forecasting. The keystone of this improvement is Doppler Weather Surveillance Radar, which can more easily detect severe weather events that threaten life and property – including weather events that can lead to riverine flooding. Most important, the lead-time and specificity of warnings for severe weather have improved significantly.

National Weather Service Watches/Warnings

The National Weather Service issues flood watches and flood warnings when conditions are right for flooding. A flood watch indicates meteorological conditions are conducive to flooding. People in the watch area are instructed to stay tuned to local radio or television stations for updates on flooding and weather conditions. When flooding is

imminent, a flood warning is issued. The warning will identify the anticipated time, level and duration of flooding. Persons in areas that will be flooded are instructed to take appropriate protective actions, up to and including evacuation of family members and removal or elevation of valuable personal property.

The State and local government agencies are warned via the Law Enforcement Information Network (LEIN), National Oceanic and Atmospheric Administration (NOAA) weather radio, and the Emergency Managers Weather Information Network (EMWIN). Public warning is provided through the Emergency Alert System (EAS). The National Weather Service stations in Michigan transmit information directly to radio and television stations, which in turn pass the warning on to the public. The National Weather Service also provides detailed warning information on the Internet, through the Interactive Weather Information Network (IWIN).

Severe Weather Awareness Week

Each spring, the Emergency Management and Homeland Security Division, Michigan Department of State Police, in conjunction with the Michigan Committee for Severe Weather Awareness, sponsors Severe Weather Awareness Week. This annual public information campaign focuses on severe weather hazards such as tornadoes, thunderstorms, lightning, hail, high winds, and flooding. Informational materials on flooding and the other severe weather hazards are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public.

Map Modernization Program

The Federal Emergency Management Agency (FEMA) is continuing its program to update the nation's floodplain maps. This program is commonly referred to as Map Mod. The MDEQ is collaborating with FEMA in this effort through the Cooperating Technical Partners (CTP) Program. The MDEQ is playing an integral role in the mapping program by performing studies, reviewing studies prepared by others, and overseeing the mapping effort in Michigan. More information about the Map Modernization effort is at http://www.fema.gov/plan/prevent/fhm/mm_main.shtm.

Once FEMA has completed its production of new digital flood insurance rate maps for a county, the communities within the county will need to consider formal adoption of the new maps to either become eligible to join the NFIP or to maintain participation. The MDEQ has developed model documents for communities to use for the adoption process. Those documents and further discussion can be viewed and accessed on the NFIP Map Modernization Map Adoption page. Digital maps can be acquired or perused at FEMA's online Map Service Center.
http://www.msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1&userType=G

Michigan Flood Hazard Regulatory Authorities:

Land Division Act, 1996 PA 591, as amended by 1997 PA 87 – The Land Division Act governs the subdivision of land in Michigan. The Act requires review at local, county and state levels to ensure that the land being subdivided is suitable for development. From a flood-hazard viewpoint, a proposed subdivision is reviewed for proper drainage by the County Drain Commissioner, and for floodplain impacts by the MDEQ, Water Resources Division.

Provisions of the Act and its Administrative Rules require that the floodplain limits be defined and prescribe minimum standards for new residential developments in areas within or affected by a floodplain. Restrictive deed covenants, filed with the final plat, stipulate that any building used or capable of being used for residential purposes in areas within or affected by a floodplain shall meet the following conditions:

- Be located on a lot having a buildable site of 3,000 square feet of area with its natural elevation above the floodplain limit. (Lots with less than 3,000 square feet of buildable area above the floodplain may be filled to achieve that area.)
- Be served by streets within the proposed subdivision that have surfaces no lower than one foot below the elevation defining the floodplain limits.
- Have lower floors, excluding engineered basements, that are not lower than the elevation defining the floodplain limits. (The Michigan Building Code requires the lowest floor to be at least one foot above the 1% annual chance flood elevation level, and this requirement includes regular basements.)
- Have openings into the basement that are not lower than the elevation defining the floodplain limits.

- Have basement walls and floors that are below the elevation defining the floodplain limits made watertight and designed to withstand hydrostatic pressures.
- Be equipped with a positive means of preventing backup from sewer lines and drains serving the building.
- Be properly anchored to prevent flotation.

Floodplain Regulatory Authority, found in Water Resources, Part 31 of the Natural Resources and Environmental Act, 1994 PA 451, as amended – The floodplain regulatory portion of Act 451 regulates residential occupation of high-risk flood hazard areas and ensures that other uses do not obstruct flood flows. A permit is required from the MDEQ for any occupation or alteration of the 100-year floodplain. In general, construction and fill may be permitted in the portions of the floodplain that are not floodway, provided local ordinances and building standards are met. (Floodways are the channel of a river or stream and those portions of the floodplain adjoining the channel that are reasonably required to carry and discharge a 100-year flood. These are areas of moving water during floods.) New residential construction is specifically prohibited in the floodway. Non-residential construction may be permitted in the floodway, although a hydraulic analysis may be required to demonstrate that the proposed construction will not harmfully affect the stage-discharge characteristics of the watercourse.

The Act does not apply to watersheds that have a drainage area of less than two square miles. (Those small watersheds are considered to be local drainage systems, and do not fall under the Floodplain Regulatory Authority.)

Soil Erosion and Sedimentation Control, Part 91 of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended – This portion of the Act seeks to control soil erosion and protect the waters of the state from sedimentation. A permit is required for all earth changes that disturb one or more acres of land, as well as those earth changes that are within 500 feet of a lake or stream. The Act itself does not address flood hazards, per se. However, if sedimentation is not controlled, it can clog streams, block culverts, and result in continual flooding and drain maintenance problems.

Inland Lakes and Streams, Part 301 of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended – This portion of the Act regulates all construction, excavation, and commercial marina operations on the State's inland waters. It ensures that proposed actions do not adversely affect inland lakes, streams, connecting waters and the uses of all such waters. Structures are prohibited that interfere with the navigation and/or natural flow of an inland lake or stream. Though reduction of flooding is not a specific goal of this Act, minimizing restrictions on a stream can help to reduce flooding conditions.

Wetlands Protection, Part 303 of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended – This portion of the Act requires a permit from the Department of Environmental Quality for any dredging, filling, draining or alteration of a wetland. This permitting process helps preserve, manage, and protect wetlands and the public functions they provide – including flood and storm water runoff control. The hydrologic absorption and storage capacity of wetlands allows them to serve as natural floodwater and sedimentation storage areas. The Act recognizes that the elimination of wetland areas can result in increased downstream flood discharges and an increase in flood damage. Permits for wetland alterations are generally not issued unless there is no feasible alternative and the applicant can demonstrate that the proposal would not have a detrimental impact upon the wetland's functions.

Natural Rivers Program, Part 305 of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended – The Natural Rivers Act was originally passed in 1970, and has been incorporated as Part 305 of the Natural Resources and Environmental Protection Act. The purpose of this program is to establish and maintain a system of outstanding rivers in Michigan, and to preserve, protect, and enhance their multi-faceted values. Through the natural rivers designation process, a Natural River District is established (typically 400 feet either side of the riverbank) and a zoning ordinance is adopted. Within the Natural River District, permits are required for building construction, land alteration, platting of lots, cutting of vegetation, and bridge construction. Not all of the zoning ordinances on the natural rivers have the same requirements, but they all have building setback and vegetative strip requirements. Although the purpose is not specifically to reduce flood losses, by requiring building setbacks (in many cases prohibiting construction in the 100-year floodplain), flood hazard mitigation benefits can be realized.

Dam Safety, Part 315 of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended – The Dam Safety Unit within the Land and Water Management Division of MDEQ has the primary responsibility to ensure dam safety within the state. Following the September, 1986 flood in central Lower Michigan (see the description in the Significant Riverine Floods section), the current Dam Safety Act was passed to ensure that dams are built and maintained with necessary engineering and inspections for safety of the public and the environment. The Department of Environmental Quality is required to review applications involving construction, reconstruction, enlargement, alteration, abandonment and removal for dams that impound more than five acres of water and have a height of six feet or more.

Refer to the Dam Failures section for more information on this regulatory authority and hazard.

Manufactured Housing Commission Act, 1987 PA 96, as amended – The Michigan Manufactured Housing Commission Act and its implementing Administrative Rules provide regulation on the placement of manufactured homes, and establish construction criteria. Manufactured homes are prohibited from being placed within a floodway, as determined by the Department of Environmental Quality. In addition, manufactured homes sited within a floodplain must install an approved anchoring system to prevent the home from being moved from the site by floodwaters (or high winds), and be elevated above the 100 year flood elevation.

Local River Management Act, 1964 PA 253 – Enacted in 1964, the Local River Management Act provides for the coordination of planning between local units of government in order to carry out a coordinated water management program. Implementation of the water management program occurs through the establishment of watershed councils. These councils conduct studies on watershed problems, water quality, and the types of land uses occurring within the watershed. Watershed councils have the authority to develop River Management Districts for the purpose of acquisition, construction, operation, and financing water storage and other river control facilities necessary for river management. The provision to allow the acquisition of land adjacent to the river, for the purpose of management, aids in regulating the development of land prone to flooding.

State Flood Hazard Mitigation Plan

Michigan's governors have long recognized the need for flood mitigation activities. Executive orders and directives have been issued to create a State Flood Hazard Mitigation Plan. This responsibility has been shared by the Michigan Department of Environmental Quality, the Michigan State Police, and other governmental departments, in coordination with the MHMCC (now the MCCERCC). Thus, those parts of the Michigan Hazard Mitigation Plan that deal with flooding have also served the function of providing the most recently updated detail for the State Flood Hazard Mitigation Plan, which (starting in 1977) mandated (1) the consideration of flood risks in the construction of buildings and roads, (2) the identification and mitigation of flooding at such facilities, where practical and economically feasible, (3) the attachment of appropriate restrictions upon flood prone lands that may be sold or given to non-state entities, and (4) the inclusion of flood hazard considerations by all state agencies involved in land use planning activities. Details regarding flood regulations, land use development efforts, coordination, and educational activities appear in this plan, including its list of hazard mitigation strategies.

Floodplain Service Program

The need to identify a flood hazard area before construction is essential to the goal of flood mitigation. The MDEQ regularly provides floodplain information to public and private interests as part of its Floodplain Service Program under the Water Resources Division. The goal of the program is to provide 100-year floodplain information to interested parties so that informed purchase or development decisions can be made. In addition to providing floodplain information, the MDEQ will provide information on land and water "interface" permit requirements and on building requirements relating to construction in flood hazard areas.

National Flood Insurance Program

For many years, the strategy for reducing flood damages followed a structural approach of building dams and levees and making channel modifications. However, this approach did not slow the rising cost of flood damage, and did not provide an affordable opportunity for individuals to purchase insurance to protect themselves from flood damage. It became apparent that a different approach was needed.

The National Flood Insurance Program (NFIP) was instituted in 1968 to make flood insurance available in communities that have agreed to regulate future floodplain development. As a participant in the NFIP, a community must adopt regulations that: 1) require any new residential construction within the 100-year floodplain to have the lowest floor, including the basement, elevated above the 100-year flood elevation; 2) require non-residential structures to be elevated or dry floodproofed (the floodproofing must be certified by a registered professional engineer or architect); and 3) require anchoring of manufactured homes in floodprone areas. The community must also maintain a record of all lowest floor elevations or the elevations to which buildings in flood hazard areas have been floodproofed. In return for adopting floodplain management regulations, the federal government makes flood insurance available to the citizens of the community. In 1973, the NFIP was amended to mandate the purchase of flood insurance, as a condition of any loan that is federally regulated, supervised or insured, for construction activities within the 100-year floodplain.

As of December 2010, there were 25,555 active flood insurance policies in Michigan. Officials from FEMA and the MDEQ estimate that only 15% of all flood-prone structures in Michigan eligible to purchase flood insurance actually have flood insurance. Furthermore, since only about 49% of the communities in Michigan participate in the NFIP, there are thousands of structures that are floodprone, but are not eligible to purchase flood insurance. (There were 867 participating communities as of December 22, 2010, and another 108 communities that were mapped but not participating—probably since the mapping was recently completed under FEMA's Map Modernization program.)

The following table provides listings of the 10 counties in Michigan which have the highest number of flood insurance policies in effect. The list is one indicator of the areas in Michigan that have the greatest potential for flood damage:

Top 10 Michigan Counties – Number of Flood Insurance Policies

County	Number of Policies
Wayne	3,975
Macomb	3,404
Monroe	2,452
St. Clair	2,085
Saginaw	1,828
Bay	1,368
Oakland	1,318
Ingham	957
Kent	721
Washtenaw	689

As of 12/31/2010; Source: Michigan Department of Environmental Quality

The top counties include the most urbanized areas of the state. The top counties are also located along the eastern shoreline of Michigan, along Lake Huron, Lake Erie, Lake St. Clair, and/or a connecting waterway such as the Detroit River or the St. Clair River.

The following table presents a slightly different ranking, in terms of the total amount of coverage, per county:

Top 10 Michigan Counties – Flood Insurance Coverage

County	Coverage (Thousand of Dollars)
Macomb	618,133
Wayne	586,507
Monroe	375,047
St. Clair	354,144
Oakland	286,764
Saginaw	201,381
Bay	189,667
Ingham	165,476
Kent	141,864
Washtenaw	129,390

As of 12/17/2010; Source: Michigan Department of Environmental Quality

Since 1978, about $45.1 million in claims have been paid due to flooding in Michigan. It should be remembered that officially claimed flood losses are only a small percentage of the total losses that are occurring from flood events. The flood insurance losses provide a good indication of where flooding problems currently exist, but they do not provide a good estimate of the total losses that are actually occurring. The following table lists the top ten Michigan counties in terms of highest amounts of flood insurance claims paid.

Top 10 Michigan Counties – Flood Insurance Claims Paid

County	Claims Paid (thousands of dollars)
Monroe	5,699
Wayne	4,094
Macomb	3,678
Kent	3,372
Bay	3,122
St. Clair	2,959
Berrien	2,654
Oakland	2,645
Saginaw	2,272
Ottawa	2,146

As of 12/31/2010; Source: Michigan Department of Environmental Quality

Since the Great Lakes experienced record high lake levels in 1985-86, and again in 1997-98, it is not surprising that seven of the ten communities showing the highest amount of flood insurance payouts occurred on the Great Lakes and connecting waterways. It should also be noted that the major riverine flood events that have occurred since 1978 have largely occurred in the inland and more rural areas of the state, which typically have lower flood damage potential.

The following tables present ranked lists of NFIP-participating communities, according to flood insurance coverage amounts, number of policies, and total claim amounts.

Top 10 Michigan Communities – Flood Insurance Coverage

Community	Coverage (Thousand of Dollars)
Harrison Township	243,621
Clay Township	190,730
St. Clair Shores, City of	177,661
Dearborn Heights, City of	154,184
Ann Arbor, City of	89,199
Gibraltar, City of	77,473
Lansing, City of	65,997
Chesterfield Township	64,277
Hamburg Township	50,400
Monroe Charter Township	49,957

As of 1/2011; Source: Michigan Department of Environmental Quality

Top 10 Michigan Communities – Number of Flood Insurance Policies

Community	Active Policies
Dearborn Heights, City of	1,343
Harrison Township	1,264
Clay Township	1,108
St. Clair Shores, City of	1,009
Frenchtown Charter Township	625
Gibraltar, City of	465
Lansing, City of	457
Bangor Township	438
Luna Pier, City of	352
Monroe Charter Township	315

As of 1/2011; Source: Michigan Department of Environmental Quality

Top 10 Michigan Communities – Flood Insurance Claims Paid

Community	Claims Paid (thousands of dollars)
Grand Rapids, City of	1,866
Midland, City of	1,823
Gibraltar, City of	1,807
Farmington Hills, City of	1,688
Luna Pier, City of	1,117
La Salle Township	1,109
Frenchtown Charter Township	1,097
Clay Township	1,080
Kalamazoo, City of	870
Castleton Township	863

As of 1/2011; Source: Michigan Department of Environmental Quality

The "Community Rating System" allows participating communities to earn discounts for their residents' flood insurance premiums. The following communities (as of October, 2010) are all CRS participants that have earned discounts of between 5% and 25% on the policy premiums for their NFIP-insured properties:

CRS Class 9 (5% discounts earned on NFIP policy premiums): Fraser Township, Park Township, Plainfield Township
CRS Class 8 (10% discounts earned): Bedford Township, Brooks Township, Commerce Township, Gibraltar City, Hamburg Township, Luna Pier City, Portage City, Richfield Township, Saginaw Township, Saugatuck City, Shelby Township, Taylor City, Taymouth Township, Zilwaukee City
CRS Class 7 (15% discounts earned): Dearborn Heights City, Novi City, Sterling Heights City
CRS Class 6 (20% discounts earned): Vassar City
CRS Class 5 (25% discounts earned): Midland City

Flood Management and Mitigation Education

The Water Resources Division of MDEQ has developed several guidance documents aimed at local officials involved in floodplain management and flood mitigation. These guidebooks are used as textbooks in training workshops and as a reference for day-to-day activities.

The Emergency Management and Homeland Security Division, Department of State Police, has developed a local hazard mitigation planning handbook for local officials. This guidance document provides an overview of a planning process that communities can follow to help reduce their vulnerability to a wide array of natural, technological and human-made hazards – including riverine flooding.

The Water Resources Division and the Emergency Management and Homeland Security Division periodically conduct floodplain management and flood hazard mitigation training courses and workshops for state and local officials. The Water Resources Division also conducts regular community assistance contacts and visits as part of its administrative duties under the National Flood Insurance Program. Such contacts/visits are a form of training aimed at improving a community's implementation of floodplain management practices. In addition, the Water Resources Division continuously conducts flood hazard workshops for lenders, realtors, building officials, engineers, citizens and any other interested parties.

Road Infrastructure Flood Mitigation Committee

Following the September, 1986 floods, the Michigan Department of Transportation (MDOT) formed a flood mitigation committee to determine ways to lessen damage to road infrastructure caused by riverine flooding. The committee consisted of representatives from the County Road Association of Michigan, the Federal Highway Administration, the MDEQ, and MDOT. One of the primary purposes of the committee was to identify reasons for failed stream crossings and damaged roads during a flood event, and make recommendations for achieving more flood-resistant stream crossings. The committee published its findings and recommendations in a report that is used today as a reference guide for officials involved in road infrastructure design and maintenance.

As a result of one of the committee's recommendations, the MDEQ regularly sponsors workshops and seminars on stream crossing design and erosion control practices. These workshops are geared toward design engineers at the state, county and local levels, in addition to private consultants and county drain commissioners.

1980s Voluntary Community-Initiated Acquisition and Relocation Projects

With the understanding that acquisition and relocation is one of the best ways to guarantee that homes and businesses will not continue to be repeatedly damaged by cyclical flooding, in the 1980s the cities of Owosso and Midland initiated voluntary acquisition and relocation programs using various community and privately-generated funds.

The **city of Owosso, Shiawassee County,** used Small Cities Block Grants and private investment to relocate 40 homes out of the floodplain, revitalize downtown development, and develop a park along the Shiawassee River.

The **city of Midland, Midland County,** rejected U.S. Army Corps of Engineer's proposals for dikes and channel improvements as too expensive and visually unfavorable. Instead, the City used Dow Foundation Grants and matching general revenue funds to purchase floodprone structures and return the property back to its natural state. The ongoing purchase of properties has been entirely voluntary. Over 120 structures were purchased and removed from the floodplain.

Flood Mitigation Assistance Program (see also the other state-administered federal grants listed next)

With the passage of the National Flood Insurance Reform Act of 1994, Congress authorized the establishment of a federal grant program to provide financial assistance to states and local communities for flood mitigation planning and activities. The Federal Emergency Management Agency (FEMA) has designated this the Flood Mitigation Assistance Program (FMAP). The FMAP funds can be used to fund activities that reduce the risk of flood damage to structures insurable under the National Flood Insurance Program. The FMAP is state-administered (Emergency Management and Homeland Security Division) and cost-shared on a 75% federal, 25% local basis.

Three types of FMAP grants are available: 1) **planning grants** to assist local communities in developing flood mitigation plans; 2) **project grants** to fund eligible flood mitigation projects, with emphasis on repetitively or substantially-damaged structures insured under the NFIP; and 3) **technical assistance grants** to assist the State in providing technical assistance to applicants in applying for the program or implementing approved projects.

Repetitive Flood Claims Program

The Repetitive Flood Claims Program (RFCP) was created pursuant to Section 1323 of the National Flood Insurance Act of 1968, as amended by the Bunning-Bereuter-Blumenauer Flood Insurance Reform Act of 2004, with the goal of reducing flood damages to individual properties for which one or more claim payments for losses have been made under flood insurance coverage and that will result in the greatest savings to the National Flood Insurance Fund in the shortest period of time. RFCP funds may only mitigate structures that are located within a community that cannot meet the cost share or management capacity requirements of the FMAP. Grants under the RFCP are funded at 100% federal share. The RFCP is an annually appropriated, nationally competitive grant program. Eligible RFCP project activities include: 1) voluntary acquisition or elevation of qualifying structures, 2) dry floodproofing of qualifying non-residential structures, and 3) minor localized flood risk reduction projects that protect qualifying structures.

Severe Repetitive Loss Program

Similar to RFCP (listed above) but eligible properties are selected only from a special list noted as having suffered severe repetitive losses, and at up to a 90%/10% federal/local match share.

State and Federally-Assisted Relocation of Floodprone Properties

The State of Michigan has been very pro-active in its initiation and participation in the acquisition and relocation of floodprone properties, in both pre and post-disaster situations, using federal Hazard Mitigation Grant Program (HMGP) and Flood Mitigation Assistance Program funds. For extensive lists of these projects, and related information, please refer to Attachment C (Hazard Mitigation Funding Sources and Projects) in the Michigan Hazard Mitigation Plan.

Other State and Federally-Assisted Flood Hazard Mitigation Projects

The State of Michigan has used a variety of federal funding sources to assist in the implementation of flood mitigation projects. Those funding sources have included (1) the Hazard Mitigation Grant Program (HMGP), (2) the Flood Mitigation Assistance Program (FMAP), (3) the Pre-Disaster Mitigation Program (PDMP), (4) the Public Assistance Grant Program (PAGP), (5) the Presidentially Declared Disaster Assistance to Individuals and Households program, (6) Section 1362 of the National Flood Insurance Program (no longer in existence), (7) Community Development Block Grants (CDBG), and (8) Farmers Home Administration (FmHA) loans. State and local funds have been used to match the federal sources of funding. Please refer to Attachment C in the Michigan Hazard Mitigation Plan (Hazard Mitigation Funding Sources and Projects) for more information.

Flood Guidance for Local Hazard Mitigation Planning

Riverine flooding is a hazard that has been modeled for many decades now, and has some of the clearest methods of detailed analysis. Communities that are members of the NFIP probably have floodplain maps (called Flood Insurance Rate Maps, or FIRMs) that show where the floodplain areas are in the community and provide Base Flood Elevation (BFE) measurements. These calculations are based on surveying the topographical, hydrological, pedological, and land cover characteristics of the area's watershed. The result is a statistical model—a “100-year” floodplain area has a 1% chance of flooding in a given year, and the BFE is the water depth associated with an event of that probability. Some areas may flood less frequently, such as a 500-year floodplain which has a 1-in-500 chance of flooding in a given year. The names "100-year" and "500-year" can be very misleading. A "100-year" level flood may occur several times in a century, just as it is possible to flip a coin and get tails many times in a row. For detailed analysis of flooding, the basic principle of risk is that there is a 1% chance per year of flooding that is at the BFE level. For example, if BFE is 365' and the elevation of a structure's first floor is 363' above sea level, then the result would be floodwaters that are two feet over the ground floor of that structure. Lesser flooding is likely to occur with even greater frequency—if two feet of floodwaters hit that structure with 1% probability, the likelihood of getting just a few inches of floodwaters is even greater in a given year. Conversely, the likelihood of flooding that has three or four foot depths is far less than a 1% annual chance. FEMA models for flooding divide these events into different degrees of severity, based on their likelihood of annual occurrence. A few inches of water may be a "10-year" event in one area, but a "100-year" event somewhere else. Within the same floodplain area, a structure's elevation (and whether it has a

vulnerable basement) may make all the difference between suffering severe damages, and experiencing no damages. Ideally, flood risk information can be combined with structural information (such as might be available through a building department or assessor's office) and a Geographic Information System (GIS) could make the analysis of such information easier.

It must also be noted that for some communities, these flood studies have become rather old and have not yet been verified or updated under the current Map Modernization program. Therefore, those who refer to these maps for hazard mitigation planning purposes are advised to review the original study's data, model assumptions, and conclusions, to make sure that they are still representative of current conditions.

Once risk categories have been established for vulnerable structures, the amount of damage from flood events can be estimated using FEMA techniques. The basic technique is to find the replacement value of the structure, and to estimate damages by equating different flood depths with appropriate percentages of that replacement value. The following table estimates damages to structures, in terms of the percentage of a building's replacement value, for different flood depths and structure types. (This table was adapted from Flood Insurance Administration guidance, based on historical averages from observed flood damages.)

FLOOD DAMAGE ESTIMATION TABLE
(Numbers given are damages as a percentage of the structure's replacement value)

	Type of structure					
Flood depths (depth of flooding in feet)	1 story, no basement	2 story, no basement	Split-level, no basement	1 or 2 story with basement	Split level with basement	Mobile home
Under ½ foot, in basement only	0	0	0	4	3	0
About 1 foot, in basement only	0	0	0	8	5	0
2+ feet in basement, <½' surface	9	5	3	11	6	8
About 1 foot flooding at surface	14	9	9	15	16	44
About 2' flooding on ground floor	22	13	13	20	19	63
About 3' flooding	27	18	25	23	22	73
About 4' flooding	29	20	27	28	27	78
About 5' flooding	30	22	28	33	32	80
About 6' flooding	40	24	33	38	35	81
About 7' flooding	43	26	34	44	36	82

NOTE: Since replacement value may exceed the current market value of a structure, damages greater than 50% of replacement value can be considered a total loss of the structure, unless special historic or service functions require that additional expenses be undertaken to repair and preserve it.

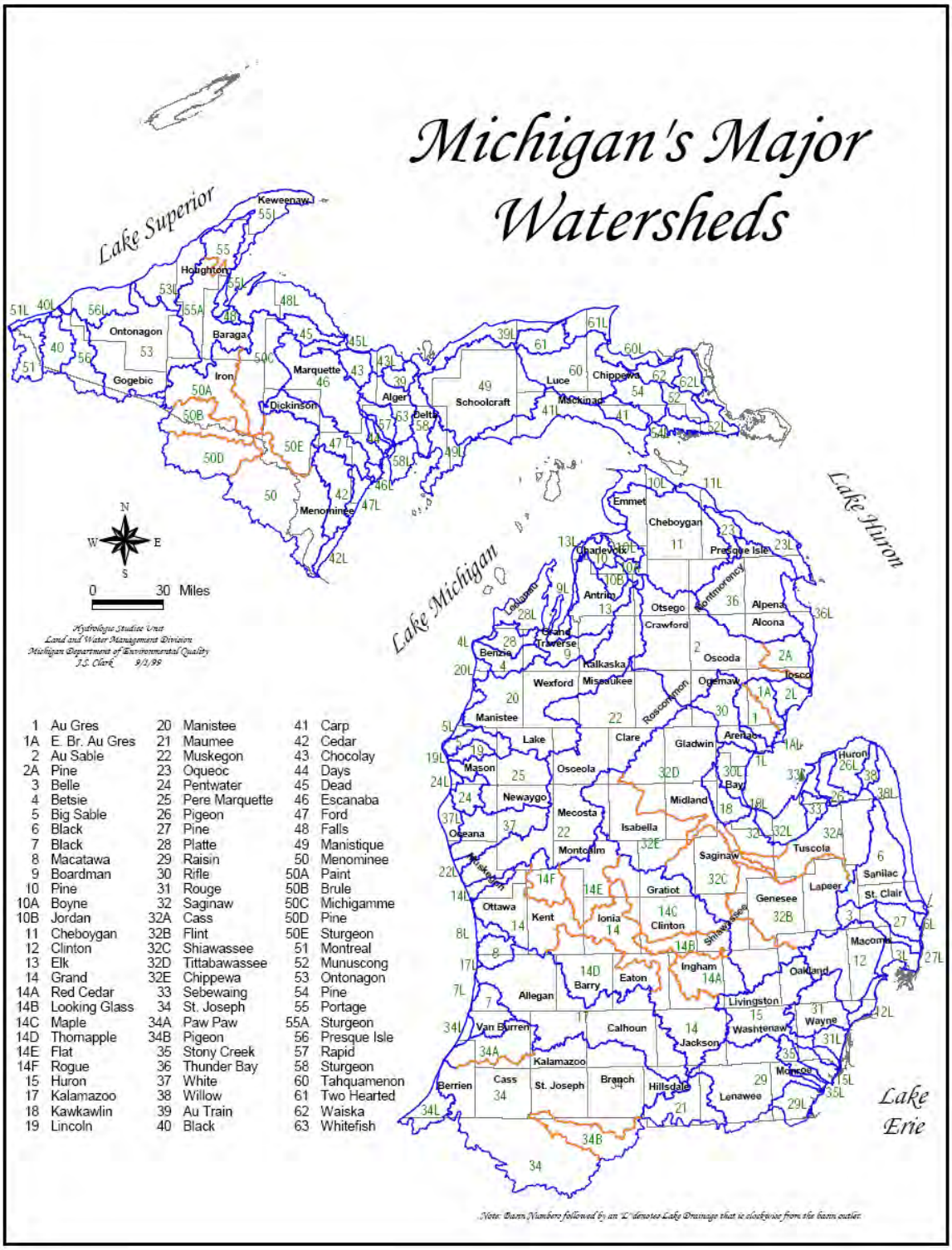
In addition, damages to the contents of structures can be estimated, by assuming that their value is 30% of the replacement value of the home, and then assuming that damages to those contents will be 1.5 times the percentages listed in the table above. This simple formula should be adequate for residential losses. (The structural and contents formulas combine as follows: $T=pR+.3R(1.5p)=pR+.45pR=1.45pR$) Loss of contents in commercial facilities can be assessed more accurately by business owners or organizations participating in the development of a local plan. Other damages and costs could be those involving public facilities and infrastructure, road closures, diverted traffic, loss of rental income, and so on.

NOTE: The replacement value of a residential structure can be estimated, where information is not readily available. For example, construction costs for residential structures have been estimated to range from $101 to $116 per square foot (as found in the 2010 Residential Building Replacement Values of the International Code Council). In such a case, the typical price of $101 per square foot might be used unless you know that your area's costs are substantially higher or lower than average. This price can then be multiplied by the approximate square footage of residential use. For example, a 1000 s.f. house would have an estimated replacement cost of $101,000.

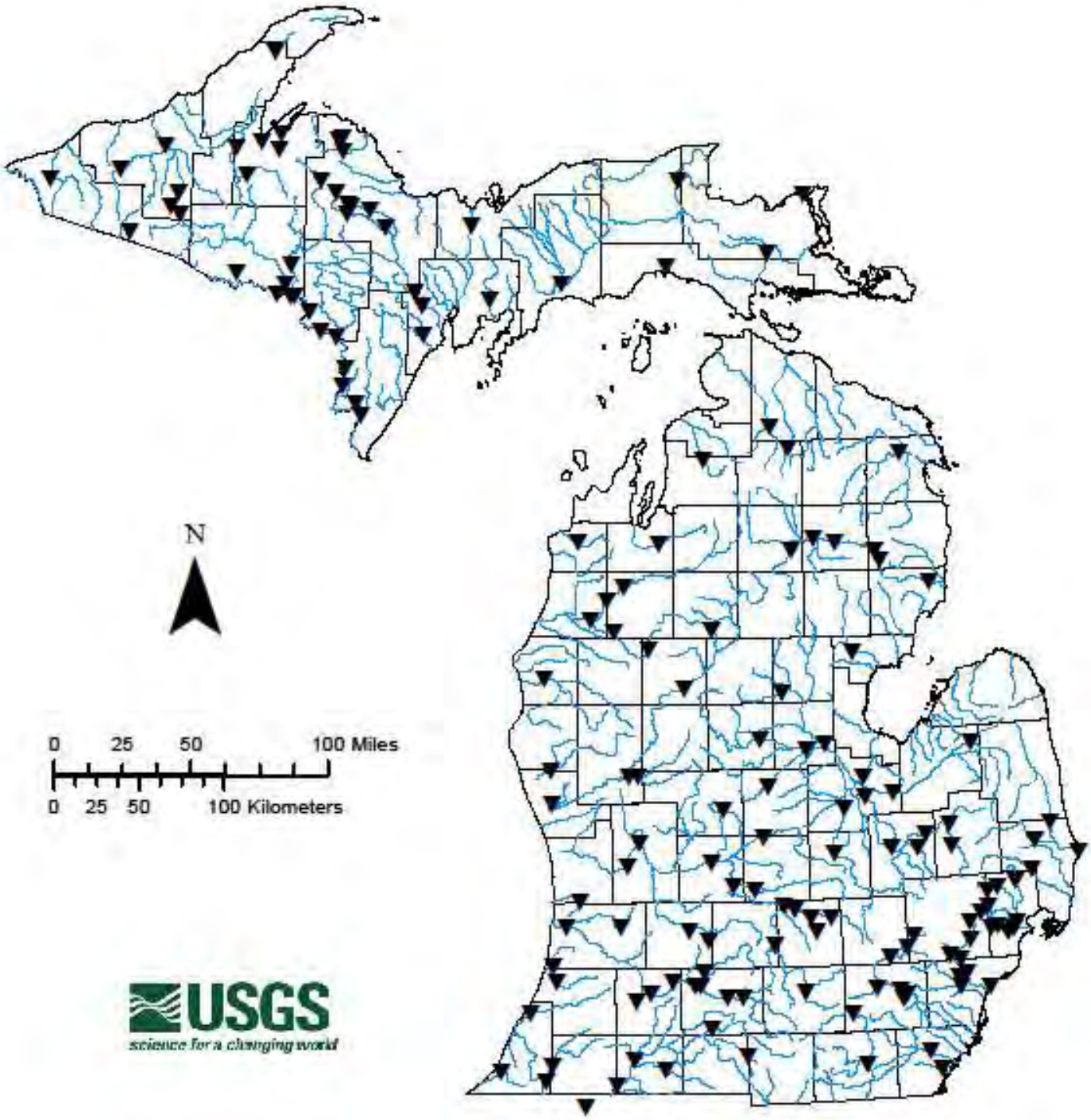
"Urban flooding" may involve low-lying areas that collect runoff waters even though they are not adjacent to drains or bodies of water. Information on the topography, soils, and impervious ground surfaces in your area can help to identify areas at risk for this type of flood hazard. Other kinds of urban flooding stem from flaws or shortcomings in existing sewer infrastructure. Some flood events may come from undersized or poorly designed sewer systems that cannot always process the amounts of precipitation and runoff that affects an area. Other events may have less to do

with system design than with the collective effects of land use and development trends, illegal diversion of water, or actions that plug storm drains or otherwise interfere with system function. In some cases, flooding may result from power failures that temporarily shut down needed pumps and other facilities. (Backup systems can be a vital flood mitigation strategy in such cases.) Many communities are in the process of upgrading their systems, separating combined sewer systems (in which storm and sanitary sewer systems share many of the same components), and enforcing local codes, but have not yet achieved the long-term benefits that such actions will produce.

Some forms of flood damage even come from the decisions of individual homeowners and must be addressed on that level. Proper landscaping and downspout placement can prevent rainwaters from pooling around a structure and seeping into a basement. The use of sump pumps and sewer backflow preventers can prevent a great deal of the damages that are reported each year. Property developers and purchasers should be aware of the possibility of flooding in many areas, and should either locate their homes outside of risk areas, or engineer them to be unaffected by such events. This is an especially important concern in areas that are scenic and desirable because of their riparian locations. Some of these individual-level decisions and risks can be difficult to assess, but should be discussed in the flood analysis section of a plan, to increase public awareness and encourage individuals to be proactive and responsible.


Michigan's Major Watersheds
Lake Superior
Lake Michigan
Lake Huron
Lake Erie
Keweenaw
Houghton
Ontonagon
Baraga
Gogebic
Iron
Marquette
Dickinson
Menominee
Alger
Delta
Schoolcraft
Luce
Chippewa
Mackinac
Emmet
Cheboygan
Presque Isle
Charlevoix
Antrim
Otsego
Montmorency
Alpena
Alcona
Crawford
Leelanau
Grand Traverse
Benzie
Kalkaska
Oscoda
Iosco
Wexford
Missaukee
Ogemaw
Roscommon
Manistee
Lake
Clare
Gladwin
Arenac
Huron
Mason
Osceola
Bay
Newaygo
Midland
Mecosta
Isabella
Oceana
Tuscola
Montcalm
Saginaw
Sanilac
Muskegon
Gratiot
Lapeer
St. Clair
Ottawa
Kent
Ionia
Clinton
Genesee
Shiawassee
Macomb
Ingham
Oakland
Barry
Eaton
Allegan
Livingston
Wayne
Van Buren
Calhoun
Washtenaw
Jackson
Kalamazoo
Monroe
Berrien
Cass
St. Joseph
Branch
Hillsdale
Lenawee
N
W
E
S
0
30 Miles
Hydrologic Studies Unit
Land and Water Management Division
Michigan Department of Environmental Quality
J.S. Clark 9/2/99
1 Au Gres
1A E. Br. Au Gres
2 Au Sable
2A Pine
3 Belle
4 Betsie
5 Big Sable
6 Black
7 Black
8 Macatawa
9 Boardman
10 Pine
10A Boyne
10B Jordan
11 Cheboygan
12 Clinton
13 Elk
14 Grand
14A Red Cedar
14B Looking Glass
14C Maple
14D Thornapple
14E Flat
14F Rogue
15 Huron
17 Kalamazoo
18 Kawkawlin
19 Lincoln
20 Manistee
21 Maumee
22 Muskegon
23 Oqueoc
24 Pentwater
25 Pere Marquette
26 Pigeon
27 Pine
28 Platte
29 Raisin
30 Rifle
31 Rouge
32 Saginaw
32A Cass
32B Flint
32C Shiawassee
32D Tittabawassee
32E Chippewa
33 Sebewaing
34 St. Joseph
34A Paw Paw
34B Pigeon
35 Stony Creek
36 Thunder Bay
37 White
38 Willow
39 Au Train
40 Black
41 Carp
42 Cedar
43 Chocolay
44 Days
45 Dead
46 Escanaba
47 Ford
48 Falls
49 Manistique
50 Menominee
50A Paint
50B Brule
50C Michigamme
50D Pine
50E Sturgeon
51 Montreal
52 Munuscong
53 Ontonagon
54 Pine
55 Portage
55A Sturgeon
56 Presque Isle
57 Rapid
58 Sturgeon
60 Tahquamenon
61 Two Hearted
62 Waiska
63 Whitefish
Note: Basin Numbers followed by an 'L' denotes Lake Drainage that is clockwise from the basin outlet.

USGS Stream Gauge Locations in Michigan



Great Lakes Shoreline Hazards

High or low water levels that cause flooding or erosion, and other wave and current action that threatens life, health, and property in shoreline areas, including storm surges, rip currents, and the recession of shoreline areas.

Hazard Description

Michigan has over 3,200 miles of coastline (the longest freshwater coastline in the world), and about 4.7 million persons live in the state's 41 shoreline counties. Wind, waves, water levels, and human activities constantly affect the communities along the shores of the Great Lakes. Shoreline flooding and erosion are natural processes, occurring at high, average, and even low Great Lakes water levels. However, during periods of high water, flooding and erosion are more obvious, causing serious damage to homes and businesses, roads, water and wastewater treatment facilities, and other structures in coastal communities. Low lake levels can also pose a hazard, as cargo ships are more prone to running aground and the shorelines may also become more polluted from lake bottom debris. Long-term and seasonal variations in precipitation and evaporation rates primarily control the Great Lakes water levels and their fluctuations.

The Great Lakes occupy an area of 95,000 square miles and drain an amount of land twice that size. They hold nearly one-fifth of the world's fresh surface water. Because the land draining into the Great Lakes is so vast, changes in the amount of water running into the lakes from precipitation within the basin has an enormous effect on water levels. Following long periods of above-average yearly precipitation, there is an accompanying rise in water levels. This rise is not immediately evident because of the delay between the time precipitation falls within the drainage basin and the time that runoff waters enter the lakes. (The same holds true for below-average yearly precipitation. The reduced flow of runoff water eventually results in lower Great Lakes water levels.)

Hazard Analysis

Over one hundred years of record keeping have not indicated a simple, easily-predictable cycle of water levels on the Great Lakes. (However, geologic research has indicated quasi-periodic cycles of 33 years and 160 years for lake level fluctuations; e.g. Baedke and Thompson's article in the Journal of Great Lakes Research, v.26 p. 416-426, 2000.) The time between periods of high and low water levels can vary widely. Records indicate the maximum differences in levels have varied from nearly four feet on Lake Superior to over six and one-half feet on Lakes Michigan and Huron. Seasonal fluctuations caused by more water runoff can cause lake level fluctuations averaging about one foot on Lakes Superior, Michigan and Huron, and one and one-half feet on Lake Erie. The graphs at the end of this section show the average historical water levels of the Great Lakes up through 2009.

In addition to natural causes of water level fluctuation, there are four man-made factors that can also affect water levels to some degree: (1) diversion of water for power generation, municipal water supply, and navigation, (2) regulation of water levels via dams and other control structures, (3) dredging of connecting waterways for navigation purposes, and (4) covering land surfaces with impervious materials that cause storm runoff to be delivered to water bodies more quickly than the pre-development runoff rates. Although these man-made factors do impact water levels, natural factors such as precipitation, evaporation and winds have a far greater overall impact. The vast majority of shoreline flooding and erosion that occurs along the Great Lakes is caused by natural factors. However, it should be remembered that it is humans who place themselves in harm's way by building structures in dynamic coastal areas. If that did not occur, the natural processes of flooding and erosion would not be viewed as problems.

Generally, low-lying lands along the coastline are prone to shoreline flooding during both high and low lake water periods. The Michigan Department of Environmental Quality estimates that approximately 10% of Michigan's Great Lakes shoreline (30 counties encompassing greater than 45,000 acres) is floodprone.

The map at the end of this section indicates those townships that contain high-risk erosion areas as determined by the MDEQ under Part 323, Shorelands Protection and Management. A high-risk erosion area is defined by the MDEQ as an area where erosion studies have indicated that the erosion hazard line is receding at an average of one foot or more per year over a minimum 15-year period. The MDEQ has identified 121 township areas along the Great Lakes coast as containing one or more sections of high-risk erosion areas. Within those areas, any new permanent structure must comply with building setback regulations that require a minimum distance between the existing erosion hazard line and

the structure. (The MDEQ also designated 41 communities on Michigan's shoreline as flood risk areas, meaning that they have floodplain-like areas with at least a 1% annual chance of a designated flood level being exceeded.)

The intent of these and other applicable building restrictions is to minimize the extent and magnitude of shoreline flooding and serious erosion problems along the Great Lakes shoreline. Although shoreline flooding and erosion is inevitable, severe damage can be avoided if prudent shoreland management practices are followed and adequate emergency procedures are implemented. Coordination of federal, state and local shoreland management and emergency preparedness efforts is vital to keeping Michigan's shoreline areas as safe and undamaged as possible. The recession of the Great Lakes water levels is also inevitable, but there is not much, other than dredging, that can be done to combat the negative effects. That is why it is important for all those involved in water transportation to be prepared for all types of water fluctuations.

Much of Michigan's character is defined by the Great Lakes. The beaches provide numerous recreational opportunities and are considered prime real estate. Unfortunately, the inherent hazards of coastal areas are not always apparent. Development activities along the shoreline significantly alter the natural ebb and flow of coastal dynamics. Continuing and increasing development of coastal areas threatens to exacerbate the shoreline flooding and erosion problem. As more people and structures are put in harm's way, the problem of shoreline flooding and erosion will continue to grow in frequency and significance.

The MDEQ administers programs aimed at balancing the impact of shoreline flooding and erosion with the development pressures facing the Great Lakes shoreline by implementing non-structural approaches, such as construction setbacks and lowest floor elevation requirements. These types of approaches do not interfere with the natural processes of erosion and flooding, but instead take what is known about the coastal hazard and develop construction standards to prevent the premature collision between homes and nature.

The MDEQ has the responsibility of administering the permitting programs that implement the coastal construction standards. However, under Part 323, local governments have the authority to take over the permitting programs for high-risk erosion and flood risk areas. In the area of floodplain management, permitting responsibility is handled at the local level due to the overlap of regulations found in Part 323, the NFIP, and the building codes. However, few communities have shown an interest in adding the regulatory responsibility of the erosion program to their already busy building and zoning departments. As with many regulatory programs that address private property development rights, the potential for conflict in these areas is high. This is especially true in the realm of expensive shoreline real estate where a view of the water can outweigh the threat of future flood or erosion damage. Political pressure can also come into play in some situations. Compliance with these regulations has best been achieved through cooperation between the State and local governments. Public understanding and support of these programs can be increased by improved communication with property owners regarding the natural hazards associated with the Great Lakes shoreline. About 10 major periods of flooding/erosion have occurred on the Great Lakes since 1918—about every 8.3 years.

Shoreline erosion hazards typically involve the loss of property as sand or soil is removed by water action and carried away over time. Erosion effects that are experienced along rivers may be included in this category of hazard. Worst case scenarios typically involve occupied structures that, over the years, have had adjacent lands eroded away and now stand perilously close to waters or cliffs. The foundation of a structure, or underground utility pipes in the area, may become fully exposed and vulnerable to weather, extreme temperatures, water damage, or other sources of risk.

Another frequent situation in Michigan involves shoreline roadways whose banks erode and cause the road surface to crack, become unstable, or more prone to deposits of sand, snow, water and ice from nearby beaches and water bodies. The costs of delayed traffic and detours can be counted as harmful shoreline effects.

Storm Surges (Seiches)

Weather-related events can also cause lake fluctuations that can last from several hours to several days. For example, windstorms combined with differences in barometric pressure can temporarily tilt the surface of a lake up at one end by as much as eight feet. This phenomenon is called a **storm surge** or **seiche** (typically pronounced as saysh) and can drive lake waters inland over large areas, cause weakening and erosion of shoreline areas, make water travel hazardous, and cause flood damages, deaths, and injuries to occur. The following list presents some of the most significant seiche events to have affected Michigan.

Significant Seiche Events in Michigan

November 11, 1940 – Lake Michigan

Enormous waves were generated by a huge storm system, with winds blowing in from the southwest and reaching speeds of up to 75 mph. The northern shore of Lake Michigan was reported to have sustained considerable damage from the push of water during the resulting seiche. Five vessels and 66 lives were lost (including 57 deaths from the sinking of two freighters that are also listed in the Transportation Incidents section of this document). A car ferry was damaged and driven ashore at Ludington.

May 31, 1998 – Lake Michigan Seiche

A derecho produced widespread wind gusts of 60 to 90 miles per hour and moved across Lake Michigan, causing the sinking of a tugboat north of Muskegon (in White Lake Channel north of Wabaningo). Repairs for the boat were estimated at $20,000. Consumers Energy reported more than 600,000 customers without power, marking the most destructive weather event in the company's history. It took up to 10 days to restore power to all areas. Although most of the damages, deaths, and injuries in this storm system were caused by other storm effects, one component was the wave action that took its toll just north of Muskegon.

October 28-29, 2006 – Lake Erie

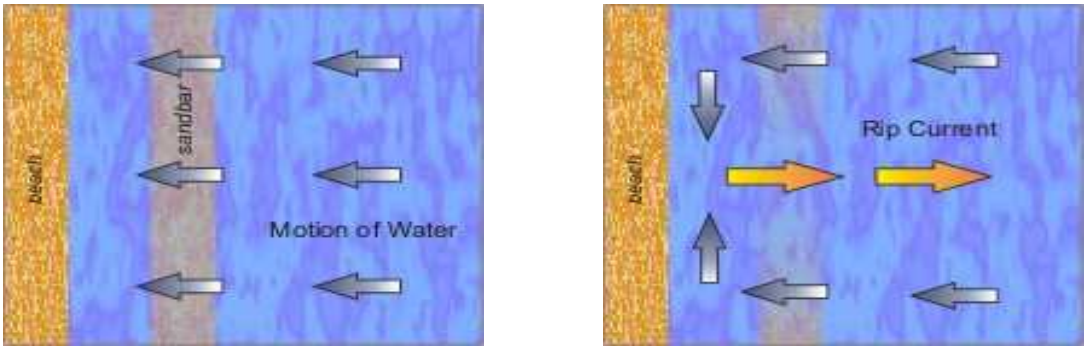
After two days of wind blowing at speeds of 30 to 40 mph, the difference in water levels between one end of Lake Erie and the other reached 8 feet. Fortunately, the seiche caused a drop rather than a rise of waters along Michigan's coastline, but this can still cause a weakening and erosion of shoreline areas. The waters at Monroe were 4 feet below the level they had been at merely two days before, on October 27.

Rip Currents

A rip current is a strong flow of water returning seaward from the shore. When wind and waves push water towards the shore, the previous backwash is often pushed sideways. This water streams along the shoreline until it finds an exit back to the sea. The resulting rip current is usually narrow and located between sandbars, under piers or along jetties. The current is strongest at the surface, and can dampen incoming waves, leading to the illusion of a particularly calm area. Rip current speeds are typically 1-2 feet per second. However, speeds as high as 8 feet per second have been measured. Rip currents cause approximately 100 deaths annually in the United States, more than all other natural hazards except excessive heat. In the Great Lakes alone, the average over the last six years is 10 drownings per year caused by rip currents. About 80% of rescues by surf beach lifeguards are due to rip currents. A picture showing how rip currents are formed can be found below.

In recent years, rip current advisories have been announced by the National Weather Service, as a part of their weather warning information system. These warnings advise about dangerous swimming conditions, and that rip currents are more likely to exist near break walls, sandbars, jetties, and piers. Persons who are caught in a rip current should wade or swim sideways (parallel to the beach) so as to leave the rip current area before it pulls them too far away from shore. The most important action is to conserve one's strength so as to stay afloat (rather than expending one's strength in an over-desperate struggle to "fight the current"). Once out of the rip current's pull, head back to shore at a pace that is appropriate to one's strength. In some circumstances, a swimmer may have been observed by beach lifeguards while being pulled by the current, and in such a case, if waves and weather are not too severe to allow a rescue, a swimmer may simply need to stay afloat until the lifeguards can bring aid.

Rip Current Formation



According to the National Climatic Data Center, Michigan has experienced at least 17 deaths and 9 injuries caused by rip currents in just the past 10 years. Out of 17 events, 8 took place in the Lake Michigan waters off of Berrien County (a total of 7 dead and 8 injured). Problem locations included the waters south of Bridgman down to Harbart, and a couple of incidents off of Silver Beach (in the City of St. Joseph). Three events occurred in the waters north of Marquette County—one near Presque Isle, and off of Picnic Rocks. Other incidents occurred in waters off of Allegan County, Manistee County, Benzie County, and Mackinac County. One Alger County incident involved two drowning deaths in the Grand Marais Harbor.

Another Great Lakes hazard is the potential effect of severe winds upon boating activities. Although some description of marine accidents can be found in the Transportation Accidents section, it must be noted here that severe winds tend to be felt more strongly on open waters (winds from an approaching storm front often strike in advance of the storm itself, by 5 minutes or even more). Waterspouts (which are like a tornado, but involve contact with water instead of land) are a common occurrence posing a great threat to marine traffic. Seventeen Michigan waterspouts have been noted by NCDC between 1993 and 2001, including one that caused $200,000 in damage to a boat house and storage building at Drummond Island on July 3, 1999. Many additional events have occurred since, which NCDC has classified according to the corresponding lake location rather than as part of Michigan itself. Waterspouts are less frequent on Lake Superior (8 events since 2001) than on Lakes Huron (23 events) or Michigan (51 events).

Impact on the Public

Great Lakes shoreline flooding is similar to inland (riverine) flooding in some ways (such as having a probabilistically definable flood risk area), but the shoreline tends to have a much greater risk of allowing strong wave action as part of a flood's impacts. Storm seiches can make the magnitude of shoreline flooding much greater than what is possible in most inland areas. In addition, patterns of Great Lakes shoreline erosion tend to be a larger issue than the erosion associated with Michigan's rivers, since the water effects are greater, and the topographic relief in Michigan's shoreline areas is sometimes considerable. For example, the erosion effects from a single severe thunderstorm have caused large sections of shoreline roadway to crumble and disappear into the crashing waters, involving a drop of dozens of feet on the southern coasts of Lake Michigan, and have encroached upon structures located nearby.

Impact on Public Confidence in State Governance

Great Lakes shoreline flooding and erosion impacts are probably similar to those of riverine flooding, except that shoreline impacts may seem to be less controllable than riparian impacts. Erosion severity is likely to be far greater along the shoreline, especially when involving substantial elevations in which the roads and homes are located along bluffs or cliffs and are thus clearly imperiled by any degradation in the solidity of the supporting land structure that is subjected to erosion and weakening. Thus, part of the public may be prone to question why structures were allowed to be built in an area at-risk from erosion effects, or whether some government-funded mitigation action may be undertaken to preserve the condition and value of such property, once it is recognized as being at-risk.

Impact on Responders

Compared to riverine flood events, the main additional risks posed by shoreline flooding and erosion hazards involve the generally greater topographic relief along certain shoreline areas, and the greater potential impact likely to be seen from a single event such as a storm or seiche that involves substantial wave action. The event may cause roadways and property to crumble and tumble dozens of feet into the waters of one of the Great Lakes. Thus, weakened shoreline roads may cause personnel, vehicles, or equipment to plummet down a steep incline, if erosion has been severe enough to cause such a collapse. Shoreline events may also require more extensive use of boats and marine equipment during response activities, with an associated increase in the variety of risks to responders.

Impact on the Environment

Great Lakes shoreline flooding and erosion does the greatest amount of harm to the built environment by destroying structures that are built too close to the shoreline. However, shoreline erosion can also affect the natural environment by altering the landscape, with the potential to permanently destroy wildlife habitat.

Significant Periods of Shoreline Flooding and Erosion

In most decades, high water levels on the Great Lakes have caused significant damage and impacts to Michigan coastal communities.

During 1972-73, high water levels caused flooding in over 30 counties, resulting in more than $50 million in public and private damage. Thousands of people were forced to evacuate their homes. Similar high water-level flooding occurred in the early 1950s and late 1960s, also resulting in millions of dollars worth of damage to shoreline communities.

Record-high lake levels in 1985-86 culminated in a Governor's disaster declaration for 17 shoreline counties. The USACE implemented its Advance Measures Program, and the State of Michigan implemented three unique shoreline

flooding and erosion mitigation programs aimed at reducing future flood impacts on shoreline communities and homeowners. (See Programs and Initiatives section.)

The most recent high water period, in 1997-98 (although it should be noted that Lake St. Clair and Lake Erie have recently gone back up to above-average levels), resulted in the Great Lakes being at or near the record levels set in the mid-1980s. In response to the threat of severe shoreline flooding and erosion, the U.S. Army Corps of Engineers (USACE), at the request of the Governor, implemented its Advance Measures Program to assist Michigan shoreline communities in their flood and erosion mitigation efforts. (See Programs and Initiatives section for more details.) More than 20 Michigan jurisdictions have since taken advantage of this program.

Significant Periods of Great Lakes Recession

Just as damaging high water levels frequently occur in the Great Lakes, low water levels are also cyclical and can have severe economic impacts.

The low water levels in Lakes Michigan, Huron and Erie between 1998-2004 (Lake Erie has since recovered) were the fastest decline in water levels in the Great Lakes in nearly a century and a half. Between the summer of 1997 and the spring of 2003, the middle Great Lakes (Michigan, Huron, and Erie) each dropped by almost five feet.

One contributing factor to low lake levels is a lack of snow pack runoff from moisture that had originated outside of the Great Lakes basin, such as the Gulf of Mexico. (In some years with low lake levels, there may be good snow pack runoff, but it had all originated from lake-effect snow and thus didn't cause a net increase in lake water levels.) The Lake Superior basin, which is the headwaters for the Great Lakes, is an important factor in lake levels. In the past, low snow pack in the Lake Superior basin has disrupted the other lakes' seasonal replenishment cycle, driving water levels down.

Among those most affected by the low water levels are the shipping companies that operate massive, 1,000-foot-long iron ore and coal carriers on the Great Lakes. Low water levels can force these cargo ships to lighten their loads by as much as 6,000 tons to reduce their drafts and avoid running aground in channels and ports. Also, in recent years, ferry services that transport people to and from islands have been forced to shut down because of low water depths. Significant drops in water levels can also result in an increase in demand for dredging projects, which can be very expensive. In addition to the high cost of the dredging itself, homeowners and marina operators are faced with the cost of safely disposing of sediments that have been contaminated with heavy metals, pesticides, diesel fuel and other toxic substances. Under strict environmental laws, such dredged material has to be deposited in confined disposal facilities.

August to September 2007 – Muskegon County

Local reports described drought-related effects upon marine traffic in the Muskegon area. A super-freighter became stuck in the mouth of Muskegon Harbor and was reported as the second large ship to run aground within the space of a month, in the same location. Shipping officials stated that additional dredging was needed in Great Lakes ports because of low water levels.

Programs and Initiatives

Michigan Shoreline Flood and Erosion Hazard Regulatory Authority

Shorelands Protection and Management, Part 323 of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended – Part 323 is designed to provide protection to Michigan's Great Lakes shoreline. While these fragile and dynamic shorelines are desirable vacation and recreational areas, they also present inherent hazards to development and are vulnerable to the effects that development often brings. Part 323 gives the MDEQ responsibility to identify hazardous and fragile coastal areas, to establish regulations designed to minimize the impact of development on these areas, and to minimize risks facing new developments. Part 323 identifies three coastal areas: 1) high-risk erosion areas – those shorelines identified as receding at an average long-term rate of at least one foot per year; 2) flood risk areas – those coastal areas that are vulnerable to Great Lakes flooding; and 3) environmental areas – those coastal areas necessary for the preservation and maintenance of fish and wildlife. Regulations have been developed for the unique management issues facing each area.

Mechanisms provided in the law to accomplish this protection are state-developed zoning ordinances, special studies, plans, and remedies for violation of rules. The Act gives the MDEQ the authority to identify and regulate high-risk

erosion, flood, and environmental areas using setbacks, zoning, and building code standards. Permits are required for construction in high-risk erosion or flood areas, or for alterations in an environmental area. If a local ordinance has been approved by the MDEQ, the regulation will be done at the local level. In the absence of a local ordinance, permits must be obtained from the MDEQ.

In high-risk erosion areas, the Administrative Rules for the Act require: 1) a 30-year setback for small, readily moveable permanent structures having a foundation size of 3,500 square feet or less; 2) a 60-year setback for all other permanent structures; and 3) all proposed structures of 3,500 square feet or less located within the 60-year setback must be readily moveable. The readily moveable provision expands the options a property owner may economically consider if the home is ever threatened with erosion damage. High-risk erosion areas can be identified through the lists and maps available at http://michigan.gov/deq/0,1607,7-135-3307_3331-107407--,00.html.

In flood risk areas, the Administrative Rules require that (1) residential structures must have the lowest portion of all floor joists located at or above the 100 year flood elevation and (2) any additions to existing structures must be elevated above the 100 year flood elevation.

Environmental areas are portions of the Great Lakes shorelands that have been determined to be necessary for the preservation and maintenance of fish and wildlife. Within environmental areas, permits are required for any dredging, filling, grading, other alteration of soil, vegetation, construction of permanent structures, and natural drainage.

National Flood Insurance Program

For many years, the strategy for reducing flood damages followed a structural approach of building dams and levees and making channel modifications. However, this approach did not slow the rising cost of flood damage, and did not allow individuals to purchase insurance to protect themselves from flood damage. It became apparent that a different approach was needed.

The National Flood Insurance Program (NFIP) was instituted in 1968 to make flood insurance available in communities that have agreed to regulate future floodplain development. As a participant in the NFIP, a community must adopt regulations that: 1) require any new residential construction within the 100-year floodplain to have the lowest floor, including the basement, elevated above the 100-year flood elevation; 2) allow non-residential structures to be elevated or dry floodproofed (the floodproofing must be certified by a registered professional engineer or architect); and 3) require anchoring of manufactured homes in floodprone areas. The community must also maintain a record of all lowest floor elevations or the elevations to which buildings in flood hazard areas have been floodproofed. In return for adopting floodplain management regulations, the federal government makes flood insurance available to the citizens of the community. In 1973, the NFIP was amended to mandate the purchase of flood insurance, as a condition of any loan that is federally regulated, supervised or insured, for construction activities within the 100-year floodplain.

As of December, 2010, there were 25,555 flood insurance policies in force in Michigan, which amounts to almost $3 billion worth of coverage. Officials from FEMA and the MDEQ estimate that only 15% of all floodprone structures in Michigan eligible to purchase flood insurance actually have flood insurance. Furthermore, since only about 49% of the communities in Michigan participate in the NFIP, there are thousands of structures that are floodprone, but are not eligible to purchase flood insurance. (There were 867 participating communities as of December 22, 2010, and another 108 communities that were mapped but not participating—probably since the mapping was recently completed under FEMA's Map Modernization program.)

For more information about the participation of Michigan communities in the NFIP and CRS, please refer to the preceding chapter about Riverine Flooding.

Community Education

The MDEQ periodically holds workshops for lenders, realtors, insurance agencies, citizens and any other interested parties. The workshops provide a wide variety of information tailored to the specific group(s). Topics typically include building code requirements, other state and federal regulations, floodplain management programs, and the responsibilities of involved parties such as local governments, lending institutions, citizens, etc. Staff from the MDEQ will also meet with property owners onsite to discuss shoreline flooding and erosion problems and possible solutions based on the specifics of the property.

National Weather Service Watches/Warnings

In 2005, The National Weather Service announced that it would start issuing Coastal Flood Warnings for the Lower Peninsula shorelines of Lake Michigan and Lake Huron using a model that calculates such factors as wind speed, wave height, and time between waves. Advisories that warn when conditions present an increased risk of rip currents will be posted on the agency's web site and shared with weather broadcasters.

State-Administered Shoreline Hazard Mitigation Programs

In 1986, in response to the Great Lakes shoreline flooding and erosion problems, the State of Michigan established three unique shoreline hazard mitigation programs designed to prevent or minimize damage and impact caused by shoreline flooding and erosion. (Note: These temporary programs were established only for the 1985-86 high water period. They have since been closed out and are no longer available.)

The **Shoreline Community Protection Program** provided grants for community shoreline damage prevention efforts. From 1986 through 1988, the program provided support for flood and erosion mitigation projects undertaken by local governments in the form of grants which would cover 85% of the cost of projects. Four hundred seventy one (471) grants were awarded, totaling approximately $4.2 million.

Two interest-rate buy-down programs, the **Emergency Home Moving Program** and **Emergency Flood Protection Program**, were established on a temporary basis to encourage a non-structural approach to erosion and flood hazards during the 1985-86 high water levels on the Great Lakes. The programs provided a lump sum payment equaling 3% of the interest rate of the secured loan amount for projects to move houses away from the eroding bluff line or elevate homes in floodprone areas. From 1986 through 1988, a total of $2 million was made available to interested homeowners. A total of 72 structures were relocated under the program, and 43 were elevated.

USACE Advance Measures Program

The USACE Advance Measures Program can be implemented to assist a state or local government in mitigating the potential damage and impact caused by flooding. Under the Advance Measures Program, the Army Corps of Engineers may provide "self-help" materials (i.e., sandbags, sand, and plastic sheeting), at 100% federal cost, to participating units of government for use in direct pre-flood mitigation activities. An example of a self-help project would be the construction of temporary sandbag dikes. The Advance Measures Program also has a construction component under which the Corps can provide assistance with permanent construction projects designed to mitigate potential flood damages. Such projects are funded on a 75% federal and 25% local cost-share basis. Construction projects require a written cooperation agreement between the Corps and the participating jurisdiction. The jurisdiction must agree to furnish all land, easements and rights-of-way, agree to operate and maintain the project for 25 years, pay the 25% project cost-share, and provide interior drainage. Examples of construction projects that could potentially be funded under this component of the program include earthen levees, rock and/or sand-filled cribs, and concrete and/or steel sheetpile seawalls.

The Advance Measures Program and its predecessor, Operation Foresight, has been implemented during the last three high water periods on the Great Lakes. Over 100 flood mitigation projects have been funded under these programs in Michigan and other Great Lakes states over the last three decades. In response to the high lake levels in 1972-73, the Corp's Operation Foresight program provided over $13.5 million in funds for self-help and flood mitigation construction projects. During the 1985-86 high water period, total project costs for self-help and construction projects under the Advance Measures Program exceeded $12.5 million. In the most recent high water period (1997-98), in response to request by the Governor, the USACE provided approximately one million self-help sandbags, and worked with seven communities to complete eight Advance Measures construction projects. Those projects are located on or adjacent to Lake Erie, Lake St. Clair, and Saginaw Bay.

Great Lakes Shoreline and Wetlands Task Force Report

A special task force was assembled to study state and federal regulations on wetlands and to develop recommendations for the regulatory agencies to allow shoreline property owners access to their waterfront while maintaining the ecological value of the areas. The report identified areas of inconsistency in existing Army Corps of Engineers and Michigan Department of Environmental Quality (MDEQ) permitting processes and recommended that the agencies work together to alleviate the inconsistencies. The report identified and listed the activities that shoreline property

owners can undertake without requiring a permit from either the state or federal regulatory agency. The report is available at www.lre.usace.army.mil.

The Great Lakes Beach and Pier Safety Campaign

The Great Lakes Beach and Pier Safety Campaign is a collaborative effort between multiple agencies and organizations from Michigan, Illinois, Pennsylvania, and Ohio. It is a comprehensive approach to addressing the lack of education and understanding of rip currents and the dangers they present during storms on the Great Lakes. The campaign was developed by The Great Lakes Beach and Pier Safety Task Force, which has produced an educational video on rip currents entitled "Respect the Power." The task force, along with assistance from State Farm Insurance, has mailed out 3,000 copies to all of the middle schools, high schools, and public libraries in Michigan.

Other State and Federally-Assisted Flood Mitigation Projects

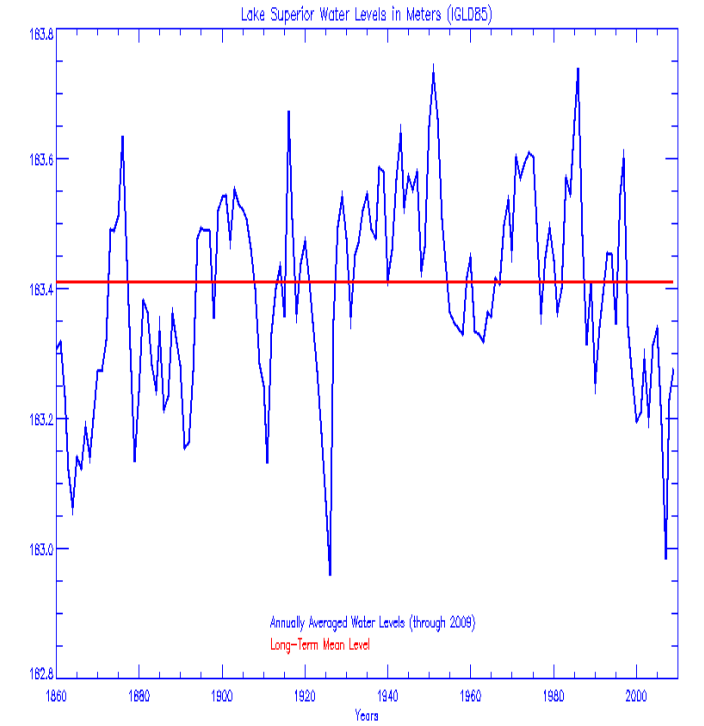
The State of Michigan has used a variety of federal funding sources to assist in the implementation of flood mitigation projects. Those funding sources have included: 1) the Hazard Mitigation Grant Program (HMGP); 2) the Flood Mitigation Assistance Program (FMAP); 3) the Pre-Disaster Mitigation Program (PDMP); 4) the Public Assistance Grant Program (PAGP); 5) the Individual and Family Grant Program (IFGP) – no longer in existence; 6) the National Flood Insurance Program, Section 1362 (no longer in existence); 7) Community Development Block Grants (CDBG); and 8) Farmers Home Administration (FmHA) loans. State and local funds have been used to match the federal sources of funding.

Coastal Management Program

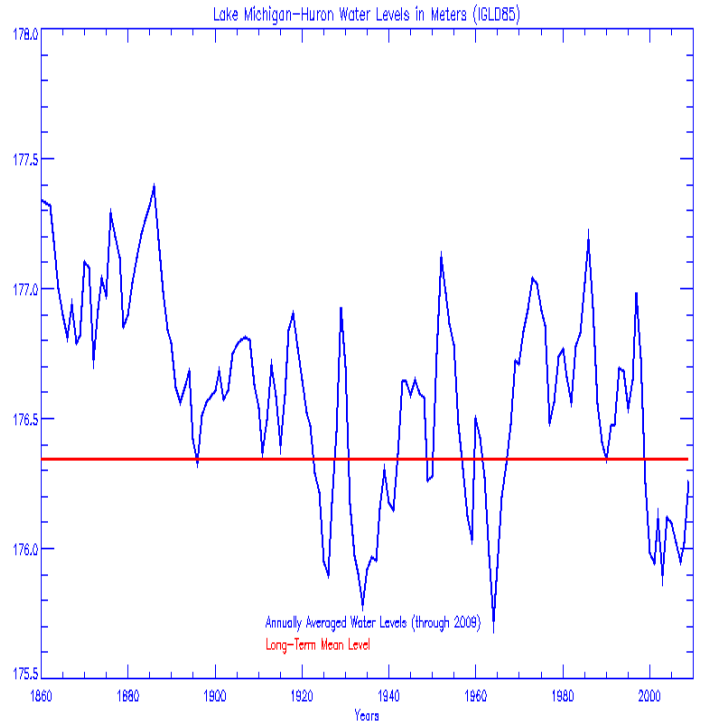
The Coastal Zone Management Act (CZMA), originally passed in 1972, enables coastal states, including Great Lakes states, to develop a coastal management program to improve protection of sensitive shoreline resources, to identify coastal areas appropriate for development, to designate areas hazardous to development, and to improve public access to the coastline. Michigan was among the first states to have its coastal program approved in 1978. The program is administered by the Administration Section of the Environmental Science and Services Division (ESSD) of the MDEQ. The program includes local pass-through grants and administration of coastal related sections of the Natural Resource and Environmental Protection Act, 1994 PA 451. Review of federal agency activities (for consistency with Michigan's approved program) is performed by the Great Lakes Shorelands Section in the Land and Water Management Division (LWMD) of the MDEQ.

Great Lakes Water Levels Since 1860
(Plus Lake St. Clair Since 1900)
Measurements are in meters

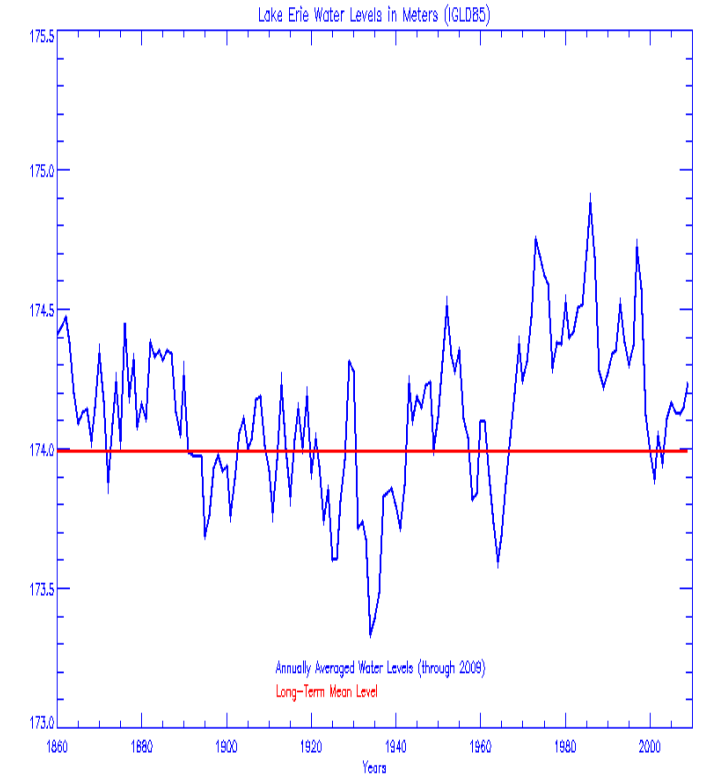
Superior



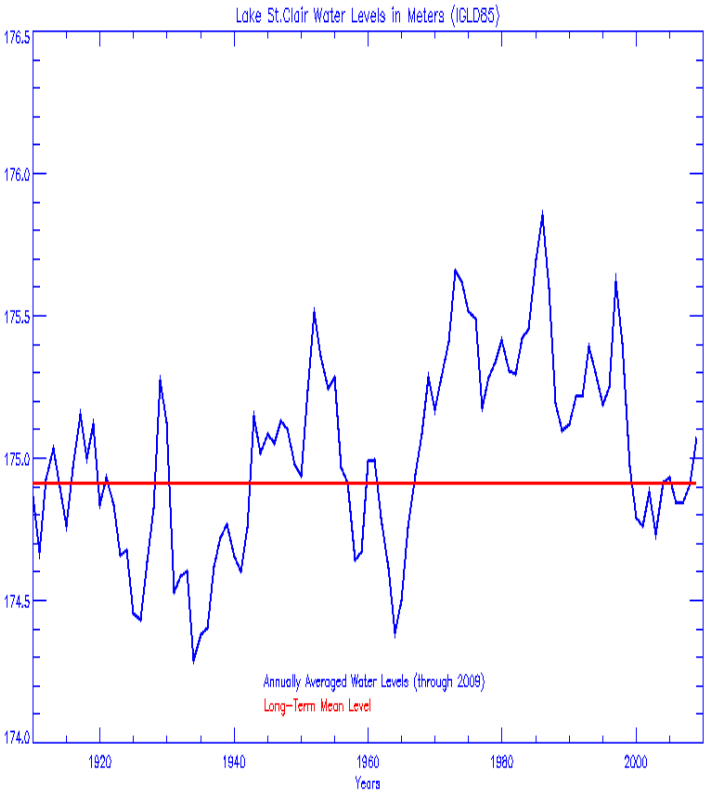
Michigan / Huron



Erie



(Lake St. Clair, 1900-2009)



Source: National Oceanic and Atmospheric Administration hydrographs from http://www.glerl.noaa.gov/data/now/wlevels/levels.html

Michigan Great Lakes Shoreline Erosion Hazard Areas

Source: Michigan Department of Environmental Quality web site at http://michigan.gov/deq/0,1607,7-135-3307_3331-107407--,00.html

Dam Failures

The collapse or failure of an impoundment that results in downstream flooding.

Hazard Description

A dam failure can result in loss of life, and in extensive property or natural resource damage for miles downstream from the dam. Dam failures occur not only during flood events, which may cause overtopping of a dam, but also as a result of poor operation, lack of maintenance and repair, and vandalism. Such failures can be catastrophic because they occur unexpectedly, with no time for evacuation. The Michigan Department of Environmental Quality (MDEQ) has documented approximately 287 dam failures in Michigan since 1888.

The federal levee database for the State of Michigan is provided on the map below. In addition, the following is a list of some areas known to the Water Resources Division of the MDEQ. This listing is for informational purposes only, to comply with federal recommendations for hazard analysis, and the listing of an area is not intended to suggest any specific risk or vulnerability in the vicinity at this time.

Information on dams with low hazard potential may be available from the National Inventory of Dams. The most recent information counted 927 dams in Michigan, with only 161 classified as "high hazard" (meaning there was at least some development downstream, in the dam's "hydraulic shadow") and 158 as "significant." Development should be discouraged in areas that would increase the risks from potential dam failures. Effects from dam failures can be more severe than those from riverine flooding, due to the possibility of the extra effects of flash flooding and wave action from a catastrophic dam failure.

Hazard Analysis

The worst recorded dam failure in U.S. history occurred in Johnstown, Pennsylvania on the afternoon of May 31, 1889. More than 2,200 persons were killed when the South Fork Dam on the Conemaugh River upstream from Johnstown failed, sending 20 million tons of water downstream in a huge wall of water (at times 60-70 feet high) moving at 40 miles per hour. The wall of water, laden with debris, hit Johnstown within an hour, completely inundating the town and crushing everything in its path. The flood was over in 10 minutes, but the effects were felt for years to come. The cause of this catastrophic failure was later determined to be inadequate maintenance of the South Form Dam by the South Fork Fishing and Hunting Club – a private lake association who counted among its members wealthy Pittsburgh steel and coal industrialists such as Andrew Carnegie and Andrew Mellon. The Conemaugh Valley was again the site of dam failures in May of 1977 when nearly 12 inches of rain fell in a 10-hour period, causing six dams surrounding Johnstown to fail. These six failures poured more than 128 million gallons of water into the Conemaugh Valley, resulting in the deaths of 45 persons and heavy property losses. The storm event that caused the dam failures was said to be a once in a 5,000 to 10,000 year occurrence.

Some Michigan areas with levees, or similar structures:

Village of Clinton	Along the River Raisin in Lenawee County
City of Detroit	A series of "seawalls" may be providing some protection
East China Township (St. Clair Co.)	Several ring dikes are shown on the community's map
City of Frankenmuth	USACE flood-control project on the Cass River
Cities of Grand Rapids and Walker	Floodwalls along the Grand River
City of Grosse Pointe Park	Sea wall along the Detroit River and Lake St. Clair
Hampton Township (Bay Co.)	Coastal levee
Kalamazoo City and Township	Levees surrounding waste disposal ponds
City of Manistique	One dam includes a flume that may have levee-like functions
Saginaw County	Low-level dikes along the Flint River in Albee, Spaulding, and Taymouth Townships
Saginaw County	Low-level dikes along the Cass River in Bridgeport and Spaulding Townships
Sebewaing (Huron Co.)	USACE flood-control project
Village of St. Charles (Saginaw Co.)	Levee
Wisner Township (Tuscola Co.)	Dikes

Dams are important components of the state's infrastructure and provide benefits to all citizens. However, as history has demonstrated, dams can fail with disastrous consequences, causing unfortunate loss of life and property and natural resources. Many existing dams are getting older, and new dams are sometimes built in developed areas. At the same time, development continues in potential inundation zones downstream from dams. More people are at risk from dam failure than ever before, despite better engineering and construction methods. As a result, continued loss of property can be expected to occur. The challenges facing local emergency management officials are: 1) minimize loss of life and property by working closely with dam owners in the development of the EAPs to ensure consistency with the Emergency Operations Plan (EOP) for the jurisdiction; 2) developing procedures in the EOP for responding to a dam failure (including a site-specific standard operating procedure for each dam site); 3) participating in dam site exercises; and 4) increasing public awareness of dam safety procedures.

The risk of dam failures should be calculated, where possible, from past occurrences. If a community has had no history of dam failures, the community may wish to examine the histories of similar types of dams (based on size, construction, ownership, maintenance schedules) and use that information to estimate the annual chance of a failure. Remember that not all failures result in damaging floods—many failures are caught in time to prevent flood damages, but still have costs associated with emergency response and repairs. It makes sense to calculate costs from different types of events. In most years, there will be no incident. If there is an incident, it may be relatively minor in its impact. The worst case scenario would involve catastrophic dam failure.

Although none of the 287 recorded dam failures in Michigan were truly catastrophic in terms of massive loss of life, property damage from major events has sometimes been very significant, particularly in terms of the related flooding that tends to follow a dam failure. Millions of dollars of damage resulted from the 2002 to 2004 events in the Upper Peninsula, which were the largest recent events of this type. Although dams vary widely in their significance and environmental context throughout Michigan, the historical record shows a frequency of about 2.3 failures per year, on average. Not all of these failures were damaging events, since most of Michigan's dams are small and located in rural areas.

Impact on the Public

No catastrophic dam failures have been reported in Michigan, of a type that actually had unanticipated flash-flood style impacts on anyone who might have been affected by them. However, significant dam failure events have occurred and caused displacement, infrastructure failure, road/bridge closures, and property damage. The impacts have generally been similar to those of riverine flooding (please see that chapter in this analysis), except that dam failures present the possibility for a faster release and inundation of the affected areas, and that failed dams may affect the area's hydrology and infrastructure. (For example, hydroelectric dams may need to be shut down in the event of a breach, causing impacts on the power supply of an area, or local economic effects.)

Impact on Public Confidence in State Governance

Recorded dam failures in Michigan have not been catastrophic, but still may cause problems in residents' perceptions of the reliability of government standards and policy regarding the engineering, inspection, and maintenance of such structures. The failure of levies in the New Orleans hurricane event may carry over into more general concerns about the adequacy of structural water containment infrastructure nationwide.

Impact on Responders

Some dam failures can cause catastrophic flash flooding to take place, which is especially dangerous to any who are near the floodway area, as responders often must be. In addition, access to dam areas is often made difficult by their remoteness, the presence of barbed wire, hunting areas, rugged terrain, etc.

Impact on the Environment

Dam failure has the potential to cause great harm to the natural ecosystem by pushing sedimentation throughout the floodplain. Dam failure can also push water onto agricultural land, which can then carry fertilizers and pesticides into other areas.

Significant Dam Failures in Michigan

1939: Lenawee County

A dam failure occurred in Lenawee County when the Rollin Mill Dam was struck by a tornado in 1939. The Rollin Mill Dam was not rebuilt after being destroyed in the incident.

September 1986: Central Lower Peninsula

On September 10 - 11, 1986 an intense rainstorm in the central portion of the Lower Peninsula produced rainfall amounts ranging from 8 to 17 inches over an area 60 miles wide and 180 miles long. As a direct result of that storm, 11 dams failed and 19 others were threatened with failure, resulting in about 1,500 people being evacuated downstream of the dams. The failure and threatened failure of these dams was primarily the result of inadequate spillway capacity. Most of the dams were constructed without an emergency spillway, and didn't have an adequate inspection and maintenance program. The excessive rainfall resulted in the design capacity of the dam being exceeded, causing failure of the dam or intentional breaching of the embankment to save certain portions of the structure. Fortunately, no deaths or injuries were attributable to this series of dam failures.

2002-2004: Upper Peninsula Flooding and Dam Failures

A pattern of flooding and dam failures occurred in the Western and Central Upper Peninsula for several years in a row. In April of 2002, several dams in Gogebic County were breached by floodwaters, with the City of Wakefield being especially affected. The city's water treatment, wastewater treatment, and electric plant were all in danger of inundation and shutdown, and the State Police Post there was evacuated due to flooding. The Wood Dam (Presque Isle Wildlife Dam) was breached and an embankment to its north partially eroded, allowing waters to flow through. In Gogebic County, 48 homes were destroyed, 91 suffered major damage, and 27 endured minor damage; 7 businesses were destroyed, and 11 were damaged. A federal Disaster Declaration was issued by the president.

In Marquette County, two dams were at maximum levels, but held during that 2002 event. In May of the next year, however, Marquette County was the one to suffer from flooding, as a series of dikes and dams failed, starting with the Silver Lake dike, and caused excessive water to flood low-lying areas in the City of Marquette. Marquette County declared a local state of emergency, and damages were estimated at about $3.2 million, of which $1,000,000 was caused to the failed dike and downstream dams themselves. The Governor ordered the evacuation of persons living along waterways in the Dead River Basin area and its tributaries downstream of Silver Lake. Although the U.S. Small Business Administration issued a "Declaration of Economic Injury," no federal Disaster Declaration was approved for this event.

In 2004, similar flooding threatened to occur, but did not have quite the same level of impact as had happened in the previous two years.

Historically Significant Dam Failures across the U.S. (selected events before 1990)

Year	Dam Name / Location	Deaths
1874	Mill River, Massachusetts	143
1890	Walnut Grove, Arizona	150
1899	Johnstown, Pennsylvania	2,209
1911	Bayless, Pennsylvania	80
1928	St. Francis, California	450
1972	Black Hills / Canyon Lakes, South Dakota	278
1972	Buffalo Creek, West Virginia	125
1976	Teton, Idaho	11
1976	Big Thompson River, Colorado	144
1977	Tocca Falls, Georgia	39
1977	Laurel Run / Shady Run, Pennsylvania	45
1978	Texas Hill Country, Texas	25
1990	Shadyside, Ohio	24

Sources: National Performance on Dams Program, Center on Performance of Dams, Stanford University, (M. McCall), 1995; *Multi-Hazard Identification and Risk Assessment*, 1997, FEMA.

Programs and Initiatives

The series of tragic dam failures that occurred across the United States in the 1970s prompted government action to more stringently regulate dams and heightened public concern about hazards created by unsafe dams. Both the MDEQ and the Federal Energy Regulatory Commission (FERC) classify and regulate dams in Michigan. Under state and federal legislation, certain dam owners are required to develop a survey of the downriver area, develop flood-prone area maps and develop emergency action plans (EAPs). Furthermore, the FERC requires the owners of such dams to exercise these plans; the MDEQ has initiated an effort to encourage owners of state-regulated dams to voluntarily perform exercises of their EAPs. In Michigan, well over 100 dams are covered by Emergency Action Plans.

Dams in Michigan are regulated by Part 315 of The Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. Part 315, Dam Safety provides for the inspection of dams. This statute requires the MDEQ to rate each dam as either "high," "significant," or "low" hazard potential, according to the potential downstream impact if the dam were to fail (not according to the physical condition of the dam). The MDEQ has identified and rated over 2,400 dams. Dams over 6 feet in height that create an impoundment with a surface area of 5 acres or more are regulated by this statute. Dam owners are required to maintain an EAP for "high" and "significant" hazard potential dams. Owners are also required to coordinate with local emergency management officials to assure consistency with local emergency operations plans. Dams regulated by FERC, such as hydroelectric power dams, are generally exempt from this statute.

The FERC licenses water power projects (including dams) that are developed by non-federal entities, including individuals, private firms, states and municipalities. Under provisions of the Federal Power Act and federal regulations, the licensee of the project must prepare an EAP. This plan must include a description of actions to be taken by the licensee in case of an emergency. Inundation maps showing approximate expected inundation areas must also be prepared. Licensees must conduct a functional exercise at certain projects, in cooperation with local emergency management officials.

Recognizing the importance of mitigating dam failures, the State of Michigan in recent years has used federal grant funds for several projects designed to reduce local vulnerability to dam failures by upgrading dams or removing persons from harm's way.

The federal Dam Safety and Security Act of 2002 addresses safety and security of dams through the coordination by the Federal Emergency Management Agency (FEMA) of federal programs and initiatives for dams and the transfer of federal best practices in dam security to the states. The Act includes resources for the development and maintenance of a national dam safety information network and the development by the National Dam Safety Review Board of a strategic plan that establishes goals, priorities, and target dates to improve the safety and security of dams in the United States.

The Act continues all of the programs established by the 1996 Act that have been serving to increase the safety of the nation's dams, including: 1) increased funding authority to support improvement of the state dam safety programs that regulate over 77,000 dams in the United States; 2) the work of the Interagency Committee on Dam Safety (ICODS); 3) the development of the strategic plan and the biennial report on the National Dam Safety Program; 4) training for state dam safety staff and inspectors; 5) a continued program of technical and archival research, including the development of devices for the continued monitoring of the safety of dams; and 6) increased reliance on the National Dam Safety Review Board, which provides the Director of FEMA with advice on national policy issues affecting dam safety and helps oversee the operation of state dam safety programs.

Potential Dam Hazards in Michigan
(as of December 2010)

County	High Hazard	Significant Hazard	Total	County	High Hazard	Significant Hazard	Total
Alcona	1		**1**	Lake		2	**2**
Alger	1		**1**	Lapeer	1	6	**7**
Allegan	7	2	**9**	Leelanau	2	1	**3**
Alpena	2	1	**3**	Lenawee	3	5	**8**
Antrim	2		**2**	Livingston	3	7	**10**
Arenac		1	**1**	Luce			**0**
Baraga	2		**2**	Mackinac	1		**1**
Barry		3	**3**	Macomb	2	1	**3**
Bay			**0**	Manistee	2		**2**
Benzie		1	**1**	Marquette	9	7	**16**
Berrien	2	2	**4**	Mason	2		**2**
Branch		1	**1**	Mecosta		4	**4**
Calhoun		3	**3**	Menominee	4	2	**6**
Cass	2	1	**3**	Midland	4		**4**
Charlevoix		3	**3**	Missaukee		1	**1**
Cheboygan	6	3	**9**	Monroe		2	**2**
Chippewa		1	**1**	Montcalm		2	**2**
Clare	3		**3**	Montmorency		2	**2**
Clinton		2	**2**	Muskegon	1	2	**3**
Crawford			**0**	Newaygo	3	1	**4**
Delta	1	1	**2**	Oakland	8	15	**23**
Dickinson	2	3	**5**	Oceana	2	2	**4**
Eaton	3		**3**	Ogemaw		3	**3**
Emmet		1	**1**	Ontonagon	2	2	**4**
Genesee	3	7	**10**	Osceola		1	**1**
Gladwin	5	1	**6**	Oscoda	1		**1**
Gogebic			**0**	Otsego			**0**
Grand Traverse	4	4	**8**	Ottawa	1	1	**2**
Gratiot		2	**2**	Presque Isle			**0**
Hillsdale		5	**5**	Roscommon	1	3	**4**
Houghton		2	**2**	Saginaw	1		**1**
Huron			**0**	St. Clair			**0**
Ingham	1	1	**2**	St. Joseph	5	3	**8**
Ionia	1	1	**2**	Sanilac			**0**
Iosco	4	1	**5**	Schoolcraft	1	1	**2**
Iron	3	2	**5**	Shiawassee		2	**2**
Isabella	1	3	**4**	Tuscola			**0**
Jackson	1	4	**5**	Van Buren	1	1	**2**
Kalamazoo	5	5	**10**	Washtenaw	8	6	**14**
Kalkaska	1		**1**	Wayne	8	1	**9**
Kent	2	5	**7**	Wexford		2	**2**
Keweenaw			**0**	**TOTAL**	**141**	**160**	**301**

Dams in Michigan
Michigan Department of Natural Resources
institute for Fisheries Research, 10-27-2003
N
0 25 50 100 150
Miles
Produced by:
Michigan State Police
Emergency Management and Homeland Security Division
December 2010

Drought

A water shortage caused by a deficiency of rainfall, generally lasting for an extended period of time.

Hazard Description

Drought is the consequence of a natural reduction in the amount of precipitation received over an extended period of time, usually a season or more in length. Drought is a normal part of the climate of Michigan and of virtually all other climates around the world – including areas with high and low average rainfall. In low rainfall areas, drought differs from normal arid conditions in that the extent of aridity exceeds even that which is usual for the climate. The severity of a drought depends not only on its location, duration, and geographical extent, but also on the area's water supply needs for human activities and vegetation. This local variation of drought standards makes the hazard difficult to refer to and makes it difficult to assess when and where one is likely to occur.

Drought differs from other natural hazards in several ways. First, in the lack of an exact beginning and endpoint for a drought, whose effects may accumulate slowly and linger even after the event is generally thought of as being over. Second, the lack of a clear-cut definition of drought can make it difficult to confirm whether one actually exists, and if it does, its degree of severity. Third, drought impacts are often less obvious than other natural hazards, and they are typically spread over a much larger geographic area. Fourth, due primarily to the aforementioned reasons, most communities do not have in place any contingency plans for addressing drought. This lack of pre-planning can hinder support for drought mitigation capabilities that would otherwise effectively increase awareness and reduce drought impacts.

Hazard Analysis

Droughts can cause many severe impacts on communities and regions, including: 1) water shortages for human consumption, industrial, business and agricultural uses, power generation, recreation and navigation; 2) a drop in the quantity and quality of agricultural crops; 3) decline of water quality in lakes, streams and other natural bodies of water; 4) malnourishment of wildlife and livestock; 5) increase in wildfires and wildfire-related losses to timber, homes and other property; 6) declines in tourism in areas with water-related attractions and amenities; 7) declines in land values due to physical damage from the drought conditions and/or decreased economic or functional use of the property; 8) reduced tax revenue due to income losses in agriculture, retail, tourism and other economic sectors; 9) increases in insect infestations, plant disease, and wind erosion; and 10) possible loss of human life due to food shortages, extreme heat, fire, and other health-related problems such as diminished sewage flows and increased pollutant concentrations in surface water.

Although it is difficult to determine when a drought is actually occurring, once a drought is recognized it can be classified within four different categories - meteorological, hydrologic, agricultural, and socioeconomic. A **meteorological** drought is based on the degree of dryness, or the departure of actual precipitation from an expected average or normal amount based on monthly, seasonal, or annual time scales. A **hydrologic** drought involves the effects of precipitation shortfalls on stream flows and reservoir, lake, and groundwater levels. An **agricultural** drought concerns soil moisture deficiencies relative to the water demands of plant life, usually crops. A **socioeconomic** drought is when the effective demand for water exceeds the supply, as a result of weather-related shortfalls.

The U.S. Drought Monitor (http://www.drought.unl.edu/dm/monitor.html) uses four classifications of severity, from the least intense category (D1) to the most intense (D4), with an additional (D0) category used to designate a "drought watch" area in which long-term impacts such as low reservoir levels are probably present. The Drought Monitor summary map is available online, identifying general drought areas and labeling their intensity. While not the only way to characterize droughts, the U.S. Drought Monitor is convenient and their classification levels have recently been used in various reports and assessments of drought conditions. Short-term indicators are on the level of 1-3 months, while long-term indicators focus on a duration of 6 to 60 months.

Palmer Drought Classification Categories

Category	Description	Possible Impacts	Palmer Drought Index	CPC Soil Moisture Model, USGS Weekly Streamflow, Objective Short & Long-term Drought Indicator Blends (Percentiles)	Standardized Precipitation Index (SPI)
D0	Abnormally Dry	Going into drought: short-term dryness that slows planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered.	-1.0 to -1.9	21-30	-0.5 to -0.7
D1	Moderate Drought	Some damage to crops, pastures, streams, reservoirs, or wells low; some water shortages developing or imminent; voluntary water-use restrictions requested.	-2.0 to -2.9	11-20	-0.8 to -1.2
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed.	-3.0 to -3.9	6-10	-1.3 to -1.5
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions.	-4.0 to -4.9	3-5	-1.6 to -1.9
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies.	-5.0 or less	0-2	-2.0 or less

Source: U.S. Drought Monitor web site http://drought.unl.edu/dm/classify.htm

In addition, the U.S. Drought Monitor uses two general drought categories in assessing an event—an A to denote agricultural effects on crops, pastures, and grasslands, and an H to denote hydrologic effects on water supplies such as rivers, groundwater, and reservoirs.

Despite the thousands of miles of rivers and streams in the state, Michigan has experienced occasional drought conditions. Most common are agricultural droughts, with severe soil-moisture deficits, which have had serious consequences for crop production, particularly when coupled with extreme summer temperatures. Also, various water bodies, both inland lakes and the Great Lakes themselves, cyclically go through periods of low-water levels. Michigan has been in such a period for a number of years now. (See the section on Flooding Hazards: Great Lakes Shoreline Flooding and Erosion for more information about these trends in water levels.)

Recent trends suggest that the pattern in Michigan will continue to be one of low water and lake levels, and even declared declarations of drought. The only exception appears to be the water levels in Lake Erie and Lake St. Clair, which are currently at or above their historically normal levels. (Updated graphs of Great Lakes water levels can be found in the Great Lakes Shoreline Hazards section.) In 2007, all 83 counties received drought disaster declarations from the U.S. Department of Agriculture due to crop losses from drought. In the Muskegon harbor, two freighters became stuck, with low water levels increasing the need for dredging activities and causing ships to unintentionally run aground on the sandy harbor bottom. These events occurred in August and September of 2007, at the same time that drought conditions were present in Michigan. At the beginning of August, three counties (Allegan, Kalamazoo, and Van Buren) were judged to be at D2 (severe drought) status. Twelve other counties in Southwest Michigan were evaluated as having D1 (moderate drought) conditions. Several others were considered to have abnormally dry (D0) status. Wildfire dangers were similarly escalated, due to these dry conditions, with fire danger levels in Southern Michigan ranging from “high” to “extreme.” (Usually fire dangers become less significant after a spring “green up,” but this year was an exception due to the drought effects.) Water flows in various rivers and creeks were far below normal—in many cases only about 60% of their usual rates. In addition to various Red Flag Warnings, by mid-August the Michigan Department of Natural Resources released a proclamation prohibiting the use of fire on or adjacent to forest lands for 75 counties in Michigan. In late August, drought conditions worsened, with 23 Northern Michigan counties at moderate (D1) drought status and two (Chippewa and Mackinac) at severe (D2) drought status. Although some rainfall in early September allowed the fire restriction proclamation to be rescinded in 23 southern Michigan counties, it remained in effect for 52 of the more northern counties. By late September, drought conditions had been alleviated somewhat by additional rainfall, except for the Upper Peninsula, which still had severe drought (D2) status in seven of its western counties, and moderate (D1) drought status for 5 of its eastern counties. (Source: Law Enforcement Information Network messages)

In the United States, drought conditions often exist in some region of the country, with some area likely to be experiencing drought conditions at a particular time.

Urbanized Areas

The entire state is subject to the impacts of drought. However, some areas are more vulnerable to certain drought-related impacts than others. Large urbanized areas can be more vulnerable to water shortages and business disruptions due to the sheer number of water users that are competing for the limited water resources. In those areas, water management strategies typically have to be implemented to deal with the water shortage problems. Public health and safety concerns are also numerous - everything from maintaining adequate water supply for firefighting to addressing the needs of the elderly, children, ill or impoverished individuals suffering from heat-related stress and illness. The latter is particularly problematic for densely urbanized, inner-city areas, because heat-related deaths occur much more frequently in those areas than in suburban and rural areas. (See the Extreme Temperatures section for more detailed information.)

Rural Areas

In rural agricultural areas and the heavily forested areas of Northern Michigan, drought brings on a host of other problems to address. The agricultural areas of southern Lower Michigan are highly vulnerable to drought conditions that impact the quantity or quality of crops, livestock, and other agricultural activities. These areas often depend heavily on agricultural production for their economic needs. A prolonged drought can seriously impact local and regional income, which in turn has a rippling effect on the other components of the economy. Drought can also cause long-term problems that can negatively affect the very viability of some agricultural operations.

In Northern Michigan's forested regions, drought can adversely impact timber production and some tourism and recreational enterprises. This can also cause a drop in income, which impacts other economic sectors. The biggest problem drought presents, however, is the increased threat of wildfire. Many Northern Michigan counties are heavily forested and are therefore highly vulnerable to drought-related wildfire threats. As the 1976 Seney fire proved, a drought-impacted landscape could quickly turn a small fire into a raging, out of control conflagration.

Statewide

Tourism is an important source of revenue for Michigan. The Great Lakes attract numerous boaters and vacationers each year. Many of the "nice weather" activities and attractions involve water-related swimming, boating, fishing, and resort activities, and these forms of recreational and tourist attractions can all be negatively impacted by the effects of drought conditions. Resort areas and boat docks have physical designs that tend to be based on particular water levels. In recent cases of moderate and severe drought, as described above, stream flows can fall below 50% of their normal levels, in many cases reducing the navigability of waterways and altering the relationship between water levels/locations and built facilities for recreational access to that water (boardwalks, docks, fishing sites, et cetera).

Drought Contingency Planning

Because of variations in the drought threat throughout the state, local communities should develop and maintain drought contingency plans (as part of their overall emergency preparedness effort) that address the primary threats that drought presents in their area. For urban jurisdictions, that threat is primarily related to water supply and use management, heat-related illnesses, and continuation of industrial and business operations. For rural jurisdictions, that threat is primarily agricultural and wildfire-related. Such preparedness efforts will not eliminate the negative effects of drought, but they can at least help minimize and manage the consequences of those effects on the population.

Because drought is a low-profile hazard, it does not receive as much attention as it probably should from the emergency management community, governmental agencies, or the public in general. As a result, drought contingency planning is typically a lower priority activity than is planning for other types of natural hazards. Because of the lack of pre-planning, historic responses to drought have been ad hoc and typically involve the creation of special task forces or interagency groups to address drought-related issues as they arise. Once the crisis is over, little is typically done in terms of time or resource commitment in order to ease the impacts of the next drought. Part of the problem stems from the fact that drought contingency planning faces many obstacles, including: 1) lack of a single definition of drought that works in all regions of the country; 2) lack of unified, consistent policies on natural resource management (including water) among states and regions in the U.S.; 3) lack of a lead, coordinating agency for drought mitigation and planning; 4) lack of "dramatic," high-profile impacts (i.e., property damage, casualties, debris, etc.) – which lessens the severity of drought in the minds of community decision-makers and the public; 5) the infrequent nature of drought makes it difficult to garner support for planning and mitigation actions; and 6) the widely-held perception that,

because the problem is so enormous in scope and magnitude, there is little that can be done to prevent drought or lessen its impacts.

Having a Drought Contingency Plan for a community is quite important in the event that a severe drought impacts your area. Such a plan should be a separate document detailing what steps need to be taken in the event of a drought. The plan should cover the following questions:

1) Where are primary water sources for the general population?
2) Where are alternative sources for water if the primary sources are inadequate for the community's needs?
3) At what point of lessening water resources do local water restrictions go into place?
4) Are there incrementally strict water regulations related to drought severity?
5) At what point do water restrictions cease?
6) What are the costs of bringing outside water into the community?
7) What is the hierarchy of water distribution to residential, commercial, agricultural and industrial areas?
8) How will children, the elderly, the ill, and other vulnerable citizens be accounted for?

One thing is certain when it comes to drought. As the population increases (both in the U.S. and worldwide), so too does the need for water for drinking, growing food, and running businesses and homes. That increasing need greatly heightens vulnerability to future droughts.

Impact on the Public

Drought impacts may include limited or restricted access to water, and higher prices for water and agricultural goods. There is a threat to public health and safety, as water shortages and decreased water quality raise threats of illness, land subsidence, and wildfires. Conflicts between water users can arise, especially when a river or lake has competing uses among municipal, agricultural, industrial, and recreational users. Water restrictions and limitations among residents can also change daily lifestyle patterns and create social unrest in severe cases. There is also the possibility of a substantial economic impact on an area's agricultural sector, and that sector is very important for many of Michigan's rural areas, both in terms of the local area's economics (export value) as well as its employment (proportion of the labor force). Drought may also cause erosion of topsoil (with an associated loss of productivity and land value) and exacerbate other types of erosion, involving associated costs for property owners.

Impact on Public Confidence in State Governance

In some areas, the government is responsible for infrastructure maintenance and water supply planning and storage, and could be perceived as having failed during a major drought event. Actual responsibility for these issues varies with the specific jurisdiction(s) and agencies involved. Public expectations of government responsibility may be lower in areas with many natural water sources, and areas that make heavy use of individual rather than municipal supply sources. Some interesting cases emerge, however, in areas that have industries that commercially bottle area groundwater for profit. In cases of drought, or of lessened quantity or quality of local groundwater, there is likely to be popular discontent among segments of the public who hold local or state government responsible for "allowing" (or even "favoring") for-profit water bottling businesses to compete with the claimed interests of the area's residential water-users.

Impact on Responders

Droughts may be expected to affect a community's capacity to fight wildfires, and perhaps even major structural fires as well. There may be access issues involving egress into private property. For example, a water shortage may require access to a water pond on private property, to assist with efforts to fight a wildfire in the area. Otherwise, no particular responder issues should arise from a drought event.

Impact on the Environment

A drought can have serious consequences for the environment if the length and severity of the event is great enough. The hydrological effects of drought can include a loss of wetlands, and lower water levels in lakes, ponds and rivers that are used for irrigating agricultural crops. Additionally, a deficit in rain for an extended period of time may cause ground water depletion and a reduction in the water quality. Drought may also impact plant and animal life by a reduction in drinking water and loss of biodiversity. Drought is also the cause of many wildfires, which destroy wildlife habitats and alter an area's ecosystem. Air quality is reduced by an increase of dust and pollutants in the air.

Soil quality and quantity is also diminished due to enhanced erosion, especially around freshly exposed areas near lowered lakes and streams.

Drought Related Monitoring and Measurement

The process of drought monitoring involves having ready access to an ongoing supply of information regarding precipitation, stream flows, lake levels, etc. By examining one or more drought indices, encroaching or existent drought conditions can be monitored and adapted to. Drought-related scales include river and stream flows (expressed either as a percentage of normal or as a percentile), the Standardized Precipitation Index, Crop Moisture Index, Surface Water Supply Index, and the Drought Monitor. This type of information may be found through the National Drought Mitigation Center website, http://www.drought.unl.edu/index.htm, or the USGS Drought Watch web page at http://waterwatch.usgs.gov/?m=dryw&r=mi. Through these, an assessment of present conditions and forecasts are at your fingertips. Using the indicators given by these agencies, you can determine how close or how severe drought conditions may be for your area. Depending on the readings and predictions from the indices, you can determine how much risk and what kind of potential losses may arise from year to year. Heading into springtime in a given year with above average precipitation lessens the threat of impending drought (and its consequences) while dry fall and winter conditions lead to a heightened awareness of potential summer drought conditions.

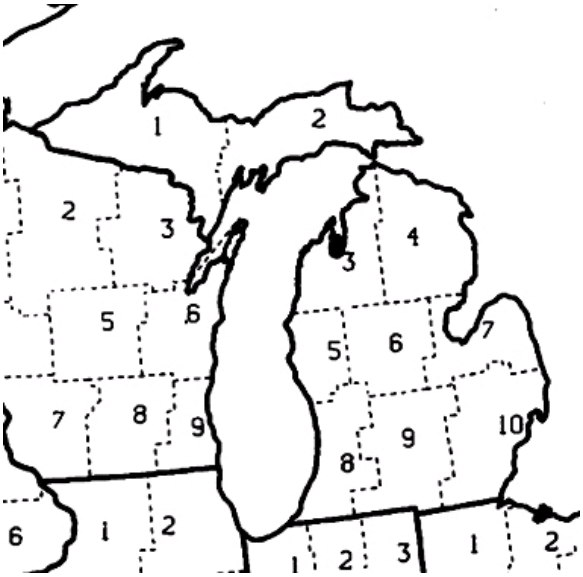
Significant U.S. Droughts: 1900-present

Drought Years	U.S. Location(s) Primarily Affected
1924-1934	California
1930-1940	Midwest ("Dust Bowl" drought)
1942-1956	Southwest
1952-1956	Mid-continent and Southeast
1961-1967	Northeast
1976-1977	Great Plains, Upper Midwest, West
1980-1981	Central, Eastern
1987-1989	Central, Eastern
1987-1992	California, Upper Great Plains
1998-1999	Northeast, Mid-Atlantic
2000-2001	South-Central, Southeast, Michigan / Ohio
2002-2003	Western, Central Midwest, Eastern

Source: Multi-Hazard Identification and Risk Assessment, FEMA, 1997; National Drought Mitigation Center; National Oceanic and Atmospheric Administration; MSNBC; USA Today

Of these historic national event periods, several were of particular significance to Michigan. After some explanation of Michigan's 10 climate divisions, which have been used for drought monitoring by the National Climatic Data Center, more extensive detail will be provided about the most notable historic drought events, in terms of their effects on Michigan.

Michigan's 10 climate divisions (for drought monitoring and analysis)



Information from the National Climatic Data Center is available for the current tracking and historical research of drought events in Michigan, but since dry conditions in one region may be balanced (in a statewide average) by wet conditions in another region, it is necessary to look at specific regions rather than the state as a whole, to assess the presence and severity of drought conditions from the historical data. For this plan, 126 years of data was analyzed (since 1895) for each of the 10 climate divisions illustrated in the map at left.

To assist with local planning efforts, the counties contained within these 10 climate divisions are hereby listed, and although historical data can at this time only be provided for the divisions as a whole, a summary of the most severe events from NCDC records have been included for each of the ten Climate Divisions. Following this is an overarching description of incidents and trends shown in historical drought records for Michigan.

Division 1: Baraga, Dickinson, Gogebic, Houghton, Iron, Keweenaw, Marquette, Menominee, and Ontonagon Counties. The most extreme drought was in January 1977, when the Palmer index hit a record low of -6.67. Lengthy drought incidents took place in 1895-1896 (9 months), 1898-1899 (8 months), 1910-1911 (19 months), 1930-1931 (16 months), 1933-1934 (9 months), 1943-1944 (8 months), 1947-1949 (23 months), 1957-1958 (16 months), 1963-1964 (14 months), 1976-1977 (14 months), 1986-1987 (12 months), 1989-1990 (13 months), and 2006-2007 (16 months).

Division 2: Alger, Chippewa, Delta, Luce, Mackinac, and Schoolcraft Counties. The most extreme drought was in January 1931, when the Palmer index hit a record low of -7.18. Lengthy drought incidents took place in 1895-1896 (15 months), 1898-1899 (8 months), 1909-1911 (26 months), 1919-1920 (8 months), 1920-1922 (17 months), 1925-1926 (14 months), 1929-1931 (26 months), 1947-1949 (20 months), 1955-1956 (14 months), 1962-1964 (21 months), 1976-1977 (8 months), 1987 (8 months), 1989-1990 (9 months), 1997-1999 (21 months), 2000-2001 (14 months), and 2005-2007 (22 months).

Division 3: Antrim, Benzie, Charlevoix, Emmet, Grand Traverse, Kalkaska, Leelanau, Manistee, Missaukee, and Wexford Counties. The most extreme drought was in January 1931, when the Palmer index hit a record low of -8.07. Lengthy drought incidents took place in 1895-1896 (17 months), 1898-1899 (8 months), 1899-1901 (21 months), 1901-1902 (15 months), 1908-1911 (37 months), 1913-1914 (11 months), 1914-1915 (10 months), 1919-1920 (8 months), 1920-1922 (17 months), 1925-1926 (17 months), 1929-1931 (28 months), 1935-1936 (20 months), 1955-1956 (13 months), and 1976-1977 (13 months).

Division 4: Alcona, Alpena, Cheboygan, Crawford, Iosco, Montmorency, Ogemaw, Oscoda, Otsego, Presque Isle, and Roscommon Counties. The most extreme drought was in February 1931, when the Palmer index hit a record low of -8.51 (the all-time record for Michigan). Lengthy drought incidents took place in 1895-1896 (17 months), 1898-1899 (8 months), 1899-1902 (37 months), 1909-1911 (28 months), 1913-1915 (26 months), 1919-1922 (33 months), 1924-1926 (19 months), 1929-1931 (28 months), 1948-1949 (9 months), 1955-1956 (12 months), 1963-1964 (11 months), 1976-1977 (13 months), 1981-1982 (12 months), 1989-1990 (8 months), and 1999-2000 (9 months).

Division 5: Lake, Mason, Muskegon, Newaygo, and Oceana Counties. The most extreme drought was in January 1931, when the Palmer drought severity index hit a record low of -7.20. Lengthy drought incidents took place in 1895-1896 (15 months), 1899-1900 (11 months), 1901-1902 (10 months), 1909-1911 (24 months), 1925-1926 (11 months), 1930-1931 (18 months), 1956-1957 (8 months), 1962-1963 (9 months), 1964-1965 (9 months), 1971-1972 (12 months), 1976-1977 (13 months), and 2002-2003 (12 months).

Division 6: Clare, Gladwin, Gratiot, Isabella, Mecosta, Midland, Montcalm, and Osceola Counties. The most extreme drought was in February 1931, when the Palmer index hit a record low of -7.56. Lengthy drought incidents took place in 1895-1896 (15 months), 1899-1900 (13 months), 1900-1902 (20 months), 1910-1911 (19 months), 1913-1915 (23 months), 1919-1922 (30 months), 1924-1926 (16 months), 1930-1932 (25 months), 1934-1935 (10 months), 1936-1937 (13 months), 1944-1945 (8 months), 1963-1964 (10 months), 1971-1972 (12 months), and 1976-1977 (14 months).

Division 7: Arenac, Bay, Huron, Saginaw, Sanilac, and Tuscola Counties. The most extreme drought was in February 1931, when the Palmer index hit a record low of -7.57. Lengthy drought incidents took place in 1895-1896 (15 months), 1899-1900 (13 months), 1900-1902 (20 months), 1909-1912 (33 months), 1913-1915 (24 months), 1919-1922 (32 months), 1924-1926 (17 months), 1930-1932 (28 months), 1934-1935 (16 months), 1936-1937 (14 months), 1938-1939 (8 months), 1939-1940 (13 months), 1946-1947 (8 months), 1963-1965 (18 months), 1971-1972 (9 months), 1976-1977 (8 months), and 1998-1999 (12 months).

Division 8: Allegan, Berrien, Cass, Kalamazoo, Kent, Ottawa, and Van Buren Counties. The most extreme drought was in February 1931, when the Palmer index hit a record low of -6.57. Lengthy drought incidents took place in 1895-1896 (8 months), 1901-1902 (10 months), 1914-1915 (8 months), 1925-1926 (11 months), 1930-1932 (29 months), 1934-1935 (9 months), 1946-1947 (9 months), 1953-1954 (8 months), 1956-1957 (9 months), 1962-1964 (31 months), 1999-2000 (10 months), and 2005-2006 (10 months).

Division 9: Barry, Branch, Calhoun, Clinton, Eaton, Hillsdale, Ingham, Ionia, Jackson, Shiawassee, and St. Joseph Counties. The most extreme drought was in April 1931, when the Palmer index hit a record low of -6.82. Lengthy drought incidents took place in 1895-1896 (13 months), 1899-1900 (11 months), 1901-1902 (14 months), 1913-1914 (9 months), 1914-1915 (10 months), 1924-1926 (15 months), 1930-1932 (22 months), 1934-1935 (12 months), 1946-1947 (8 months), 1953-1954 (11 months), 1962-1965 (30 months), and 2002-2003 (8 months).

Division 10: Genesee, Lapeer, Lenawee, Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, and Wayne Counties. The most extreme drought was in March 1931, when the Palmer index hit a record low of -6.82. Lengthy drought incidents took place in 1895-1896 (8 months), 1900-1902 (24 months), 1913-1914 (12 months), 1914-1915 (12 months), 1925-1926 (13 months), 1930-1932 (24 months), 1933-1937 (42 months), 1939-1940 (12 months), 1952-1953 (8 months), 1953-1954 (17 months), 1963-1965 (35 months), 1971-1972 (15 months), and 1998-1999 (9 months).

The following two tables summarize 116 years of drought records in all 10 of Michigan's specified climate divisions. There are many possible ways of expressing this data and comparing Michigan's geographic areas. A consideration of the most severe Palmer drought index values has already been provided (which found that division number 4 had the most severe drought in Michigan, with a Palmer index of -8.51 for February of 1931), along with lists of lengthy drought periods (which numbered from 12 to 17 per division, during the period from 1895 to 2010). The first table below expresses the percentage of years that either had no drought months at all (with the Palmer Index always above a value of -2.0), or had drought months beyond a certain level of severity. Since a Palmer Index of -2.0 is considered to be a moderate drought (U.S. Drought Monitor category D1), this was the base criterion used to establish the presence of drought in the area during a given month. The percentage of years in which Palmer Index values fell below various cutpoints for drought severity are provided in the table. The annual figures suggest that climate division 4 is the most drought-prone within Michigan.

Drought Years in Michigan, by Climate Division
(covering the 116 years from 1895 to 2010)

Climate Division	Years without any drought months	With drought ≤ - 2.0 Palmer	With drought ≤ - 3.0 Palmer	With drought ≤ - 4.0 Palmer	With drought ≤ - 5.0 Palmer	With drought ≤ - 6.0 Palmer	With drought ≤ - 7.0 Palmer
1	50%	50%	28%	13%	9%	2%	0
2	41%	59%	39%	21%	**10%**	2%	1%
3	40%	60%	35%	20%	9%	2%	**2%**
4	**37%**	**63%**	39%	**23%**	**10%**	**3%**	**2%**
5	43%	57%	29%	12%	2%	2%	1%
6	39%	61%	31%	18%	3%	2%	**2%**
7	38%	62%	**40%**	20%	4%	2%	1%
8	44%	56%	30%	9%	2%	1%	0
9	43%	57%	29%	16%	4%	1%	0
10	46%	54%	34%	20%	6%	**3%**	0

An analysis by year tends to overstate Michigan's drought-susceptibility, because the presence of a single drought month may be counted the same as an entire year of sustained drought (although longer drought periods often will be distinguished by having more severe Palmer Index values). A single month's drought will not necessarily cause severe agricultural impacts, because the timing of the drought with regard to the crop cycle is also important for the extent of drought impact. Therefore, an analysis of the percentage of drought months is also provided here, as a different indicator of drought frequency. This table also suggests that Climate Division 4 is the most drought-prone area in Michigan. The listing (on the previous page) of lengthy drought incidents (lasting 8 months or longer) can also give a kind of indicator regarding the frequency of droughts that likely had a significant agricultural impact, although these are all summary indicators by climate division and may vary considerably from the actual performance of individual farms within a particular area. The differences between Michigan's climate divisions may be significant, but are not enormous. One reason for this is that drought is defined with respect to an area's precipitation norms. It may be noteworthy that Climate Division 4 was also the location of Michigan's highest and lowest recorded temperature extremes.

Drought Months in Michigan, by Climate Division
(covering the 1,392 months from January 1895 to December 2010)

Climate Division	Months without any drought (Palmer >-2)	With drought ≤ - 2.0 Palmer	With drought ≤ - 3.0 Palmer	With drought ≤ - 4.0 Palmer	With drought ≤ - 5.0 Palmer	With drought ≤ - 6.0 Palmer	With drought ≤ - 7.0 Palmer
1	79.1%	20.8%	9.4%	3.8%	1.3%	0.2%	0
2	73.3%	26.7%	13.7%	4.7%	1.5%	0.3%	0.1%
3	71.9%	28.1%	12.1%	5.2%	1.7%	0.7%	**0.4%**
4	**69.8%**	**30.2%**	**15.7%**	**6.8%**	1.9%	**0.8%**	**0.4%**
5	77.9%	22.1%	8.2%	2.5%	0.7%	0.4%	0.1%
6	73.7%	26.3%	10.8%	4.4%	1.1%	0.6%	**0.4%**
7	70.9%	29.1%	14.5%	5.6%	1.7%	0.6%	0.3%
8	79.7%	20.3%	8.0%	2.0%	0.8%	0.3%	0
9	79.2%	20.8%	8.6%	4.1%	1.3%	0.4%	0
10	75.6%	24.4%	12.1%	5.5%	**2.4%**	**0.8%**	0

Significant Droughts affecting Michigan

1895-1896 Statewide

The available NCDC drought records (those that use the Palmer drought index) began with a period of extreme drought throughout Michigan. Every one of Michigan's climate divisions registered drought conditions for at least 8 months—some as long as 17 months—during this period. The drought was exceptionally severe in the Eastern Upper Peninsula and the Traverse Bay area. The Eastern U.P. had Palmer index values below -5 for four months in a row, between October and January. Recovery was spotty and temporary over the following few years, and it is probable that numerous areas felt little distinction between this drought event and the one that followed closely afterward.

1898-1902 Statewide

Some areas may not have even felt much of a recovery from the preceding drought event when things again took a turn for the worse as the new century arrived. Every one of Michigan's climate divisions felt lengthy droughts, and they tended to last even longer than the previous event had. The Upper Peninsula felt relatively short impacts, with no more than 8 drought months in a row, but the Lower Peninsula had an extremely rough time. Drought severity was exceptional in the Northern Lower Peninsula, reaching Palmer Index values of -5 and even less. In the four years between July of 1898 and June of 1902, the Northwestern Lower Peninsula only experienced three months that were just barely above a Palmer value of -2, the rest of the time being officially in an extended period of drought. The Northeastern Lower Peninsula fared even worse, with only 2 months registering a tiny smidgeon above the official drought level (-1.98 on the Palmer Index) while the rest of the time was disastrously dry. To the south, things were not quite as disastrous, although extreme drought levels were still reached during that period of time. Only the far southwestern tip escaped with "merely" a severe drought classification (bottoming out twice at -3.66 on the Palmer Index in 1899 and also in 1902).

1908-1912 Northern Michigan

The area north of where State Highway 57 now lies was all struck by an exceptional drought event, and in the northernmost areas of the state, conditions were exceptionally severe, with the Palmer Index reaching levels almost as low as -6 during multiple months in climate areas 1, 2, 3, and 4. The Northwestern Lower Peninsula had a particularly rough time, in that there wasn't much break for that region between this drought event and the following one, which reached an even greater level of severity. The Northeastern Lower Peninsula, after first experiencing a fairly moderate 8 months of initial drought, then sank into 37 straight months of drought conditions. In the Northwestern Lower Peninsula, the drought took the form of three periods—eight months, then 21 months, and finally 15 months in an official state of drought. Just to the south and east (the central and thumb areas of the state), 13 initial months of drought were, after an interlude, followed by 20 additional months of drought in a row.

1913-1915 Lower Peninsula

Although the Upper Peninsula had mostly recovered from the previous period of extreme drought, the Lower Peninsula had much more suffering to endure, following only a brief interlude of sporadic recovery in 1912 and 1913. Conditions were particularly extreme on the eastern side of the state, whose Palmer Index values all fell as low as -5 at certain points, or lower. The Northeastern Lower Peninsula suffered 6 straight months of such extreme drought levels, including Palmer Index values of -6.76, -6.56, -6.37, and -6.32 from December of 1913 to March of 1914.

1919-1922 Northeastern Michigan

Just after the end of World War I, as the influenza pandemic was calming, parts of Michigan still had years of gloomy drought conditions to endure. Although not reaching the exceptional severity of the previous drought event, this new period of drought was quite persistent. Climate divisions 4, 6, and 7 all experienced 30 or more continuous months of drought. Climate divisions 2 and 3 had a slightly less deleterious pattern, with 8 continuous drought months early on, followed by a lengthier period of 17 straight months of drought. In all these areas, the drought reached the extreme level (D3).

1924-1926 Statewide

All parts of Michigan were again struck with more hydrological problems in the mid-1920s, except for the Western Upper Peninsula, where hydrologic conditions were mostly reasonable. Most conditions were severe (D2), although the northern, central, and eastern Lower Peninsula (climate divisions 3, 4, 6, 7, 9, and 10) did reach extreme (D3) drought levels at certain times.

1930s Midwest / Statewide

Without a doubt, the "Dust Bowl" drought of the 1930s was the most famous drought ever to occur in the U.S. That drought, which was the subject of John Steinbeck's 1939 Pulitzer Prize winning book The Grapes of Wrath, was an ecological and human disaster of huge proportions. It was caused by misuse of the land combined with years with lack of rainfall. As the land dried up, great clouds of dust and sand, carried by the wind, covered everything and the term "Dust Bowl" was coined. As a result of this drought, millions of acres of farmland became useless, forcing hundreds of thousands of people to leave their farms and seek an existence elsewhere. (Many migrated to California, which was featured prominently in Steinbeck's book.) Although exact figures were not kept, some researchers estimate that nearly $1 billion (in 1930s dollars) was provided in assistance to victims of the Dust Bowl drought. That event also ushered in a new era or farming and conservation programs and practices aimed at preventing a recurrence of a drought of the magnitude and impact of the Dust Bowl drought.

In Michigan, this "dust bowl" period took the form of a most severe statewide drought condition from 1929 to 1932, followed by a less severe period from 1933 to 1937 in which the general pattern involved the south and western areas seeing the hardest conditions, and finally a period of limited spotty problems between 1938 and 1940.

The most extreme conditions ever seen in Michigan occurred in the period from 1929 to 1932. Nine out of Michigan's ten climatic divisions (the Western U.P. being the only exception) set their all-time drought records during the beginning of 1931, with Palmer Drought Index values varying from -6.57 (the southwestern tip of the Lower Peninsula) to the all-time Michigan record of -8.51 (in the Northeastern Lower Peninsula). Even if only the most exceptional drought levels (D4) are considered, these conditions were unusually long-lasting. Between 1930 and 1931, all nine of Michigan's most heavily affected climate divisions experienced this most unusual level of drought for at least 6 straight months (in climate division 2) to as many as 15 continuous months (in climate division 7). Unfortunately, those areas that experienced the more prolonged conditions of extreme drought were also the most heavily agricultural areas of the state, in the southern Lower Peninsula. Nevertheless, the entire state was struck very hard—the Western Upper Peninsula had 16 straight months of drought, and most other areas had two straight years or longer in drought conditions (climate area 8 had 29 consecutive months of drought between July 1930 and November of 1932).

The mid-1930s saw the drought conditions markedly reduced in climate divisions 2, 4, and 5, although the other areas of the state were still plagued with a level of problems that still compare with practically any other drought period in Michigan. Although not extreme in the northern areas of the state, the drought was still severe during a significant portion of this time frame. Parts of the southern Lower Peninsula, however, did experience conditions that were extreme and even exceptional. Climate division 7 saw five straight months in the most extreme D4 level of drought, between November 1936 and March 1937. Climate division 10 exceeded this, with ten straight months of D4 drought, including Palmer Drought Index values of -6.05 and -6.03 in December and January of 1934-1935. During this period, the southeastern Michigan region at this time set an all-time state record for the longest number of consecutive months under drought conditions—the 42 months between August 1933 and January 1937. By 1938, the Thumb area was the only part of Michigan still experiencing serious long-term drought problems. Although the area had some months of relief in early 1938, drought conditions resumed by the end of the year for a period of 8 consecutive months, and then between 1939 and 1940, another 13 month period of drought followed. During that latter period, southeastern Michigan shared in the drought conditions for a full year, and these two regions did reach the extreme D3 level of severity.

1946-1947 Part of the Lower Peninsula

Climate divisions 7, 8, and 9 all experienced about 8 continuous months of drought, peaking at the severe D2 level of intensity.

1947-1949 Far Northern Michigan

Climate divisions 1, 2, and 4 experienced lengthy drought conditions during these years. The mildest area this time was the Northeastern Lower Peninsula (9 months of drought, peaking at the extreme D3 level), while the Upper Peninsula was very heavily struck (more than 20 consecutive months of drought, peaking at the exceptional D4 level for two to three of those months).

1953-1954 Far Southern Michigan

Climate divisions 8, 9, and 10 were the focus of drought this time, with the effects worsening as one proceeded farther east. In the southwest, 8 consecutive months of drought were felt, peaking at the extreme D3 level for two months. In the southeast, this was instead felt as 17 consecutive drought months, with a D3 peak for three straight months in the middle.

1955-1956 Northeastern Michigan

Climate divisions 2, 3, and 4 all felt at least 12 consecutive drought months. Although the Eastern Upper Peninsula peaked at the extreme D3 level of severity, the Northern Lower Peninsula hit the exceptional D4 drought level—the western region staying there for four consecutive months, and the eastern region only experiencing one such month.

1956-1958 Western Michigan

By the late 1950s, the drought problem had shifted to be felt the hardest in the western Michigan climate divisions of 1, 5, and 8. The Western Upper Peninsula experienced 16 consecutive months of drought, peaking a couple of times at the severe D2 level. The Western Lower Peninsula was only struck for 8 to 9 consecutive months, but at a more intense level, with climate division 8 plunging into the extreme D3 level of drought.

1962-1965 Statewide

This was the only clear and serious statewide drought event to take place since the 1930s, which partially demonstrates a general trend of lessening drought problems in Michigan during the second half of the 20th Century when compared with the first half. Nevertheless, this was definitely the worst drought event to strike Michigan since the 1930s. In this event, only the Northwestern Lower Peninsula was significantly spared the extended and severe effects experienced throughout the rest of the state—that area's worst point was a two month spell at the severe D2 level. By contrast, the entire Southern Lower Peninsula had to endure at least 30 consecutive drought months, many of which were at the D2 level, or worse. Again, there was a pattern in which the drought was felt more intensely the farther to the east one was located. Southeastern Michigan experienced 9 consecutive months at the exceptional D4 level of drought. In the Upper Peninsula, things were also very bad—between 14 and 21 months of drought, which also peaked at the exceptional D4 level, but for a period of 4 to 5 months. The middle years of 1963-1964 were the worst phase of this event, for most parts of the state. It was mostly in the very south that 1962 was a bad year as well.

1971-1972 Part of the Lower Peninsula

Climate divisions 5, 6, 7, and 10 had to endure 9 to 12 consecutive months of drought conditions. Although division 7 (the Thumb) peaked briefly at a severe D2 drought level, the other three areas peaked for a longer period of time at the extreme D3 drought level.

1976-1977 National (including Northern Michigan)

The 1976-77 drought in the Great Plains, Upper Midwest, and West also severely impacted Northern Michigan. Climate divisions 1 through 7 all experienced drought conditions for a stretch of between 8 and 14 consecutive months. Extreme drought conditions in the Upper Peninsula also contributed heavily to the large wildfire that struck the Seney area in July of 1976, even though this was not the most severely impacted area of the state. The fire was started by a lightning strike that ignited dry grasslands and eventually burned over 74,000 acres over a 1½ month period, costing $8 million to contain. (The chapter on Wildfires contains more detailed information about this fire.) Drought had involved a significant reduction in rainfall (6-8 inches below normal) in the area, and the water table in the 95,455 acre Seney National Wildlife Refuge had dropped one foot, exposing old vegetation, peat and muck to the drying forces of the intense sunlight. Eventually, that material became a tinderbox that helped fuel the destructive fire. Fortunately, injuries and damage to improved property were minimal, although the loss of forest resources was staggering.

The drought itself reached exceptional D4 levels in climate divisions 1, 2, 3, 4, and 6—sometimes more than once or enduring for multiple months. For example, the Western Upper Peninsula saw Palmer Drought Index values of -5.92, -6.45, -6.67, and -6.11 for the four consecutive months between November of 1976 and February of 1977. In these terms of measurement, it was the hardest-hit region of the state.

Late 1980s Central U.S. (including Michigan); Eastern U.S.

First, Michigan's Upper Peninsula experienced from 8 to 12 consecutive months of drought during 1986-1987, peaking at the extreme D3 level for one month in the Western U.P, while the Eastern U.P. reached the severe D2 level. Next, a 1988 heat wave and drought impacted the Central and Eastern U.S. and caused an estimated $40 billion in damages from agricultural losses, disruption of river transportation, water supply shortages, wildfires, and related economic impacts. In response, Michigan took several steps to combat the impact of the drought on businesses, natural resources, and individual citizens. Numerous Michigan communities instituted temporary water use restrictions to ensure an adequate water supply for human consumption and other essential uses such as firefighting. To stem the potential for wildfire in Michigan, the Governor issued (in June, 1988) a statewide outdoor burning ban, which remained in effect until the end of July, 1988 (and longer in some Upper Peninsula counties). The State also formed a task force to study issues related to the drought and formulate appropriate strategies for dealing with those drought-related concerns. Fortunately, Michigan's drought conditions were not consistently severe during that summer, although they would be seen to worsen in some of the state's northern areas over the next couple of years. The final events in the chain of drought conditions took place when the Upper Peninsula again suffered a lengthy period (between 9 and 13 consecutive months) of drought between 1989 and 1990, peaking at the severe D2 level, and the Northeastern Lower Peninsula joined them in suffering 8 months in a row of drought conditions, also peaking at D2.

1998-2003 Northeast; Mid-Atlantic; South-Central; Southeast; Michigan

Droughts / heat waves in recent years have caused considerable damage to agriculture and related industries in several areas of the U.S. The summer of 1998 drought / heat wave from Texas to the Carolinas caused an estimated $6-9 billion in damage. The summer of 1999 drought / heat wave caused over $1 billion in damage – mainly to agricultural crops in the Eastern U.S. The summer of 2000 drought / heat wave in the South-Central and Southeastern U.S. resulted in over $4 billion in damages and costs. The drought / heat wave that struck Michigan during the summer of 2001 damaged or destroyed approximately one-third of the state's fruit, vegetable and field crops, resulting in a U.S. Department of Agriculture Disaster Declaration for 82 of the state's counties. In addition, the drought / heat wave caused water shortages in many areas in Southeast Michigan, forcing local officials to issue periodic water usage restrictions. In 2002, moderate to extreme drought affected more than 45 percent of the country during the months of June, July and August. Nationwide, the summer was the third hottest on record, following only 1936 and 1934. The summer of 2002 was also very hot and dry in Michigan. Several record highs were set throughout eastern Michigan during the month of September. During the first half of the month, hundreds of communities across the area were under water restrictions. Hardest hit from the drought was the agricultural industry. September yields across most of the area were estimated at under 50 percent and many counties across eastern Michigan were declared agricultural disaster areas. The severely dry weather was classified as a drought until mid 2003.

In terms of the Palmer Drought Index, the most severe problems in Michigan jumped around from year to year. The start was actually in the Eastern U.P. during 1997, with 21 drought months then following in a row until mid-1999, but resuming the next year for another 14 consecutive drought months until more than half of 2001 had passed. The extreme D3 level was reached there more than once. Meanwhile, the southeastern and thumb areas saw drought conditions sustained for 9 to 12 months between 1998 and 1999, peaking at the severe D2 level. In 1999, the areas of highest severity had shifted to the northeastern and southwestern areas of the Lower Peninsula, where 9 to 10 months of drought were sustained until 2000, and peaked at D2 in the northeast and D3 in the southwest. Finally, the adjacent western and south-central areas (climate divisions 5 and 9) became the hardest hit by the final years from 2002 to 2003, with 8 to 12 months of drought months in a row, and with peaks at D3 drought severity in the west and D2 drought severity in the central south.

2005-2007 – Northern Michigan (also Muskegon County)

The Upper Peninsula suffered from drought conditions for between 16 and 22 months starting in 2005, peaking at the exceptional D4 level in the West, and with severe D3 levels across the East. By 2007, severe drought conditions (rated D2) were noted for the Eastern Upper Peninsula and also the tip of the Northern Lower Peninsula. Specific counties named in 2007 for this level of drought included Chippewa, Mackinac, Charlevoix, and Emmet. The hay crop in the Eastern U.P. was only 50 to 70 percent of normal, and the resulting lack of feed led some farmers to downsize their cattle herds. In the northern tip of the Lower Peninsula, very high utility bills were suffered by the proprietors of farms and golf courses, due to the need for near-constant irrigation. Corn and bean crops were severely impacted. A burning ban was also issued for most of the state (the first such ban since 1998) to reduce the risk of wildfires. Significant rains in September eventually alleviated the drought.

Local reports described some effects of lower lake levels upon marine traffic in the Muskegon area. A super-freighter became stuck in the mouth of Muskegon Harbor and was reported as the second large ship to run aground within the space of a month, in the same location. Shipping officials stated that additional dredging was needed in Great Lakes ports because of low water levels. (NOTE: Although occurring at the same time as a designated drought event, this author is not certain whether this event had drought as its definitive proximate cause. Please refer to the Great Lakes Shoreline Hazards chapter for more information about varying water levels in the Great Lakes.)

May to June, 2010 – Eastern Upper Peninsula

The first five months of 2010 were quite dry, and drought conditions developed as the year progressed, culminating in a severe (D2) drought by mid-May. At first, this was considered to apply to Western Mackinac County, but the categorization would then expand to all of the Eastern Upper Peninsula until rainier conditions eased the drought. June turned out to be a wet month, fortunately causing the end of the severe drought in the area.

Programs and Initiatives

National Drought Policy Act and Commission

Currently, no single federal or state agency monitors drought. Rather, a number of agencies have programs and initiatives in place designed to identify, monitor, analyze, and respond to drought. Recognizing the need for a nationwide, coordinated drought policy designed to prepare for and respond to drought emergencies, Congress enacted in 1998 the National Drought Policy Act (P. L. 105-199), which established the National Drought Policy Commission. The Commission is composed of fifteen members – representative of all levels of government and other drought impacted groups – and is charged by Congress to provide advice and recommendations on the creation of an integrated, coordinated Federal policy for drought emergencies. On May 17, 2000, the Commission provided its findings and recommendations to Congress and published the report "Preparing for Drought in the 21st Century." The Report outlines a national drought policy statement developed by the Commission with preparedness as its foundation. The Report establishes five broad goals and a number of specific recommendations under each. The Commission intends to achieve the goals in the coming years through a combination of legislation, planning, coordination of programs, public / private collaborative partnerships, and public education.

Interim National Drought Council

The creation of the Interim National Drought Council (INDC) was one of the recommendations in the May 2000 report of the National Drought Policy Commission. The United States Department of Agriculture (USDA) immediately moved forward and implemented the council without congressional action. The Interim Council was created to coordinate drought services between the various levels of government until Congress authorizes and funds a permanent council. It was created through a Memorandum of Understanding (MOU) signed by the U.S. Department of Agriculture, U.S. Department of the Interior, Small Business Administration, Federal Emergency Management Agency, U.S. Department of The Army, U.S. Department of Commerce, U.S. Environmental Protection Agency, National Governors' Association, Southern Governors' Association, Western Governors' Association, National Association of Counties, U.S. Conference of Mayors, the National Emergency Management Association and representatives of urban water interests, rural water interests, the credit community, and tribes. The Consortium of Regional Climate Services, the National Association of Conservation Districts, and the National Drought Mitigation Center were added by an addendum to the MOU.

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (USACE) Institute for Water Resources developed and maintains the National Drought Atlas, which provides information on the magnitude and frequency of minimum precipitation and stream flow in the United States (two important indices of drought). NOTE: Caution should be used when comparing streamflow statistics from the USACE spreadsheet with current, observed conditions at a particular location. This is because the statistics reflect the period of record of the data being analyzed—a longer period makes it harder for an extreme flow condition to be reflected in the value of the statistic. In some cases, it may be tricky to determine the period of time covered by the statistic, since some stations may have been inactive during certain time periods.

U.S. Geological Survey

The U.S. Geological Survey (USGS) is the primary federal agency that collects and analyzes streamflow data, another good index of the relative severity of drought. The agency provides a handy "Drought Watch" web site at http://waterwatch.usgs.gov/. The site presents a map that is continually updated through an automated analysis of USGS streamgaging stations. Additional drought-related links can be accessed from the Michigan-specific web page (http://waterwatch.usgs.gov/new/index.php?m=dryw&r=mi) by clicking on the map (or proceeding directly to the specific web page at http://mi.water.usgs.gov/midroughtwatch.php).

Another available resource for historical data (usually the period from 1933 to 1988) is the USGS Hydro-Climatic Data Network, which is composed of 1,659 streamflow stations that have 20 years or more of streamflow records. These stations are present in all 50 states and U.S. territories. The USGS, in cooperation with over 600 other government agencies, operates some 7,300 stream gauges for data collection. In addition to streamflow data, the USGS collects data on water quality, reservoir levels and contents, and groundwater levels for each state. For Michigan up to the 2005 water year, this data was being published annually in a Water Resources Data for Michigan document. Since the annual report ceased publication, official annual summaries can be obtained on-line, on a site-by-

site basis. These data can be accessed by visiting the Annual Water Data Reports site at http://wdr.water.usgs.gov/ or by visiting the web page for a specific stream gauge through http://waterdata.usgs.gov/mi/nwis/rt. The .pdf files present at these sites contain annual information about that stream location, including average daily flow rates that can be used to identify low and high water flow periods.

National Weather Service

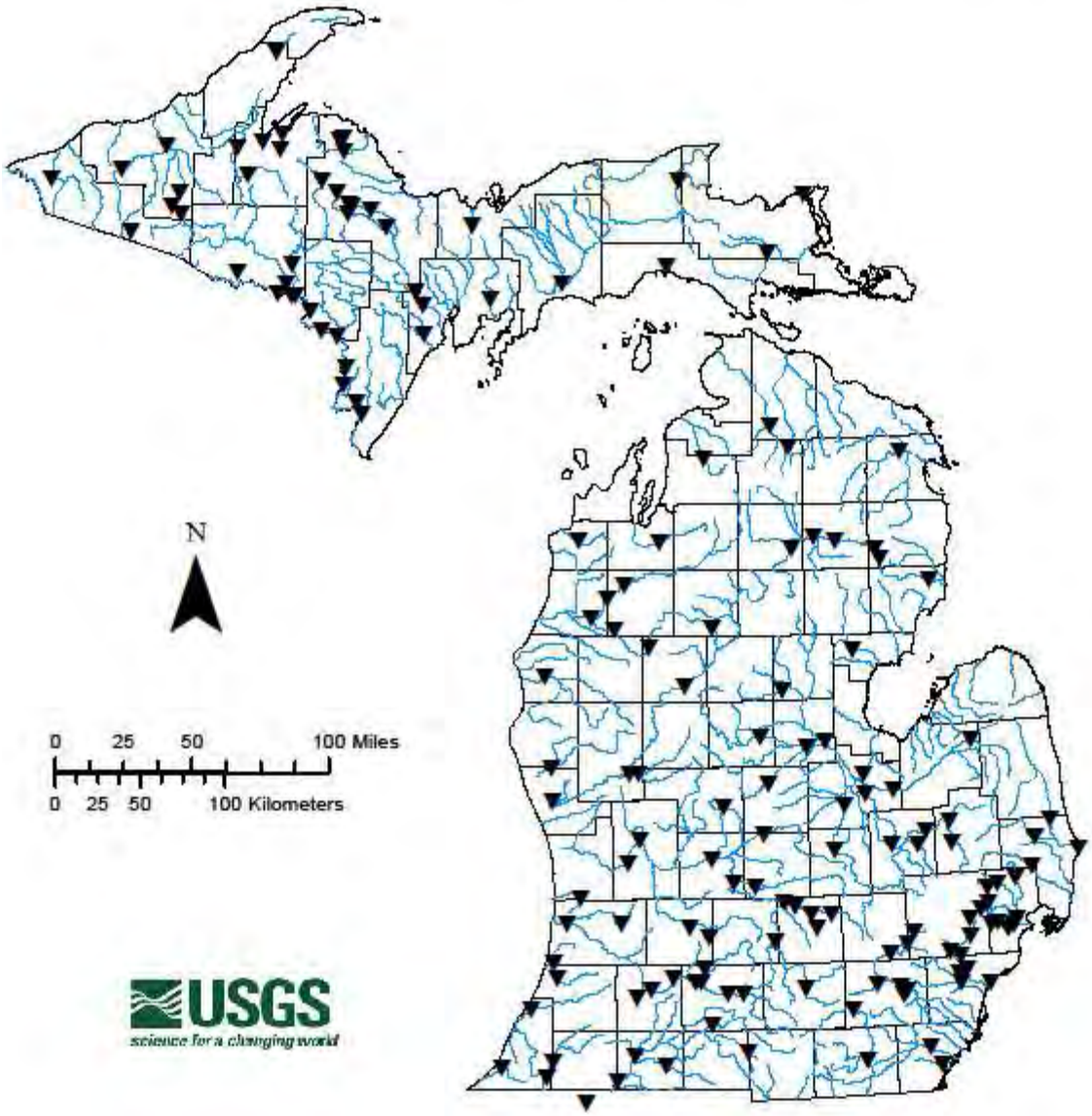
The National Weather Service (NWS) is the primary Federal agency that collects and publishes precipitation data. The NWS publishes precipitation data from approximately 9,100 non-recording and 2,100 recording stations in the United States. This data is published monthly in reports for each state, titled Climatological Data and Hourly Precipitation Data. Departure from normal precipitation is a commonly used index to determine drought severity.

U.S. Department of Agriculture

The U.S. Department of Agriculture (USDA) has a variety of programs designed to provide assistance to farmers and other agricultural enterprises adversely impacted by natural disasters – including drought. The USDA Farm Service Agency (FSA) can provide emergency loans to farmers, ranchers, and agriculture operators who have suffered property loss or economic injury. Emergency loans are made to qualified applicants in those counties designated by FEMA as eligible for Federal disaster assistance under a Presidential disaster declaration, or those that have been specifically designated in a Secretary of Agriculture disaster declaration. Eligible applicants in counties contiguous to declared or designated counties may also qualify. The USDA Natural Resources Conservation Service (NRCS) can provide technical and financial assistance to farmers and agriculture operators for land and water conservation-related efforts aimed at recovering from the adverse impacts of drought and other natural disasters.

National Drought Mitigation Center

The National Drought Mitigation Center (NDMC), located at the University of Nebraska-Lincoln, is a major research and information center whose mission is to help people and institutions in the United States develop and implement measures to reduce societal vulnerability to drought. The NDMC, through its various programs and initiatives, stresses prevention and risk management rather than crisis management. The NDMC builds on the work of the International Drought Information Center (IDIC), also at the University of Nebraska-Lincoln, which takes a worldwide perspective in its research and mitigation work related to the hazard of drought. The NDMC and IDIC are both essentially clearinghouses for drought-related research studies, policy and planning assistance, training and educational initiatives, and information sharing. They are the central coordinating points, worldwide, for drought-related programs and initiatives.



USGS Stream Gauge Locations in Michigan

State of Michigan

In Michigan, drought identification and monitoring is a multi-agency, collaborative effort that may involve the Departments of Agriculture and Rural Development, Environmental Quality, Natural Resources, Community Health, and the State Police Emergency Management and Homeland Security Division. When a drought occurs in Michigan, other agencies, such as the Office of Services to the Aging and the Department of Human Services, may also become involved to monitor the impact of the drought conditions on individuals and families. Depending on the nature and extent of the situation, a state-level task force may be set up to promote cooperation, coordination, and good information flow among participating agencies. In extreme cases, the State Emergency Operations Center may be activated and staffed for the duration of the event.

New laws came into effect on February 28, 2006 to help Michigan better manage water withdrawals to ensure adequate supplies for aquatic life and other users. These laws amended Parts 327 and 328 of the Natural Resources and Environmental Protection Act and the Safe Drinking Water Act. NOTE: This is primarily directed toward ecosystem integrity, and the low-flow conditions considered in these laws are merely representative of low-flow summer months, rather than actual drought conditions.

I. Natural Hazards
C. Ecological Hazards

The following outline summarizes the significant ecological hazards covered in this section:

1. Wildfires
2. Invasive species

These types of natural hazards deal with biological ecosystems, and their effects upon the human economy and built environment. The most well-known hazard of this type is that of major wildfires. Although wildfires, like floods, occur naturally, dangers exist because humans live in areas where the disaster event will periodically take place and cause damage and threats to human health and life. Ecological hazards must also be dealt with to maintain Michigan's environmental and recreational quality of life, as well as the important economic sectors that are closely connected with them (such as tourism, recreation, agriculture, and natural resource extraction).

Wildfires

An uncontrolled fire in grasslands, brushlands or forested areas.

Hazard Description

Forests cover approximately 49% (18.2 million acres) of Michigan's total land area. These vast forests provide Michigan with the largest state-owned forest system in the United States. In addition, Michigan has the fifth largest quantity of timberland acreage, with 4.2 million acres of softwoods and 13.1 million acres of hardwoods. That vast forest cover is a boon for both industry and recreation. However, it also makes many areas of Michigan highly vulnerable to wildfires.

Although Michigan's landscape has been shaped by wildfire, the nature and scope of the wildfire threat has changed. Michigan's landscape has changed substantially over the last several decades due to wildland development, and so the potential danger from wildfires has become more severe. Increased development in and around rural areas (more than a 60% increase in the number of rural homes since the 1980s) has increased the potential for loss of life and property from wildfires. (The map at the end of this section shows the wildland / urban interface areas of highest concern in Michigan.) There are simply not enough fire suppression forces available in rural areas to protect every structure from a disastrous wildfire.

Contrary to popular belief, lightning strikes are **not** the primary cause of wildfires in Michigan. Recently, only about 7% of all wildfires in Michigan were caused by lightning strikes, and most other causes have been attributed to human activity. Outdoor debris burning is the leading cause of wildfires in Michigan. Most Michigan wildfires occur close to where people live and recreate, which puts both people and property at risk. The immediate danger from wildfires is the destruction of property, timber, wildlife, and injury or loss of life to persons who live in the affected area or who are using recreational facilities in the area.

According to 2011 MDNR information, the leading causes of wildfires from 2001 to 2010 were:

1. Debris burning (32%)
2. Equipment (17%)
3. Miscellaneous (11%)
4. Unknown (10%)
5. Campfires (9%)
6. Lightning (7%)
7. Incendiary activity (5%)
8. Children (5%)
9. Railroads (3%)
10. Smoking (3%)

<u>Areas of Greatest Vulnerability</u>

The maps and tables at the end of this section show a breakdown of wildfires by county for the period since 1981, including both the number of fires and the number of acres burned. The maps indicate that the wildfire threat in Michigan is fairly widespread geographically. The large number of permanent and seasonal homes (especially in the northern Lower Peninsula), coupled with the increase in tourists during the most dry (and therefore most vulnerable) times of the year, greatly increase the risk from wildfires.

It should be noted that the figures shown on the maps do not include those wildfires suppressed by local volunteer fire departments or the U.S. Forest Service. If those records were readily available and broken down by county, the statistics would be significantly affected. For example, the 1976 Seney fire burned approximately 74,000 acres, which included federal, state and private lands. In addition, the statistics fail to show a major wildfire problem in the southern Lower Peninsula due to the small MDNR fire force presence in that area of the state. However, local fire departments in the southern Lower Peninsula respond to hundreds of wildfires per year, and are instrumental in keeping the wildfire threat in the southern Michigan counties in check.

In geographic terms, the percentage of forested land cover is the highest (more than 75% of the total land area) across the entire Upper Peninsula and in the Lower Peninsula counties of Cheboygan, Crawford, Kalkaska, Lake, Montmorency, Oscoda, Otsego, Presque Isle, and Roscommon (based upon a 2004 inventory by the USDA). The Michigan DNR has been involved in approximately 550 wildfire events per year, in recent decades. An average of about 4 deaths per year is estimated, from major events alone.

Role of Local Governments

Local governments can take a number of actions to reduce the risk from wildfires. One important action that can be taken at the local level is to adequately address wildfire vulnerability reduction in local zoning ordinances and comprehensive/land use plans. Most local zoning ordinances lack provisions for wildfire vulnerability reduction, and most comprehensive/land use plans are not prepared far enough in advance in rural areas to adequately direct development and institute mitigation measures in high-risk fire hazard areas. Communities are not adequately utilizing land use systems that recognize special fire problems and requirements related to vegetation, topography, weather, transportation and access, water supply, and density of development.

Local fire agencies, primarily due to lack of time and/or personnel, only sporadically review proposed lot splits, subdivisions, severances and other developments for fire protection needs. In general, communities are not requiring developers to project the fire vulnerability of their large-scale developments. These projections are also not required for most variances and special use permits. Builders seeking building permits for additions to homes do not have to retrofit the existing structure to meet wildfire safety and mitigation measures. These measures could include such actions as replacing an existing roof covering with a fire-resistant or non-combustible covering, installing smoke detectors and other fire safety controls, or maintaining a “Firewise” landscape by providing adequate vehicular access, signage streets, roads and buildings, and providing adequate emergency water supplies.

Additional measures that local governments can take to reduce wildfire vulnerability include restricting open burning of trash and yard debris (which causes nearly one-third of the wildfires in the state), and developing evacuation procedures for wildfires in the jurisdiction's Emergency Operations Plan (EOP) to minimize potential injury and loss of life.

Efforts of the MDNR Forest Management Division

The MDNR Forest Management Division is committed to a multi-jurisdictional, coordinated wildfire hazard mitigation effort. The Division is actively working toward reducing the State’s vulnerability to wildfires by: 1) participating in multi-state and interagency mitigation efforts; 2) aiding local communities in developing zoning and subdivision control ordinances that adequately address wildfire mitigation; 3) regulating the days and times people are granted permits to burn debris; 4) conducting research on wildfire prevention, containment and suppression activities; and 5) developing wildfire hazard assessments to aid community and property owners in determining their vulnerability to wildfires.

The MDNR is conducting a detailed statewide assessment to determine communities’ risks from wildfire, using Geographic Information System (GIS) technology. This assessment, which is expected to take several years to complete, will identify the areas of greatest concern for wildfires based on existing and projected land uses and population concentrations, as well as topography, hydrology, soils, vegetative cover, and other natural features. The assessment will provide the MDNR and other state agencies, local governments, builders and developers, and private citizens with information needed to make “Firewise” land use / development decisions and to facilitate the creation of community wildfire protection plans (CWPP), thereby reducing the wildfire threat to people and improved property. The risk map at the end of this section was the result of an early approximation using GIS and a basic model, but current mapping will result in products of far greater validity

Despite these ongoing initiatives of the MDNR Forest Management Division, wildfire prevention must be emphasized more at the local level if a meaningful reduction in vulnerability is to occur.

Wildfire Suppression

One trend involves wildfires outstripping the ability of firefighters to suppress them. Fire protection in wildland areas cannot be provided at the same level that it is provided in urban areas. Rural fire departments tend to be volunteer forces, the members of which may be widely geographically dispersed. That dispersion greatly increases the response

time in rural and wildland areas. In addition, these forces also tend to be not as well equipped as their urban counterparts. These factors, coupled with the tremendous increases in development in wildland areas and the lack of readily available water from pressurized underground pipes, contribute to the possibility of wildfire disasters in many areas of Michigan.

Wildfire Analysis

FEMA (and others) have created fairly detailed methods for estimating wildfire risks. The information in this workbook summarizes that given in FEMA publication 386-2 ("Understanding Your Risks"). It primarily uses weather, topography, and land cover (fuel) data to estimate wildfire risks. The first activity is to map the "fuel model" categories in the community. This process currently sorts all areas into three "fuel model" categories based on the types of vegetative land covers that could act as fuels in a wildfire event. Here is a summary of the three fuel model categories described by FEMA:

LIGHT FUEL CATEGORY – Covers any of the following general descriptions of vegetation in an area:

1. Predominantly marsh grasses and/or weeds.
2. Mosses, lichens, and low shrubs are the predominant ground fuels, but have no overstory and/or occupy less than one-third of the site.
3. Grasses and/or forbs predominate. Any woody shrubs will occupy less than one-third of the site. An open overstory of conifer and/or hardwood trees may be present.
4. Brush, shrubs, tree reproduction or dwarf tree species predominate, but this is only considered light fuel if the average height of woody plants is less than 6 feet, and they occupy less than one-third of the site.
5. Deciduous broadleaf tree species predominate and the area has not been thinned or partially cut (which would create a higher-risk fuel source called "slash.")
6. Conifer species predominate, but the primary ground fuels are grasses and forbs. If the primary ground fuels are duff and litter, branch wood, and tree boles, then the area can only be considered "light fuel" if pine needles are 2 or more inches in length, the overstory is not decadent, and there is only a nominal accumulation of debris.

MEDIUM FUEL CATEGORY – Covers any of the following general descriptions of vegetation in an area:

1. Mosses, lichens, and low shrubs are the predominant ground fuels, and an overstory of conifers occupies more than one-third of the site.
2. Grasses and/or forbs predominate, with woody shrubs occupying between one-third and two-thirds of the site.
3. Brush, shrubs, tree reproduction or dwarf tree species predominate, and woody plants are either greater than 6 feet in height, or cover more than one-third of the site.
4. Conifer species predominate, and the understory is dominated by lichens, mosses, low shrubs, woody shrubs, and/or reproduction. (If the primary ground fuels are duff and litter, branch wood, and tree boles, and pine needles are less than 2 inches long, then the overstory must not be decadent, and there must be only a nominal accumulation of debris.)

HEAVY FUEL CATEGORY – Covers any of the following general descriptions of vegetation in an area:

1. Deciduous broadleaf tree species predominate in an area that has been thinned or partially cut, leaving slash as the major fuel component.
2. Conifer species predominate, with duff and litter, branch wood, and tree boles as the primary ground fuels, and an overstory that is overmature and decadent, with a heavy accumulation of dead tree debris.
3. Slash is the predominant fuel in the area. (Counts as heavy fuel at any level of loading, regardless of whether settling has been significant or slight, and whether foliage is attached or falling off.)

The United States Department of Agriculture has created a site with wildfire analysis resources, at http://www.fs.fed.us/fire/science/index.html. Since USDA assesses fire risks nationwide, local or state resources will probably be needed to supplement this source in order to accurately assess a community's specific fuel model areas in the local hazard mitigation plan.

FEMA's wildfire model then combines these fuel type areas with assessments of local topography and weather patterns, to identify overall risk categories (called "moderate hazard," "high hazard," and "extreme hazard.") Topographic information provides three land categories, based on the severity of slopes present in an area. Low slope

areas have slopes less than or equal to 40%. Moderate slope areas contain slopes measuring from 40% to 60%. Steep slope areas contain slopes greater than 60%.

Weather information can produce estimates of the number of days per year with "critical fire weather" conditions. FEMA has stated that a local or state fire marshal, forestry department, or department of natural resources can help in determining the number of days per year that critical fire weather is experienced in an area.

Overall categories of wildfire risk (moderate, high, and extreme) are given by the following FEMA table:

	Frequency of Critical Fire Weather								
	1 day per year or less			2 to 7 days per year			8 or more days per year		
Fuel Classification	Slope ≤40%	Slope 41%-60%	Slope ≤60%	Slope ≤40%	Slope 41%-60%	Slope ≥60%	Slope ≤40%	Slope 41%-60%	Slope ≤60%
Light Fuel	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	High
Medium Fuel	Moderate	Moderate	High	High	High	High	Extreme	Extreme	Extreme
Heavy Fuel	High	High	High	High	Extreme	Extreme	Extreme	Extreme	Extreme

Additional factors that increase fire risk and may be included in a model include lightning and human factors such as the number of persons residing in, camping in, visiting, or traveling through an area. Such persons may increase fire risks through carelessness or ignorance, while other persons (including residents and fire spotters) may reduce risk of uncontrolled wildfire in an area, through their ongoing fire awareness, prevention, and response activities. It also makes sense to take into account the type of fire-fighting personnel, equipment, expertise, and related resources (such as water) that are available to a community, or lacking in adjacent communities (from which a fire might spread).

Vulnerable structures are those located in or near a potential wildfire area, unless they have taken special steps to become "Firewise" (as described previously). Nonflammable roof and patio materials, clearance of vegetation and maintenance of a defensible space around structures, available means to provide and facilitate site access by emergency responders, and so on, will make a structure potentially able to withstand wildfire events in its vicinity. Structures that are located in a wildland/urban interface area should be evaluated for these sorts of site features that will exacerbate or minimize their vulnerability. Certain design or landscaping features can render an at-risk structure completely vulnerable to any nearby wildfire event, and thus should be prioritized for wildfire mitigation strategies. Although risk-estimation models exist, FEMA has stated that there are no standardized methods for estimating the amount of damages and economic losses that a community will sustain from a wildfire event.

Impact on the Public

Wildfires can cause widespread concerns and disruptions even in cases where physical damages have been prevented. Smoke, closed roadways, and infrastructure impacts may interfere with ordinary life, as well as an area's economy and planned events (including tourism). Wildfires can also directly cause structural fires to occur. (Please refer to the preceding sections about structural and scrap tire fire events for more information about these potential impacts.)

Impact on Public Confidence in State Governance

The large scale of wildfires can cause widespread concerns and disruption, smoke, closed roadways, and infrastructure impacts. Since many wildfire locations involve state lands (especially the Michigan Department of Natural Resources), major wildfire events may raise public questions about the effectiveness of governmental policies toward the maintenance and monitoring of conditions on such lands.

Impact on Responders

Wildfires involve special training, equipment, and expertise, as well as a large-scale response and different types of risks for responders, including the large areas involved, the risks of extremely rapid fire spread, and locations that are often isolated and distant. These tend to present difficulties with responder equipment staging, transport, coordination, and communications.

Impact on the Environment

Wildfire impacts on Michigan's environment can be considerable, due to the fact that Michigan has the largest state-owned forest system in the Eastern United States, as well as the fifth largest timber acreage in the country. Wildfires physically damage natural vegetation, forests, trees, shrubs, grasslands, native animals and insect species, etc, leaving black soot, deposits of peat, smolder, and charcoal-like ground cover that can contaminate the soil and underground

water table. Wildfires can also cause dramatic and immediate changes or shock in vegetation, eliminating some species or causing others to appear where they were not present before the fire. Wildfires (depending on their size and burning time) are a significant source of gases and particulates in the atmosphere, including carbon dioxide, carbon monoxide, methane, non-methane hydrocarbons and oxides of nitrogen. Fire also produces large amounts of small, solid particles (particulate matter) that absorb and scatter solar radiation, exacerbating climate change conditions.

Even though many fires occur close to where human residences are located, they are a normal ecological phenomenon and serve long-term functions for vegetation and the natural environment. Wildfires burn excess brush, maintain large savannah-like openings, and restore wetlands by forcing out various unwanted brush and plants. The natural function of fires within the environment can be considered a renewal or "cleansing process" as long as the fire is not too severe.

Significant Wildfires

Michigan has experienced many destructive wildfires. Thousands of homes (during Michigan's first century) and millions of acres of forest have been destroyed by wildfires. According to Michigan Department of Natural Resources (MDNR) and U.S. Forest Service records, over 5.8 million acres of forest in Michigan were burned between 1910 and 1949, an average of 145,000 acres per year. By comparison, it was reported that between 1950 and 1996, the MDNR and U.S. Forest Service were involved in suppressing over 46,100 wildfires that burned 390,000 acres of forest, which averages only 8,300 acres burned per year. This drastic reduction in the acres of timber burned was largely the result of (1) increased use of specialized equipment to suppress the fires, and (2) intensified efforts toward fire prevention. The following list summarizes some of the largest and most severe wildfires that have occurred in Michigan to date.

Significant Michigan Wildfires

October 1871 - Lower Peninsula

The State's first recorded catastrophic fire occurred in the fall of 1871, after a prolonged drought over much of the Great Lakes region in the summer of 1871. The drought had left debris from logging and land clearing tinder dry, and as a result numerous fires burned throughout the state. These fires continued to smolder until, on October 8th of that year, gale and hurricane force winds fanned a series of fires across much of the northern Lower Peninsula. Because this tremendously destructive wildfire occurred at the same time as the great wildfires that struck Peshtigo, Wisconsin (which killed 1,300 people in a single night, and also affected Menominee County in the Upper Peninsula) and the Great Chicago Fire (which destroyed much of central Chicago), the Michigan wildfire received little publicity. However, the 1871 Michigan wildfire killed 200 people and burned 1.2 million acres. When the winds finally subsided, the fire's swath stretched from Lake Michigan across to Lake Huron. The most heavily affected area, north of Saginaw Bay, had an area 40 miles square that was completely destroyed, with over 50 people killed. The worst of the fire was over by October 19, although the fire wasn't completely extinguished for over a month.

August-September 1881 - Thumb Area

On August 31, 1881, several small fires in the Thumb came together to form a major conflagration (commonly known as the Thumb fire). A massive area of fires moved through the Thumb counties, and six days later, stopped at Lake Huron. This fire was, in many ways, more severe than the 1871 fire, since settlers had moved into the region in large numbers and logging had gotten underway. More than a million acres were burned; property loss exceeded $2 million, and 282 were killed. Like the 1871 fire, the fire of 1881 came at the end of an extremely severe drought and was the result of hundreds of land-clearing fires being brought together into a conflagration by high winds.

Summer 1896 – Ontonagon Fire

A dry summer exacerbated fire conditions and winds also helped to spread a wildland blaze to the town of Ontonagon, which saw heavy destruction as a result. More than 340 buildings were burned, and hundreds of residents were displaced to nearby farms and the nearby town of Rockland. Animals died and humans were injured, but fortunately, only one person was actually killed in the disaster.

October 1908 – Metz Fire (Presque Isle County)

Droughts in northern Michigan exacerbated wildfire conditions and threatened the town of Metz. Some of the evacuating residents tried to flee by train, but the train was wrecked near the station at Hawks by a burned out culvert, killing 14 passengers, plus two persons who lived at a nearby home. Since the train had found its path blocked by flames, it had attempted to proceed backwards toward Metz and Alpena, but had failed in the effort.

July 1911 – Au Sable-Oscoda Fire (Iosco County, and also Cheboygan, Crawford, and Otsego Counties)

Enormous wildfires ravaged the northern Lower Peninsula and caused massive destruction at the towns of Oscoda and Au Sable, whose 1,800 residents were evacuated by train and steamboat. At Cheboygan, a huge pile of sawdust had been burning for weeks and was beyond control. A railroad suffered heavy losses near Grayling, including 40 cars and two bridges. Fires at Oscoda and Alpena were reported to have started at slab yards. Damages were estimated at $100,000 in Alpena, and $500,000 in Oscoda and Au Sable. The town of Waters suffered $300,000 in damage to property and at least as much to lumber. At least 500 evacuees were sheltered at Tawas City and East Tawas. Total losses across the area were estimated as at least $1.5 million. Several casualties were reported, but the total number actually killed in the disaster was not clear from reports.

May 1968 – Crawford and Kalkaska Counties

The "Fletcher Road Fire" was started at approximately 2:45pm on May 8, 1968, by a pipeline welding crew whose company later paid out more than $90,000 in damages for timber losses. Tree mortality was almost total within an area of 4,216 acres across Kalkaska and Crawford Counties, and the fire crowned (reached the tree tops) in over 75% of that area. Crown fires like this allow the fire to advance and spread rapidly. The fire was able to "jump" across Fletcher Road and burned at a rate of approximately 2 miles per hour, which is considered to be a fast-moving fire. Smoke could be seen from as far as 20 miles away. A million-dollar gas refinement facility was placed at-risk by the fire, but protected by responder efforts.

August-September 1976 - Seney (Schoolcraft County)

In the late summer months of August and September 1976, a fire near Seney burned approximately 74,000 acres. At least part of the fire was started by lightning and quickly became uncontrollable due to an abundance of flammable material brought on by drought conditions. However, there were also problems involving prescribed, controlled burns and smoldering areas that later reignited and thus created unusual problems. The fire started on federal land and spread to state and privately owned lands. Fire suppression and damage costs exceeded $8 million.

May 1980 - Oscoda County

In May 1980, a wildfire in Oscoda County (known as the Mack Lake fire) destroyed 44 homes and buildings, forced the evacuation of 1,500 people, and killed one firefighter. A total of 24,000 acres were burned, resulting in a total property and timber loss of $2 million. The fire has been claimed to have stemmed from a prescribed burn that got out of control when it "jumped" across a highway. It has been claimed that a major wildfire occurs about every 20 to 30 years in the area.

May 1986 - Marquette County

In May 1986, multiple wildfires in Marquette County burned 7,000 acres and forced the evacuation of 4,000 people at K.I. Sawyer Air Force Base when flames spread right up to some of the housing units.

July 1988 – Escanaba (Delta County)

A large fire caused the evacuation of 60 families and the temporary closure of Highway U.S.-2. Two firefighters were injured battling what became known as the "Stockyard Fire," a name given because the fire area included a site that had previously been used as a stockyard. Again, conditions were exacerbated by regional drought effects.

May 1990 - Grayling (Crawford County)

In May 1990, a wildfire near Grayling in Crawford County (known as the Stephan Bridge Road fire) burned 76 homes and 125 other structures, 37 vehicles and boats, and over 5,900 acres of forestland, resulting in property losses of $5.5 million. The timber losses totaled another $700,000. The fire originated from a controlled burning of a pile of brush and timber accumulated from recently cleared land. The burning was initiated while snow covered the ground, and it had been presumed that the fire was completely extinguished. However, the pile rekindled approximately seven weeks later, and on May 8, ignited the Stephan Bridge Road fire. Strong winds and dry conditions helped spread the fire at a rate beyond that which could be controlled by human intervention. At one point in the fire, the rate of spread was an astonishing 277 feet per minute. Fortunately, the combination of human fire suppression and a passing weather front that produced rainfall finally contained the fire before it could do any additional damage. There were no fatalities as a result of this fire, and only one firefighter was injured from smoke inhalation. However, the property losses were significant.

May 1999 - Champion (Marquette County), Epoufette (Mackinac County), Oscoda County

In early May 1999, a wildfire near the village of Champion in Marquette County (known as the Tower Lake fire) burned a total of 5,625 acres of forestland, destroyed at least 8 structures, and forced the evacuation of over 400 persons in Champion as well as those in the vicinity of Fish Lake, Perch Lake, Mud Lake, eastern Michigamme, and Van Riper State Park. In addition, the fire forced the closure of US-41 and M-95 in the area of Champion and Michigamme for several days. Timber losses were estimated at $12.8 million, with property losses totaling another $700,000. Aerial firefighting assets were brought in from surrounding areas to help prevent the spread of the fire into Champion, thus saving the town from destruction. At the request of the Governor, the Federal/State Forest Fire Suppression Agreement was activated by the Federal Emergency Management Agency (FEMA) to provide financial assistance to the State and eligible local agencies to cover some of the firefighting costs incurred. At about the same time as the Tower Lake fire, major wildfires were also being fought in several other locations across Northern Michigan. In Mackinac County, an 850-acre fire burned for several days near Epoufette, while another 850-acre fire burned in the Huron-Manistee National Forest in Oscoda County. In the Northern Lower Peninsula alone during that first week of May, MDNR forces fought nearly 40 wildfires. All of the wildfires were fueled by the same dry conditions that set the stage for the Tower Lake fire.

May-June 2000 - Mio (Oscoda County), Torch Lake Township / Lake Linden (Houghton County)

A wildfire that began on April 30 near Mio and was fed by extremely dry conditions consumed nearly 5,200 acres in the Huron-Manistee National Forest before being contained a week later. Nearly 300 firefighters and two aerial water tankers were deployed to suppress the fire. The fire prompted the evacuation of approximately 30 persons for a short time. Fortunately, the fire did not cause any injuries or structural damage. About a month later, on June 6, a brush fire set on a blueberry farm near Rice Lake in Torch Lake Township, Houghton County, got out of control and eventually burned over 350 acres before being contained the next day. Firefighters from the MDNR and 15 local fire departments, plus two aerial water tankers, were called to fight the blaze. The fire forced the evacuation of over 20 homes and cottages, and at one point was one-half mile wide and almost one mile long. Brisk winds pushed the fire to within one-quarter mile of homes along the shoreline of Lake Superior. However, no structures were lost and no injuries were reported.

March-April 2005 – Roscommon County

A long period of warm and dry weather affected northern Michigan from the end of March through mid April. Once the spring snow melt was completed, the fire danger rapidly increased. A number of wildfires developed in northern Lower Michigan in mid-April. The largest occurred in Nester Township in Roscommon County. This fire (of unknown origin) started on the afternoon of the 16th, and burned over 1,500 acres before it was gradually brought under control over the next several days. There was no known structural damage, though sixteen to twenty homes in the area were evacuated.

April 30 to May 1, 2006 – Oscoda County

A wildfire in Hughes Lake began early in the afternoon of April 30th, ignited by an individual burning brush in a fire pit. The fire spread northwest from Hughes Lake, thanks to southeast winds of 10 to 20 mph. The rate of spread reached as high as 2 miles per hour late in the afternoon of the 30th, with flame heights reaching 300 feet tall. Containment activities brought the fire under control by late afternoon of May 1st, although mop-up would continue for several days after. Crews were flown in from as far away as New Mexico and Montana to fight the fire. At its height, almost 300 personnel were involved in fighting the fire. Approximately 5,950 acres of timber and brush land burned, south of M-72, east of M-18, and west of M-33. Sixteen structures and seven vehicles were destroyed. A number of evacuations were ordered, some as far west as M-18 in southeast Crawford County, although most residents returned to their homes within a few days. Total damage to property was conservatively estimated at $600,000. Note that this does not include costs incurred in fighting the fire, which were in excess of $800,000.

April 27-30, 2007 – Baraga County

A wildfire in Baraga, which started as a controlled burn by the U.S. Forest Service on the 27th, went out of control by the 29th, fueled by low relative humidity and strong winds gusting over 40 mph. The wildfire consumed more than 1,300 acres in western Baraga County between the 27th and 30th. More than 120 firefighters from the U.S. Forest Service and the Michigan DNR battled the blaze and helped authorities evacuate thirty homes in the Covington area. No injuries or structural damages were reported from the fire. Another fire in northwest Marquette County destroyed three structures and burned approximately 60 acres before it was brought under control on the 29th.

August 2007 – Luce County

On August 2, a lightning strike ignited a fire in central Luce County and grew to disastrous proportions, burning nearly 19,000 acres and resulting in a governor-declared State of Emergency. More than 220 personnel were involved in fire containment and suppression operations, from local, state, and federal agencies. Fortunately, the relatively remote location caused a limited number of properties to be lost. However, residents had to be evacuated three separate times during the substantial event period. Despite the substantial risks to nearby residents and facilities, efforts to obtain a federal disaster declaration were unsuccessful.

April 24, 2008 – Crawford County

Called the "Four Mile Road Fire," the cause may have been some sparks from a passing train. A Red Flag warning had been in effect when the fire started a few miles south-southeast of Grayling. The weather was warm, dry, and windy, and the fire quickly expanded to the northwest, crossing I-75 (which was closed for several hours) and eventually burning 1,300 acres. On the far south side of Grayling, a gas station and motel were threatened, but spared damage. About a half-dozen cabins near Simpson Lakes were lost (about two miles south of downtown Grayling), and $287,000 in damage was sustained by the Grayling Game Club. Total property damages from the event were estimated at $750,000, and MDNR response costs and timber damages were about $619,000. Fifty homes were

evacuated, and power was lost in Grayling. By the evening, winds and temperatures went down and several periods of rain during the night helped the fire to be extinguished.

May 20 to 26, 2009 – Marquette and Baraga Counties

Southwest of Ishpeming, the "Black River Falls Wildfire" started on the afternoon of May 20 when a wind-damaged pine tree fell across a power line. The wildfire destroyed 21 homes, 12 other structures, and caused an estimated $4 million in property damage. The fire had burned 811 acres but was contained by the 22nd, and final clean-up took until the 26th. Personnel and equipment costs to fight the fire were estimated at $100,000. During the same time period, in neighboring Baraga County, a "Pinery Wildfire" started in an area east of L'Anse and burned 685 acres before being contained two days later (with final clean-up also lasting until the 26th). About $50,000 in property damage was caused when flames destroyed a mobile home and damaged the Pinery Ski Lake trails area and a nearby cemetery. Firefighting costs for the Baraga event approached $125,000.

May 18 to 26, 2010 – Crawford and Kalkaska Counties

A debris fire expanded out of control and resulted in the "Meridian Boundary Fire" by about 1:30pm on May 18. A total of 8,800 acres were eventually burned by this fire, which took until May 26 to reach 95% containment. Twelve residences were destroyed, six were damaged, and 36 outbuildings were either destroyed or damaged, resulting in total property damages of about $825,000. Also on May 18, in adjacent Kalkaska County, the "Range 9 Fire" started when a controlled burn on an artillery range became uncontrolled as winds increased through the area. The Range 9 Fire burned 1,100 acres of mostly grassy areas on the Camp Grayling grounds, but also crossed over the boundary line at one point and destroyed 4 seasonal homes in Blue Lake Township, resulting in an estimated $125,000 in property damage. By late evening on the same date, that smaller fire was under control.

Programs and Initiatives

Michigan Department of Natural Resources Forest Management Division

The MDNR Forest Management Division directs and coordinates wildfire prevention, containment and suppression activities on all non-federal lands in the state, as well as Indian Reservations (under contract with the U.S. Bureau of Indian Affairs). The MDNR places great emphasis on wildfire prevention and public education, since the vast majority of wildfires in Michigan are caused by human activity. The MNDR Forest Management Division's philosophy is that preventing fires from starting in the first place, and precautionary measures around rural homes, are the best means of avoiding or minimizing wildfire losses. When conditions of extreme fire hazard exist, the MDNR can request the Governor to issue an outdoor burning ban to mitigate the potential for wildfire in all or part of the state. Such a ban restricts smoking, fireworks, and outdoor burning activities to approved locations.

Michigan Forest Fire Experiment Station

A string of disastrous wildfires in the early 20th century led to the creation of the Michigan Forest Fire Experiment Station in 1929. This Station, established by what was then the Michigan Department of Conservation (now the Department of Natural Resources) and located in Roscommon, is designed to investigate how wildfires behave, how to properly manage forest fuels, and how to use mechanized equipment to fight wildfires. Its research efforts have been invaluable in helping to prevent, contain and suppress wildfires in Michigan and across the country.

Michigan Interagency Wildland Fire Protection Association

Because the vast majority of wildfires are caused by human activity, the Michigan Department of Natural Resources established, in 1981, the Michigan Interagency Wildfire Prevention Group. It was the first such group in the nation (promoting wildfire prevention and awareness) that had the full involvement of the state's fire agencies. In 1993, the Michigan Interagency Wildfire Prevention Group was expanded to form the Michigan Interagency Wildland Fire Protection Association (MIWFPA). The MIWFPA promotes interagency cooperation in fire prevention, training, fire technology, and firefighting operations. Members of the MIWFPA include the: 1) MDNR Forest Management Division; 2) USDA Forest Service - Huron-Manistee, Hiawatha, and Ottawa National Forests; 3) USDI National Park Service - Pictured Rocks and Sleeping Bear Dunes National Lakeshores; 4) USDI Fish and Wildlife Service - Seney National Wildlife Refuge; 5) USDI Bureau of Indian Affairs; 6) Michigan Department of State Police - fire investigation; 7) Michigan State Firemen's Association; and the 8) Michigan Fire Chief's Association.

Michigan Natural Resources and Environmental Protection Act

The Michigan Natural Resources and Environmental Protection Act (1994 PA 451), Part 515, assigns responsibility for the prevention and suppression of forest fires to the Director of the Michigan Department of Natural Resources. The Act also establishes requirements for burning permits, allows the Governor to issue prohibitions against the use of fire during extreme fire hazard conditions, and allows the MDNR Director to enter into forest fire assistance agreements with other states and the federal government to control forest fires. These measures contribute to forest fire mitigation by preventing forest fires from starting in the first place, or lessening the spread of fires when they do start (and thus preventing further damage from occurring).

Solid Waste Management Act

The Michigan Solid Waste Management Act (1990 PA 264) prohibits the burning of leaves and grass clippings in municipalities with more than 7,500 population, unless a municipality has an ordinance expressly allowing such burning activities. When properly applied and enforced, this law helps prevent some wildfires, since roughly one-quarter of all wildfires are started by small residential waste fires that get out of control.

Great Lakes Forest Fire Compact

In the Great Lakes region, more than one-third of the 6,000 wildfires that occur annually are caused either by careless burning by residents or children playing with matches. The MDNR Forest Management Division is a member of the Great Lakes Forest Fire Compact in an effort to reduce these fires. The Compact is a partnership between the states of Michigan, Wisconsin and Minnesota, and the Canadian provinces of Ontario and Manitoba. Its purpose is to promote effective prevention, pre-suppression, and control of wildfires in the Great Lakes region through mutual aid and cooperation. Initiatives are implemented by committees composed of members of the Compact. An example of an activity the Compact has undertaken is the development of a fire hazard assessment for the region. Michigan took the lead on this project, and it has proven to be an extremely beneficial educational tool for communities and property owners in assessing their fire hazard potential.

The efforts of the Compact to build coordination and cooperation are based on the understanding that wildfires are multi-jurisdictional, and that suppression of fires usually requires the efforts of many groups and jurisdictions.

"Firewise Communities" Wildfire Protection Program

The MDNR is a participant in the national "Firewise Communities" Program developed by the National Wildland-Urban Interface (WUI) Fire Protection Program. The WUI Fire Protection Program is sponsored by the nation's major wildland fire agencies and the National Fire Protection Association (NFPA). In addition to the NFPA, other sponsors include the: 1) USDA Forest Service; 2) USDI; 3) USDI National Park Service; 4) USDI Bureau of Land Management; 5) USDI Bureau of Indian Affairs; 6) USDI U.S. Fish and Wildlife Service; and the 7) National Association of State Foresters. These member agencies have been promoting "Firewise" living since 1986.

The Firewise Communities Program is designed to educate governmental officials and professionals in a wide variety of disciplines (e.g. planners, builders, engineers, architects, bankers, insurance representatives, emergency managers, land managers) on ways in which communities can be designed and built to minimize the threat from wildfires. The current focus of that educational effort is a series of Firewise Communities Workshops being held around the country. At the Workshops, participants use computerized mapping and wildfire simulations to learn how to recognize wildland -urban interface fire hazards, design Firewise homes and landscapes, deliver fire education, and integrate Firewise planning into existing and developing areas of communities. The Firewise Communities Program also produces and distributes guidance documents, videos, and software packages on wildland-urban interface fire issues.

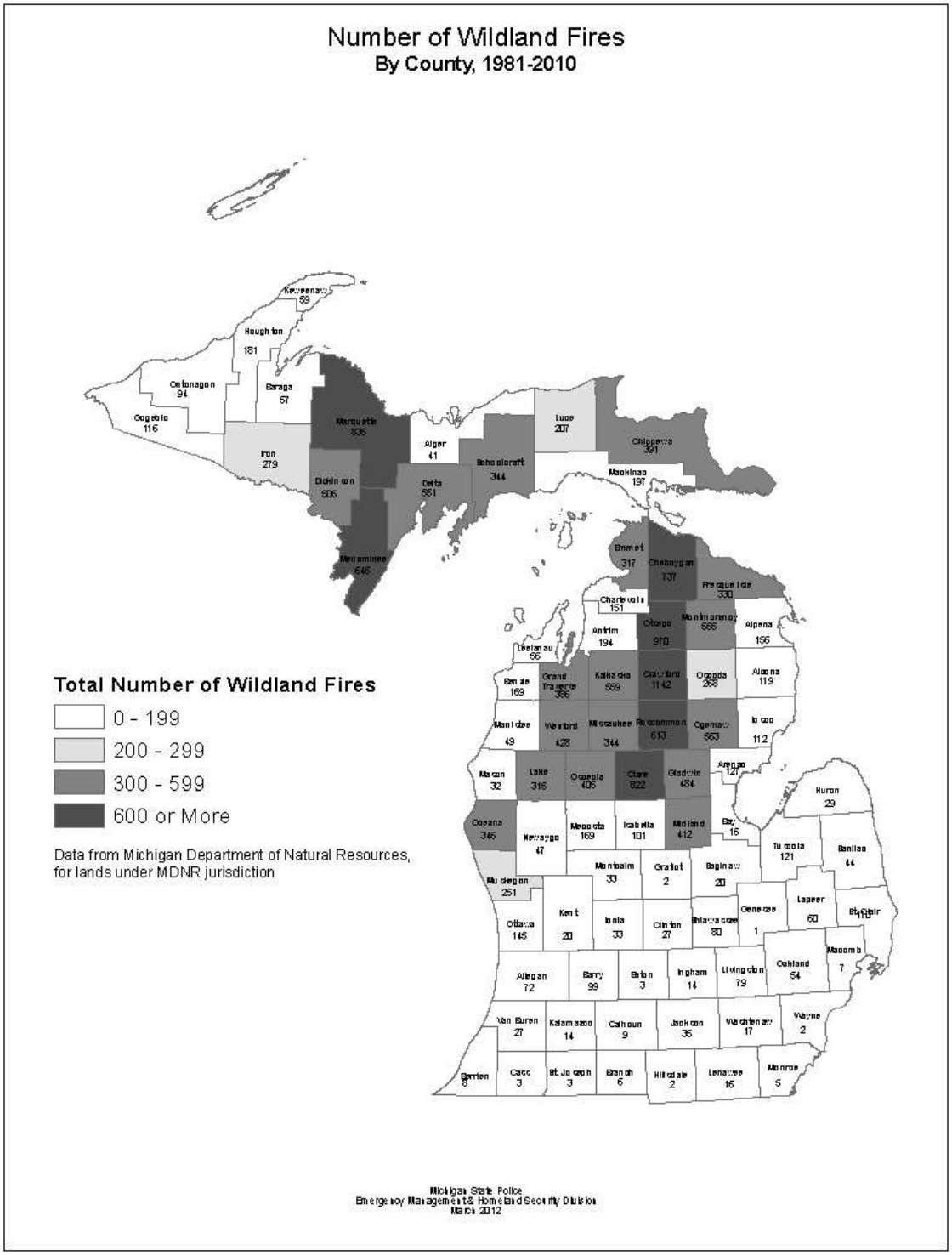
Although the MDNR had worked with the City of Grayling in a pilot program during an effort to promote this initiative, there are at the current time no communities officially recognized as Firewise communities in Michigan.

Wildfire Prevention Week

Due to the high risk of wildfires in Michigan, the state observes Wildfire Prevention Week sometime in April every year. Most Michigan wildfires are human-caused, with one-third caused by people burning debris. An increasing number of people moving into rural areas surrounded by fire-prone vegetation makes preventing wildfires in these areas a critical public safety issue for everyone. The economic value that Michigan forests contribute, in the form of travel, eco-tourism, hunting, fishing, camping and other recreational uses, and timber-related products, is an estimated 200,000 jobs and $12 billion annually. Officials throughout Michigan have stressed that thoughtful activity by humans is critical to preventing wildfires.

Number of Wildfires, by County

(MDNR jurisdiction only)



Number of Wildfires and Acres Burned, by County: 1981-2010 (MDNR jurisdiction only)

County	Number of Wildfires	Number of Wildfires/Year* (over 30 year period)	Number of Acres Burned	Number of Acres Burned/Year* (over 30 year period)
Alcona	119	4	843.8	28
Alger	41	1	123.0	4
Allegan	72	2	312.0	10
Alpena	156	5	267.2	9
Antrim	194	6	194.1	6
Arenac	127	4	418.8	14
Baraga	57	2	1897.6	63
Barry	99	3	447.3	15
Bay	16	1	142.2	5
Benzie	169	6	279.3	9
Berrien	8	0	24.4	1
Branch	6	0	19.3	1
Calhoun	9	0	41.2	1
Cass	3	0	27.0	1
Charlevoix	151	5	492.3	16
Cheboygan	737	25	1424.0	47
Chippewa	391	13	5108.2	170
Clare	822	27	2385.6	80
Clinton	27	1	138.9	5
Crawford	1142	38	25861.5	862
Delta	551	18	3213.8	107
Dickinson	506	17	2411.0	80
Eaton	3	0	0.3	0
Emmet	317	11	543.5	18
Genesee	1	0	0.1	0
Gladwin	484	16	1938.9	65
Gogebic	116	4	245.4	8
Grand Traverse	386	13	1296.9	43
Gratiot	2	0	40.0	1
Hillsdale	2	0	23.0	1
Houghton	181	6	1200.1	40
Huron	29	1	725.5	24
Ingham	14	0	474.7	16
Ionia	33	1	728.4	24
Iosco	112	4	1630.3	54
Iron	279	9	1953.9	65
Isabella	101	3	931.8	31
Jackson	35	1	520.5	17
Kalamazoo	14	0	74.3	2
Kalkaska	559	19	2953.4	98
Kent	20	1	125.9	4
Keweenaw	59	2	375.6	13
Lake	315	11	1283.5	43
Lapeer	60	2	533.8	18
Leelanau	56	2	212.0	7
Lenawee	16	1	224.2	7
Livingston	79	3	651.4	22
Luce	207	7	18679.9	623
Mackinac	197	7	1610.6	54
Macomb	7	0	15.4	1
Manistee	49	2	1041.6	35
Marquette	835	28	16087.6	536
Mason	32	1	154.6	5
Mecosta	169	6	844.9	28
Menominee	646	22	2353.4	78
Midland	412	14	1414.9	47
Missaukee	344	11	1772.0	59
Monroe	5	0	233.3	8
Montcalm	33	1	567.6	19
Montmorency	555	19	1271.5	42
Muskegon	251	8	2675.7	89
Newaygo	47	2	404.2	13
Oakland	54	2	368.5	12
Oceana	346	12	1766.0	59
Ogemaw	563	19	8296.1	277
Ontonagon	94	3	1438.1	48
Osceola	405	14	1085.2	36
Oscoda	268	9	8765.3	292
Otsego	970	32	1924.9	64
Ottawa	145	5	469.9	16
Presque Isle	330	11	838.4	28
Roscommon	613	20	4551.9	152
Saginaw	20	1	474.7	16
Sanilac	44	1	427.3	14
Schoolcraft	344	11	3210.5	107
Shiawassee	80	3	576.7	19
St. Clair	110	4	1642.8	55
St. Joseph	3	0	7.7	0
Tuscola	121	4	930.9	31
Van Buren	27	1	249.2	8
Washtenaw	17	1	217.5	7
Wayne	2	0	42.2	1
Wexford	428	14	1057.4	35
Total DNR fire events	17449	582	152228.3	5074

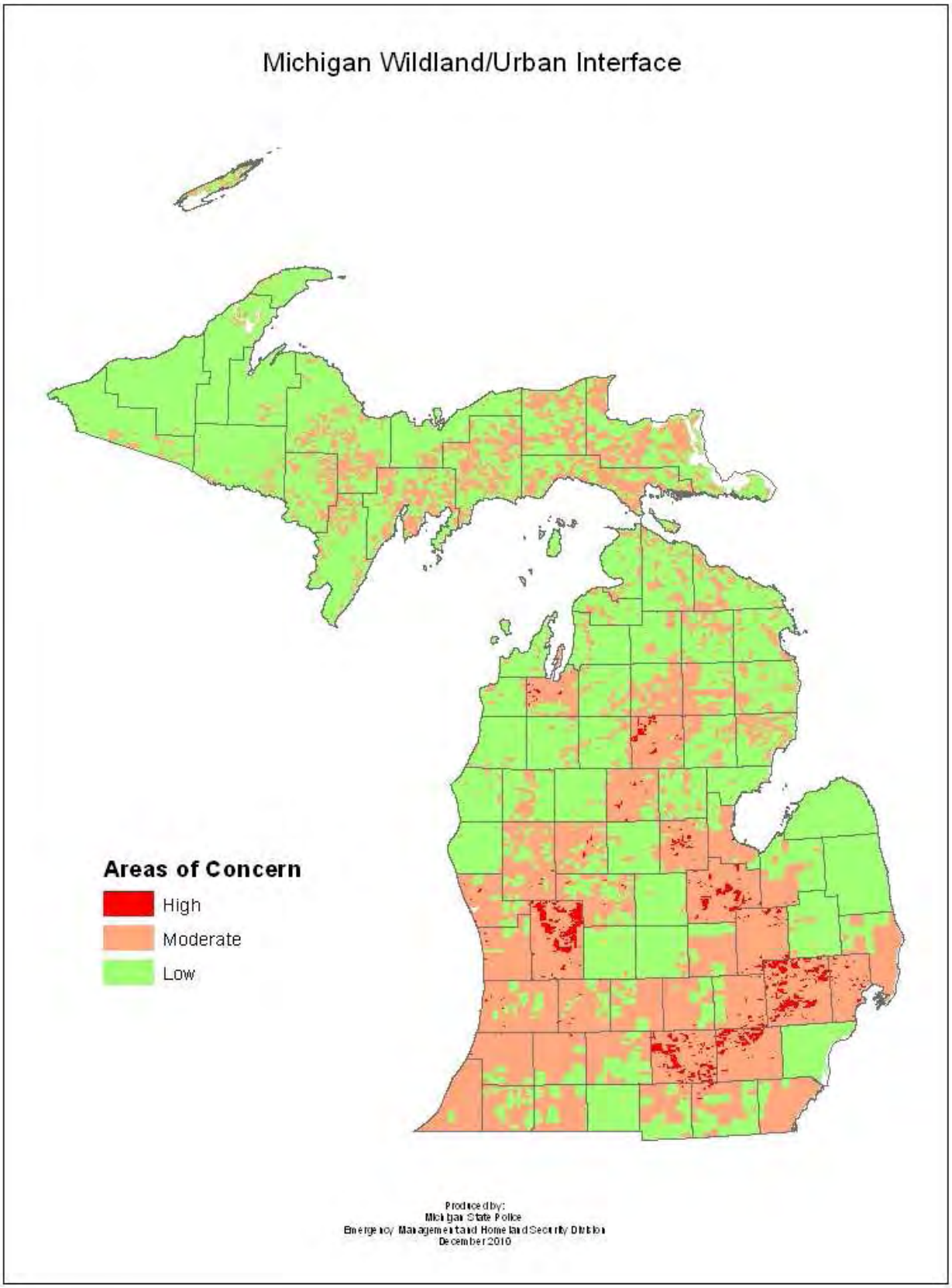
*rounded to nearest whole number

Source: Michigan Department of Natural Resources—Forest Management Division

Michigan Wildland/Urban Interface Map

Source: Michigan Department of Natural Resources, Forest Management Division

NOTE: This map is an example from a previous analysis and is being updated by more valid GIS modeling - not recommended for current use except as a highly generalized indicator



INVASIVE SPECIES

A species that has been introduced by human action to a location where it did not previously occur naturally, becomes capable of establishing a breeding population in the new location without further intervention by humans, and becomes a pest by threatening local biodiversity and causing human health impacts, significant economic costs, and/or harmful ecological effects.

Hazard Description

An invasive species is defined as a species that is (1) non-native (alien) to the ecosystem under consideration and (2) whose introduction causes or is likely to cause economic or environmental harm, or harm to human health. Invasive species can be plants, animals, and other organisms (e.g., microbes). Human actions are the primary consideration here as a means of invasive species' introduction (thus distinguishing the situation from natural shifts in the distribution of species). Nationally, the current environmental, economic, and health costs of invasive species were estimated as exceeding the costs of all other natural disasters combined.

Invasive species can be transported in many ways, such as on animals, vehicles, ships, commercial goods, produce, and clothing. Although non-native species are the foundation of U.S. agriculture, and also are used to prevent erosion, to provide fishing and hunting opportunities, and as ornamental plants and pets, occasionally a non-native organism flourishes too well and causes unwanted economic, ecological, or human health impacts. The terms "invasive" or "nuisance" are used to describe such species. New environments may affect rates of reproduction, susceptibility to disease, and other features that affect a species' success. Consequently, a plant or animal that causes little damage to agriculture or natural ecosystems in one area may cause significant problems in another. Certain non-native species are very successful in their new habitats because they out-compete native plants or animals and have no natural controls (predators, diseases, etc.) in the new area. At least 200 well-known, high-impact, non-native species presently occur in the United States. They range from the European gypsy moth and emerald ash borer to crabgrass, dandelions, and German cockroaches, annually costing well over a billion dollars to control. Some even pose human health risks. Others, like the zebra mussel, threaten widespread disruption of ecosystems and the displacement or loss of native plants and animals.

Hazard Analysis

Hundreds of new species from other countries are introduced intentionally or accidentally into the United States each year. These invasive species may arrive on our shores in a variety of ways. Transportation efficiencies that make it possible to travel around the globe in hours rather than weeks make it possible for organisms to survive transportation from one continent to another

As more adaptable and generalized species are introduced to environments already impacted adversely by human activities, native species are often at a disadvantage to survive in what was previously a balanced ecosystem. There are many examples of decreased biodiversity in such areas. One of the primary threats to biodiversity is the spread of humanity into what were once isolated areas, with land clearance and habitation putting significant pressure on local species. Agriculture, livestock, and fishing can also introduce changes to local populations of indigenous species and may result in a previously innocuous native species becoming a pest, due to a reduction of natural predators. This threat intensifies the need for scientists, managers, and stakeholders to cooperate to build better systems to prevent invasion, improve early detection of invaders, track established invaders, and to coordinate containment, control, and effective habitat restoration.

Although invasive species, in most cases, primarily cause environmental damage and degradation, there are situations in which serious threats to public health, safety, and well-being can occur due to animal disease or plant/animal infestations. For example, certain diseases could wipe out large segments of an animal population, creating a potentially serious public health emergency and the need to properly (and rapidly) dispose of the dead animal carcasses.

Similarly, a widespread insect infestation, such as that of the Emerald Ash Borer, can create serious public safety threats (especially in densely populated urban areas) due to dead and dying trees being fire prone (because of their

dry, brittle nature) or to partial/total collapse due to high winds or ice/snow accumulation. The falling trees or limbs can also bring down power lines, cause damage to public and private structures, and cause injuries or even death.

The invasive species hazard has not yet been identified as one of the most significant hazards in any of Michigan's local hazard mitigation plans.

Impact on the Public

The emerald ash borer has caused extensive damage to trees in Michigan, and those weakened trees have often (1) collapsed and caused property damage, or (2) required removal, at considerable expense. A disaster declaration request was sent to FEMA, but the request was not accepted by that agency, leaving state and local budgets, residents, and insurance companies to try to cover the considerable expenses and efforts involved in dealing with the problem. Similar terrestrial species include the Asian Long-Horned Beetle and the Cedar Long-Horned Beetle, although aquatic species and some microbes are also of concern, since they may disrupt or impede forestry, horticulture, and fishing for Michigan residents, tourists, and industries.

Impact on Public Confidence in State Governance

Terrestrial species are likely to have more general public awareness than aquatic ones, and thus more likely to be a cause for dissatisfaction or loss of public confidence in government. Although there have been well-publicized aquatic species of concern (e.g. zebra mussels, Asian carp), people tend to be more aware of the impacts of terrestrial species, unless their recreational or business activities are more heavily curtailed by aquatic ones. The most recent widespread terrestrial species of concern has been the emerald ash borer insect—trees killed by these insects are prone to collapse, causing property damage, blocked roads, broken utility lines, etc. Citizens and businesses that are more heavily connected with agriculture and tourist industries are more likely to be aware of the impact of invasive species, and thus more likely to express doubts about government policies.

Impact on Responders

The invasive species hazard is a less familiar one for the general public, generally long-term and insidious in its effects, and rooted in an understanding of the biological sciences. Most emergency management training does not focus on the topic. Emergency management consideration of invasive species is recent and therefore needs to be increased. MSP/EMHSD has recently been strengthening coordination with the U.S. Geological Survey, which has specialized offices dealing with this hazard. An Ann Arbor USGS office deals with Great Lakes aquatic species, and a separate USGS office in Fort Collins, Colorado, deals with terrestrial species. Information and resources derived from this coordination will be made available to emergency management partners, and should be promulgated through the next update of the Michigan Hazard Analysis.

Impact on the Environment

Terrestrial and aquatic forms of invasive species both pose problems for the ecosystems in which they are introduced. Whether invasive species are brought to an area on purpose or by accident, these non-native life forms can alter the existing ecosystem and decrease an area's biodiversity. Like many hazards that affect Michigan's environment, invasive species have both direct and indirect impacts. The Zebra Mussel, for example, has been invading Michigan's water bodies since the mid 1980's and is responsible for eating the microscopic food supply that is vital to the existing ecosystem. Further, the Zebra Mussel attaches to water intake pipes and screens used for drinking water and industrial plants. Not only do these pests cause environmental problems, but they cause secondary economic impacts to a community as well. Similarly, the Emerald Ash Borer, a non-native insect, is responsible for killing millions of Ash Trees in Michigan, which changes the biodiversity of the forest and diminishes wildlife habitats. Dead trees pose problems for the human-built environment, as well, pulling down nearby wires and damaging structures.

NOTE: The following lists and descriptions provide examples of invasive species that pose some threat to Michigan, or have already affected Michigan. For each of these categories, at least several other species could have been included. Some of these species, such as the Gypsy Moth, are already well-established throughout the state, but the text provides information about the kinds of impacts that can result from the invasive species hazard.

Much additional information can be found at http://www.invasive.org/ and http://web4.msue.msu.edu/mnfi/.

Examples of Potentially Threatening Invasive Insects
(Note: Not all of these species currently occur in Michigan.)

Balsam Woolly Adelgid (Adelges piceae)
Hosts: All true firs.
Symptoms: Small white masses on tree, stunted shoots, formation of galls, tree crown turns red.
Damage: Feeding on the branches of the crown and main stem, causing mortality in 2-6 years.
Control/Treatment: Spraying of individual trees from the ground with lindane has proved effective for control. The spray, prepared by mixing 2.5 pints of 10% emulsifiable concentrate per 100 gallons of water, is applied as a bark drench with a hydraulic sprayer from May through June and September through October to control crawlers. Treatment will reduce populations to below the tree-killing level, and some treated trees may remain generally free from aphids for at least 2 years. Spraying is warranted only in accessible areas supporting relatively high-value trees.

Hemlock Woolly Adelgid (Adelges tsugae)
Hosts: Eastern Hemlocks.
Symptoms: Small white cottony masses at the base of the needles. Needles turn grayish green and drop off. There is a lack of new buds, and low vigor.
Damage: Feeding on twigs by nymphs cause the trees to die within 1-4 years.
Control/Treatment: Horticulture oils that smother the insects have been the best insecticidal treatment. The oils are non-toxic to the trees, as opposed to soap, which is an otherwise effective treatment. However, the least harmful cure may be the introduction of Japanese ladybugs.

Asian Long-Horned Beetle (Anoplophora glabripennis)
Hosts: Several species of hardwood trees found in Michigan. Its favorite host is the Norway maple, although it has been found in other maple species, horse chestnut, elm, box elder, mulberry and poplar trees.
Symptoms: Dark, wet areas on branches and trunks or white foamy sap are often the first symptoms seen in infested trees. The sap often attracts bees, wasps and hornets.
Damage: Trees infested are first weakened, and then die. Damage from these insects and secondary pests will kill a tree within a few years.
Control/Treatment: The only known way to eradicate the beetle is to cut down and burn infested trees.

Japanese Cedar Long-Horned Beetles (Callidiellum rufipenne)
Hosts: Nest in white cedar, eastern red cedar, and cypress trees.
Symptoms: Oval exit holes on tree bark, or deep irregular galleries in wood.
Damage: Larvae bore into wood and weaken the tree. Heavily infested trees may die.
Control/Treatment: None at this time.

Emerald Ash Borer (EAB) (Agrilus planipennis)
Hosts: White, black, and green ash trees.
Symptoms: Typically the upper third of a tree will die back first, followed by the rest during the next year. This is often followed by a large number of shoots or sprouts arising below the dead portions of the trunk. The adult beetles typically make a D-shaped exit hole when they emerge. Tissue produced by the tree in response to larval feeding may also cause vertical splits to occur in the bark. Distinct S-shaped tunnels may also be apparent under the bark. Adults are dark metallic green in color, 1/2 inch in length and 1/16 to 1/8 of an inch wide and are only present from mid May until late July. Larvae are creamy white in color and are found under the bark.
Damage: The adult beetles feed on ash foliage but cause little damage. The larvae feed on the inner bark of ash trees, disrupting the tree's ability to transport water and nutrients. Many trees appear to lose about 30 to 50 percent of their canopy in one year and the tree is often killed after 2-3 years of infestation. Most of the devastation in Michigan has occurred in the southeastern Lower Peninsula, where about 20 million trees have been killed. Fallen trees have caused extensive property damage. Please refer to the map at the end of this section for information about EAB quarantine areas in Michigan.
Control/Treatment: Treatment options for controlling infected or at risk trees include systemic insecticides applied as soil injections, systemic insecticides applied as trunk injections, noninvasive systemic sprays, and protective cover sprays. If properly applied, these treatment options can prevent EAB larvae from taking over the ash tree about 70% of the time. Treatment also proves to be successful when managing at-risk trees in areas where EAB has been identified. In continuing efforts to halt the expansion of the EAB, the Michigan Department of Agriculture and Rural Development (MDARD) has placed restrictions on the movement of firewood throughout the state and has taken other appropriate response measures. More information on the EAB can be found on the MDARD's website: www.michigan.gov/eab.

Gypsy Moth (Lymantria dispar)
Hosts: Tree foliage.
Symptoms: The egg mass is usually laid within a few feet of the female pupa casing. They are covered by a dense coating of hairs.

Damage: During high population levels, total defoliation can occur. During the months of June and July, defoliating populations cover sidewalks, homes, children's play equipment and other objects, making outdoor activity in residential and recreational areas almost impossible. For Michigan's nursery industry, additional expense and pesticide use are required. For the forest products industry, high gypsy moth populations mean the potential loss of wood fiber from reduced production (due to tree stress or mortality).
Control/Treatment: Counties may get involved in the Michigan Cooperative Suppression Program. The only pesticide used in the Cooperative Suppression Program is Bacillus thuringiensis, most commonly referred to as Bt.

Khapra Beetle (Trogoderma granarium)
Hosts: The beetle prefers hot, dry conditions and can be found in areas where grain and other potential food is stored, such as pantries, malt-houses, grain and fodder processing plants, and stores of used grain sacks or crates.
Symptoms: Destruction of grains and seeds. They can multiple quickly in stored items such as crackers, wheat, flour and baby cereal and rapidly spread to warehouses, storage bins, and mills.
Damage: The beetles can potentially cause severe harm to the agriculture crop industry such as grains and seeds including wheat, soybean, barley, corn and rice.
Control/Treatment: Fumigation with methyl bromide in containers to quarantining shipments until treatment. Powdered neem has been used to control the beetle in wheat stores in India.

Common Pine Shoot Beetle (Tomicus piniperda)
Note: Although previously listed in the Michigan Hazard Analysis, this species is no longer considered as damaging as it originally had been when first discovered in Michigan during the 1980s. The insect is now widespread throughout the Great Lakes and currently causes little economic impact.

Some invasive insects in Michigan, from left to right: Asian long-horned beetle, cedar long-horned beetle, emerald ash borer, gypsy moth

Examples of Potentially Invasive Microbes

(NOTE: Sudden Oak Death was described in previous editions of this plan, but has only occurred in California and Oregon. Examples listed here are not necessarily found in Michigan at the present time.)

At left, Dutch elm disease; at right, the plum pox virus

Dutch Elm Disease
Hosts: Elm trees
Symptoms: Trees infected by elm bark beetles first show wilting, curling, and yellowing of leaves on one or more branches in the upper portion of the tree, as a fungus from the beetles progressively affects the tree's health.
Damage: Large trees may survive and show progressively more symptoms for one or more years. Trees infected through root grafts wilt and die rapidly; this frequently occurs in the spring, soon after the trees have leafed out, and progresses from the base of the tree upward.
Control/Treatment: Dutch elm disease control has involved two different but related programs: (1) community-wide sanitation programs designed to reduce the level of elm bark beetles (principal carriers of the Dutch elm disease fungus); and (2) prevention of the spread of the disease through natural root grafts from infected trees to adjacent healthy trees. There are probably no community-wide programs being used any more, with a shift toward disease management involving the planting of different species of trees. There is no way to eliminate Dutch elm disease once it begins, but different species such as Siberian elms are resistant to the disease.

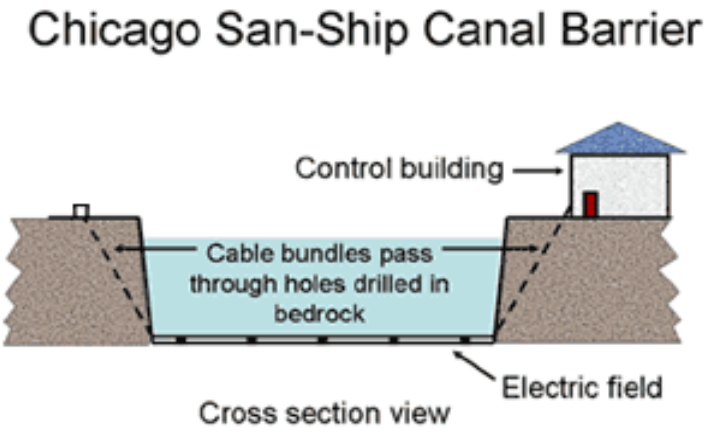
Plum Pox Virus
Hosts: Peach, plum, nectarine, apricot, almond, cherry.
Symptoms: Discolored viral rings on leaves and fruit.
Damage: Smaller deformed fruit and reduced fruit production.
Control/Treatment: Control and prevention measures include field surveys, use of certified nursery materials, use of virus-resistant plants (when available), control of aphids, and the elimination of infected trees in nurseries and orchards. A team of scientists from the United States and France has genetically engineered a PPV-resistant plum (known as C5), and this resistance can be transferred through hybridization to other plum trees. This provides a source of germplasm for future breeding programs worldwide. Similar success has not yet occurred in attempts to genetically modify other Prunus species.

Thousand Canker Disease of Walnut
Hosts: Black walnut and other walnut species.
Symptoms: Infected trees show wilting, curling, and yellowing of leaves on one or more branches in their upper portions, as a fungus from the walnut twig beetles progressively affects the tree's health.
Damage: Causes thousands of small cankers on and under the bark, disrupting the flow of nutrients to the branches. Tree mortality is directly proportional to the number of feeding sites present on the tree.
Control/Treatment: There is no practical treatment, once infected. Landowners should remove affected trees to prevent spread to nearby trees.

Examples of Invasive Water Species Affecting Michigan

Asian Carp (Ctenopharyngodon idella, hypophthalmichthys nobilis, and hypophthalmichthys molitrix)
Hosts: Asian carp made their way into the Mississippi River from Arkansas fish farms in the 1970s as a result of flooding and have steadily swum upstream for years at a pace of 40 to 50 miles a year. Asian carp are currently in the Illinois River and only miles away from entering the Great Lakes.
Symptoms: Decline in native fish species**.** There are three different species of Asian carp that have invaded the Mississippi River: grass (ctenopharyngodon idella), bighead (hypophthalmichthys nobilis), and silver (hypophthalmichthys molitrix). All three species of Asian carp pose a problem to the waterways by devastating habitats and destroying water quality. However, the bighead and silver carp are of the greatest concern, due to their size. These fish can each grow to be 50 to 100 pounds. Although great attention has been focused on these fish recently, dreissenid mussels have already invaded the Great Lakes and caused extensive impacts. (A description of mussels also appears in this section.)
Damage: Researchers expect that Asian carp would disrupt the food chain that supports the native fish of the Great Lakes. Due to their large size, ravenous appetites, and rapid rate of reproduction, these fish could pose a significant risk to the Great Lakes Ecosystem. If bighead or silver carp enter the great lakes, the economic impacts on the fishing industry would be devastating, putting the Midwest's multi-billion dollar-a-year fishing industry at risk. Also, silver carp have been known to cause injuries to boaters, as they jump out of the water.
Control/Treatment: To prevent the species from entering the Great Lakes, the U.S. Army Corps of Engineers, U.S. EPA, State of Illinois, International Joint Commission, Great Lakes Fishery Commission, and U.S. Fish and Wildlife Service constructed a temporary electronic dispersal barrier on the Chicago Sanitary and Ship Canal near Romeoville, Illinois, which was activated in April, 2002. In late October 2004, construction began on a second, more permanent barrier. The new barrier, completed in February 2005, stretches two rows of electrodes across the canal approximately 220 feet apart. The electrodes pulse DC current into the water, causing fish to turn back rather than pass through the electric current. The electric current poses no threat to humans. A model of the Chicago Canal Barrier can be seen below.
In November 2009, evidence of the presence of Asian carp was detected beyond the electric barrier, which left only a single lock/dam on the Calumet River between the carp's detected location and Lake Michigan. Due to the major ecological threat to Lake Michigan and to recreational boaters, the U.S. Army Corps of Engineers shut down one of the electric barriers for maintenance in December 2009. The Illinois Department of Natural Resources responded to the situation by dumping 2,200 gallons of the toxin rotenone into the canal. Rotenone is deadly for fish but not harmful to humans, animals, or most other aquatic life. The intentional fish kill cost $3 million and produced about 90 total tons of dead fish, but only one carp was found in the Lockport Lock and Dam area. In June 2010, a 19-pound Asian carp was found near the shore of Lake Michigan, in Lake Calumet, about six miles downstream from Lake Michigan, by a commercial fisherman hired by the state of Illinois to do routine fish sampling in the area. The fish confirmed existing DNA evidence suggesting that the Asian carp had indeed breached the electric barrier on the Chicago Sanitary and Ship Canal, which had been considered the last line of defense for Lake Michigan.

NOTE: New developments occur frequently. This information was considered accurate as of 12-2010.



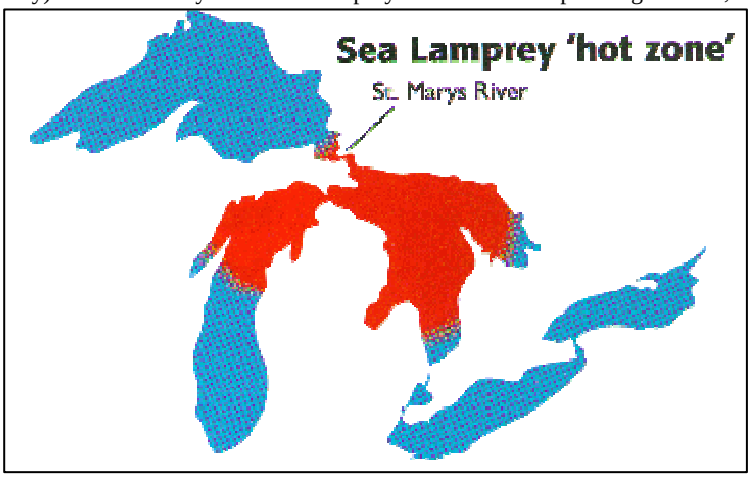
Chicago Sanitary and Ship Canal Dispersal Barrier System (Source: U.S. Geological Survey)

Sea Lamprey (Petromyzon marinus)
Hosts: Found in both fresh water and salt water habitats, they breed in freshwater streams and lakes and were first discovered in the Great Lakes in the 1800s.
Symptoms: Sea lampreys prey on a wide variety of fish. The lamprey uses its suction-cup like mouth to attach itself to the skin of a fish (possibly for days) and rasps away tissue with its sharp probing tongue and many hooked teeth, arranged in numerous rows. Secretions in the lamprey's mouth prevent the victim's blood from clotting, and the lamprey sucks the victim's blood. Victims (usually smaller ones) typically die

from excessive blood loss or infection. Mature sea lampreys average 2 to 2½ feet long, up to a maximum of about 3 feet. Sea lampreys are considered a pest in the Great Lakes region and were introduced as an invasive species in the 1800s, originating from the inland Finger Lakes and Lake Champlain in New York and Vermont. Sea lampreys created a problem for key predator fish species including lake trout, lake white fish, and lake herring. The elimination of these key predator fish allowed the alewife, another invasive species, to explode in population, having adverse effects on many native fish species.

Damage: The introduction of the sea lamprey to Lake Superior caused serious declines in fish populations, and an alteration of the ecosystem. The lake trout played a vital role in the Lake Superior ecosystem because it is considered an apex predator, which means that the entire system relies on its presence to be diverse and healthy. As an apex predator was removed from the system, the entire system felt the effects all the way down the food chain. The sea lamprey is an aggressive predator by its nature, which gives it a competitive advantage in a lake system where it has no predators and its prey lack defenses against it. The sea lamprey played a large role in the drastic decline of the Lake Superior lake trout population. One sea lamprey can upset an ecosystem and food chain by eating an estimated 40 pounds of fish or more in its lifetime. This resulted in an unbalanced relationship between predators and prey in the Great Lakes' Ecosystem.

Control/Treatment: Control efforts to mitigate the destructive effects of the sea lamprey have included the use of electric currents, chemicals, and barriers. In 1958, scientists found a chemical (still used today) that selectively killed sea lamprey larvae in their spawning streams, and brought the lamprey under control. In 1986, DNR fish managers, technicians and engineers designed a new lamprey barrier which let fish migrate through to spawn, but captured the lamprey. The new barrier was expected to reduce the number of lamprey beyond it to nearly zero. Lamprey numbers in Lake Michigan are currently only about 10 percent of their peak numbers in the 1950s. Today, biologists and researchers are still looking for new ways to stop the spread of lampreys in lakes, streams, and rivers. It is the hope of the Great Lakes Fishery Commission that at least some of this scientific work on the sea lamprey, including genetic and pheromone studies, will result in a more effective management technique that could one day drastically reduce the need for chemical treatments of spawning grounds. Several million dollars are spent each year on environmentally friendly control methods. Native predatory fish, like the whitefish and lake trout, have been restocked by fisheries professionals to help maintain a healthy level of these species.



<u>Dreissenid Mussels (including Zebra Mussels and Quagga Mussels)</u> (family Dreissenidae)

Hosts: Freshwater lakes and streams

Symptoms: By firmly attaching to hard surfaces, dreissenid mussels have clogged water-intake pipes and fouled hard-shelled animals such as clams and snails. In addition, zebra mussels have reduced plankton populations, as colonies of mussels filter large volumes of water for food, potentially depleting food resources of larval and planktivorous fishes such as smelt, chub, and alewife. Transfer of suspended material to the lake bottom in mussel waste products also leads to increased water clarity and increased growth of aquatic plants. Although clear water is often considered aesthetically pleasing, this clarity indicates that drastic changes have occurred at the base of the food web and that energy flows through the ecosystem has been altered. The mass media has given a great deal of attention to the zebra mussel, but quagga mussel infestations are actually far more extensive in the Great Lakes. Both zebra and quagga mussels belong to the same genus, dreissenid mussels, but quagga mussels are more tolerant of colder and deeper waters than zebra mussels are. Quagga mussels were first spotted in the Great Lakes around 1990, and have devoured so much plankton that the food web is being altered.

Damage: Communities along the affected lakes and rivers rely on these waters for drinking, industrial water supplies, transportation, commercial fishing and shelling, and recreation. Rapidly expanding populations of dreissenid mussels could ultimately affect many of these activities, in addition to changing the structure of the ecosystem.

Control/Treatment: Applications of hot water and bleach have been used. A new method involving bacteria is being refined.

A couple of invasive aquatic species: Asian carp and zebra mussel.

Invasive Plant Species in Michigan

Please refer to the information in the MDNR publication "Meeting the Challenge of Invasive Plants: A Framework for Action," which can be found at the following website:

http://www.michigan.gov/documents/dnr/Invasives_strategy_final_289799_7.pdf. Numerous online resources provide more information about plants, such as the NRCS database at http://plants.usda.gov/java/.

Example of a Terrestrial Animal Species that Poses a Threat to Michigan

Boar or Wild Hogs (Sus scrofa)

Feral swine are defined as free-ranging pigs and are considered to be an aggressive public nuisance. They have been known to attack and chase humans. They can become infected with, and may transmit, diseases that affect human health, domestic livestock, and wildlife, such as brucellosis, tuberculosis, bubonic plague, tularemia, anthrax, and trichinosis. In Michigan, pseudorabies-positive feral swine were removed from private land in 2008. Feral swine have the potential to cause great economic harm to the domestic swine industry, if they were to transmit such disease to commercial swine.

The appearance of feral swine may vary greatly, as they can originate from several subspecies, including the Russian Boar, the wild Eurasian boar, escaped domestic swine, and quite often a mix of domestic and wild-type breeds. These animals can weigh up to 400 pounds, may be covered in coarse hair, may have tusks, and are known to travel in groups. Females in warm states produce two large litters of 8 to 10 piglets per year. In Michigan, feral swine are known to survive the harsh winters. Feral swine tend to follow creeks and drains between food sources. They favor agricultural crops, but when the crops are harvested in the fall, they turn to wildlife food plots, acorns, and other mast foods. Feral swine are known to eat ground nesting birds, small mammals, and grubs.

Damage: Feral swine can tear up the landscape, killing wildlife and pets, damaging farm crops and wildlife habitats, and scavenging uncovered garbage. Their devastating effect on crops accounts for up to $1.5 billion in annual damages nationally. Unlike most animals, feral swine don't stop at just eating crops. They also root holes in the ground as deep as a foot, destroying the crops. Wild hogs can damage as much as 10 percent of a farmer's crop.

To date, the Department of Natural Resources has logged 288 unofficial feral swine sightings by residents in almost every county in Michigan. Since 1999, national experts have estimated that, if unchecked, the feral swine population could become established statewide and cause economic hardship for farmers, and for businesses that cater to wildlife enthusiasts.

Control: On May 13, 2010, the Michigan Legislature amended Public Act 328 of 1976 (Domestic Animals Running at Large) by allowing people to pursue and harvest feral swine at any time. The law does the following: (1) declares swine running at large on public or private property to be a public nuisance, (2) permits a local animal control officer or a law enforcement officer to kill swine running at large on public or private property, (3) permits a person with a concealed weapon permit or a valid hunting license to kill swine running at large on public property, and (4) permits a property owner or other authorized person to kill swine running at large on private property. In the last case, the landowner does not need a hunting license.

Michigan residents who see or shoot a feral pig are asked to report it to the Michigan Department of Natural Resources at (517) 336-5030. USDA Wildlife Services (517-336-1928) and the Wildlife Conservancy (517-641-7677) have feral swine traps available for the use of landowners who are experiencing feral swine damage. The animals will be trapped, removed, and tested for disease, then euthanized and disposed of.

In December, 2010, the Michigan Department of Natural Resources classified feral swine as an invasive, exotic or prohibited species under Public Act 451, the state's Natural Resources and Environmental Protection Act of 1994, but the Director's order does not go into effect until April of 2011.

Partners: The Feral Swine Working Group is an interagency team of veterinarians, biologists, and policy personnel within the state and federal governments, Michigan State University, and from numerous stakeholder groups, including the Michigan Animal Control Association, Michigan Farm Bureau, Michigan Pork Producers Association, Michigan United Conservation Clubs, Michigan Corn Growers Association, the Nature Conservancy, United Deer Farmers of Michigan, the Michigan Hunting Dog Federation, and the Michigan Wildlife Conservancy.

Animal Diseases

There are many animal diseases that have the potential to impact Michigan. Diseases from outside Michigan or the United States have the potential to cause widespread mortality in livestock, wildlife, and companion animals. They could result in huge economic losses (primarily through trade restrictions), require significant resources to be allocated for response, and in some cases could also threaten public health. For more information, please refer to the Reportable Animal Diseases documents of the Department of Agriculture and Rural Development. (One introductory link is: http://www.michigan.gov/mda/0,1607,7-125-48096_48097_48155-71720--,00.html.) Foot and Mouth Disease is an example of a foreign animal disease that would require a heightened response from Michigan agencies.

Example of a Livestock Disease That Poses a Threat to Michigan

Foot and Mouth Disease

Hosts: This infectious virus spreads on surfaces and in the air, and impacts cattle, swine, sheep, goats, deer, and other cloven-hoof ruminant animals. It does not currently exist in Michigan or the United States and has not existed in the U.S. since 1929. However, the disease is of great concern because it is highly contagious and would have grave economic consequences for Michigan's livestock industry.

Symptoms: In cattle, blisters inside the mouth that lead to excessive secretion of stringy or foamy saliva and to drooling; and blisters on the feet that may rupture and cause lameness. Adult animals may suffer weight loss from which they do not recover for several months, as well as swelling in the testicles of mature males. In cows, milk production can decline significantly.

Damage: Though most animals eventually recover from FMD, the disease can lead to myocarditis (inflammation of the heart muscle) and death, especially in newborn animals. Some infected animals do not suffer from or show signs of the disease, but they are carriers of FMD and can transmit it to others.

Control/Treatment: The Michigan Department of Agriculture and Rural Development (MDARD) licenses and regulates Michigan's 500 livestock dealers, truckers, livestock sales, and auction markets to help monitor animal health and ensure the safe and humane handling of

animals. The MDARD also monitors and controls the interstate and intrastate shipment of animals and animal products, to eradicate and control the spread of disease. If this disease were discovered in the United States, it would trigger national and state response plans and require rapid and coordinated response in order to control the disease and protect the nation's livestock industry.

Wildlife Diseases that Pose a Threat to Michigan

Chronic Wasting Disease (CWD)

This is a prion disease of the brain. The infectious agent contaminates the environment and is transmitted from one animal to another.

Hosts: Deer and elk are affected by this brain disease that is present in several western states and in Minnesota and Wisconsin. It was also detected in one Michigan location in 2008 (at an enclosed deer breeding facility in Kent County). Mule deer, white-tailed deer, and Rocky Mountain Elk are the only three species of the family Cervidae that are known to be naturally susceptible to CWD. However, it is very likely that other subspecies of C. elaphus are susceptible to the disease. Although no other deer in Michigan have tested positive for CWD (outside of the isolated Kent County case), it remains a major concern due to the large wild population of deer in the state.

Symptoms: Emaciation, wide stance, lowered head, droopy ears and excessive salivation.

Damage: Animal fatalities

Control/Treatment: Chronic wasting disease is both transmissible and infectious, but most details of its transmission remain to be determined. No treatment is available for animals affected with CWD. Once clinical signs develop, CWD is invariably fatal. Affected animals that develop pneumonia may respond temporarily to treatment with antibiotics, but ultimately the outcome is still fatal. Similarly, no vaccine is available to prevent CWD infection in deer or elk.

Two threatening animal diseases: Chronic wasting disease and foot and mouth disease.

Programs and Initiatives

Note: These listings highlight the breadth of existing programs and initiatives currently under way, but are not intended to be comprehensive.

Michigan Aquatic Nuisance Species (ANS) Program

In 1996, Michigan developed its first comprehensive ANS state management plan to provide guidance on actions for the prevention, control, and impact-management for ANS that have invaded, or may invade, Michigan waters. This state management plan was updated in 2002, and includes a summary of accomplishments, goals, and activities. The MDNR was awarded funding through the Great Lakes Restoration Initiative in 2010, to update and continue the implementation of the plan. A core team of staff members and managers from the Fisheries, Wildlife, Water Resources, Recreation, and Law Enforcement Divisions (of the DNR and DEQ), as well as representatives from the Pesticide and Plant Pest Management Divisions (of the Department of Agriculture and Rural Development) and the Project Planning Division (of MDOT) are currently in the initial stages of updating the state management plan. The plan is accessible at http://www.michigan.gov/documents/deq/deq-ogl-ANSPlan2002_249062_7.pdf.

These efforts include the Asian Carp Control Strategy, which includes studies performed by the U.S. Army Corps of Engineers. The USACE Asian Carp Study stems from a nearly 80 million dollar initiative from the White House Council on Environmental Quality in 2007, involving a multi-pronged federal attack against Asian Carp. The Asian Carp study examines the possibility of permanently shutting down the Chicago waterway system that links Lake Michigan to the Mississippi River Basin, and coordinating state efforts in response to the Asian carp threat. Although some actions may be taken before the study is completed, a final recommendation on how to stop the movement of the Asian Carp and other related species is expected to be made by 2013. However, the USACE has been accused of moving too slowly to prevent Asian carp and other exotic species from invading the Great Lakes. The USACE will release a short list of possible solutions in 2013 to quicken the process. The USACE will pick up the pace under a revised strategy in which it no longer will devise a single preferred method. Instead, the agency will put forward several options and leave it to congress and the public to decide.

The Permanent Prevention of Asian Carp Act (proposed legislation)
Due to Asian Carp being detected beyond established barriers and less than six miles from direct access to the Great Lakes, a bill was created to direct the U.S. Army Corps of Engineers to study the watersheds of the Illinois, Chicago, and Calumet Rivers, and their tributaries, that drain directly into Lake Michigan, to determine the feasibility and best means of implementing the hydrologic separation of the Great Lakes and Mississippi River basins to prevent the introduction or establishment of populations of aquatic nuisance species along that pathway. In 2010, this bill was introduced in the U.S. House of Representatives (H.R. 5625) and the U.S. Senate. At the time of this writing, the bill was in a House subcommittee. If it eventually becomes law, the required study must begin within 30 days of its passage, with periodic progress reports then submitted by the USACE.

The Sea Lamprey Control Program
Administered by the Great Lakes Fishery Commission, this program may be the best example of integrated pest management in North America. The program costs over $20 million per year, but has been tremendously successful in protecting the multi-billion dollar Great Lakes fishery for millions of persons who fish or are involved in a related sector of the economy. Sea lamprey control efforts have resulted in a 90% reduction in sea lamprey populations throughout the Great Lakes. http://www.glfc.org/lampcon.php

National Strategy and Implementation Plan for Invasive Species Management
The National Strategy and Implementation Plan for Invasive Species Management was developed by a team of researchers and specialists. This plan is responsible for preparing the Forest Service to deal with the ecological and economic problems associated with the types of invasive species that affect the nation. The plan maps out a strategic direction for Forest Service programs, which include Research and Development, International Programs, State and Private Forestry, and the National Forest System.

Animal and Plant Health Inspection Service
The Animal and Plant Health inspection Service (APHIS) is responsible for protecting and promoting U.S. agricultural health, administering the Animal Welfare Act, and carrying out wildlife damage management activities. The APHIS mission is an integral part of U.S. Department of Agriculture's (USDA) efforts to provide the nation with safe and affordable food. In recent years, the scope of APHIS' protection function has expanded beyond pest and disease management. Because of its technical expertise and leadership in assessing and regulating the risks associated with agricultural imports, APHIS has assumed a greater role in the global agricultural arena. Now, the agency must respond to other countries' animal and plant health import requirements and negotiate science-based standards to ensure that America's agricultural exports, worth over $50 billion annually, are protected from unjustified trade restrictions. In response to needs expressed by the American people and Congress, APHIS' protection role also includes wildlife damage management, the welfare of animals, human health and safety, and ecosystems vulnerable to invasive pests and pathogens. In carrying out its diverse protection responsibilities, APHIS makes every effort to address the needs of all those involved in the U.S. agricultural sector.

The United States Geological Survey (USGS)
The U.S. Geological Survey plays an important role in federal efforts to combat invasive species in natural and semi-natural areas. USGS services include the early detection and assessment of newly established invaders, the monitoring of invading populations, contributions to the understanding of the ecology of invaders and the understanding of factors involved in the resistance of habitats to invasion. The USGS is also involved in the development and testing of prevention, management, and control methods. USGS science centers conduct research relevant to invasive species in Michigan, and these are located at La Crosse, Wisconsin (the Upper Midwest Environmental Science Center), and Ann Arbor, Michigan (the Great Lakes Science Center). Each state in the U.S. is also home to a USGS Water Science Center, some of which conduct or support research relevant to invasive species in the Great Lakes.

The USGS maintains databases that may assist with the monitoring and reporting of invasive species occurrences, as well as provide information on their control. A couple of examples of these resources include the Nonindigenous Aquatic Species Database, at http://nas.er.usgs.gov, and the National Biological Information Infrastructure (NBII), an electronic information network that provides access to biological data and information on the nation's plants, animals, and ecosystems. Sophisticated modeling capabilities, to predict the potential distribution of invasive species, are also available through the National Institute of Invasive Species Science in Fort Collins, Colorado.

NOAA Great Lakes Environmental Research Laboratory (GLERL)

This agency includes research on aquatic invasive species, and focuses on the biological and ecological effects of these species in the Great Lakes, and on the prevention of new species introductions. GLERL houses the NOAA National Center for Research on Aquatic Invasive Species (NCRAIS), which helps to coordinate the agency's aquatic invasive species outreach efforts across the U.S.

Eastern Michigan University Detroit River International Wildlife Refuge Study

Researchers from Eastern Michigan University made an effort to study and help contain the spread of invasive species at the Detroit River International Wildlife Refuge, along 5,700 acres of the Detroit River and Lake Erie. In November 2010, EMU was awarded $487,000 by a program that is part of the National Oceanic and Atmospheric Administration. The purpose is to expand upon work that had examined the spread of phragmites australis (which impairs the refuge's economic and environmental viability), that had set up monitoring points, looked at efforts to control the reed, and also measured effects on water quality. The purple loosestrife and reed canary grass are among the invasive plant species that also might be studied. For the next phase of the project, researchers plan to use a combination of on-the-ground surveys, water quality analysis, and remote satellite detection of invasive species to study their spread. Locations will be mapped, and data will be presented in a new way that is designed to help refuge officials in making management decisions.

Michigan Invasive Plant Council

The Michigan Invasive Plant Council (MIPC) is a non-profit organization that spans a wide array of groups, including government agencies, commercial enterprises, conservation organizations, educational institutions, and the gardening public. MIPC is an affiliate organization of the Southeast Exotic Pest Plant Council and its mission is to protect Michigan from the threat of invasive species. The council develops and publishes an invasive species list; facilitates the exchange of information concerning the management, control, and monitoring of invasive plants; provides a forum for all interested parties to discuss issues relating to invasive plants; serves as an educational, advisory, and technical support council for all aspects of invasive plants and related issues; and helps to prevent future introductions of new invasive plants.

Emerald Ash Borer (EBA) Awareness Week

EAB Awareness Week provides information on the steps that everyone can take to prevent the spread of EAB infestation, as well as fostering a cooperative spirit between citizens, communities, government and industry to reduce the risk that the insect poses to the 700 million ash trees blanketing the state. During the week and throughout the year, the Michigan Department of Agriculture and Rural Development (MDARD) urges Michigan residents and visitors to learn about EAB, be on the look-out for and immediately report possible signs of infestation, and adhere to the State's order banning the transport of ash trees, materials and all firewood from quarantined areas. Each spring, many outreach, education and compliance activities are planned (or will be highlighted) to help increase awareness and understanding of the EAB. The EAB Awareness week is typically held during the last week in May.

Michigan Chronic Wasting Disease Task Force-Final Report

In 2003, Governor Granholm signed an executive order creating a task force to address the threat of Chronic Wasting Disease in Michigan's deer and elk populations. The task force includes five members appointed by the Governor, who serve as the voting members of the task force. The directors of the Department of Agriculture (now MDARD), Community Health, Natural Resources, Environmental Quality, State Police, and Transportation serve as non-voting members of the task force. In October of 2003, the task force presented its findings and recommendations in a report delivered to the Governor. The report can be found at www.michigan.gov/cwd.

Michigan Cooperative Suppression Program – Gypsy Moth Infestations

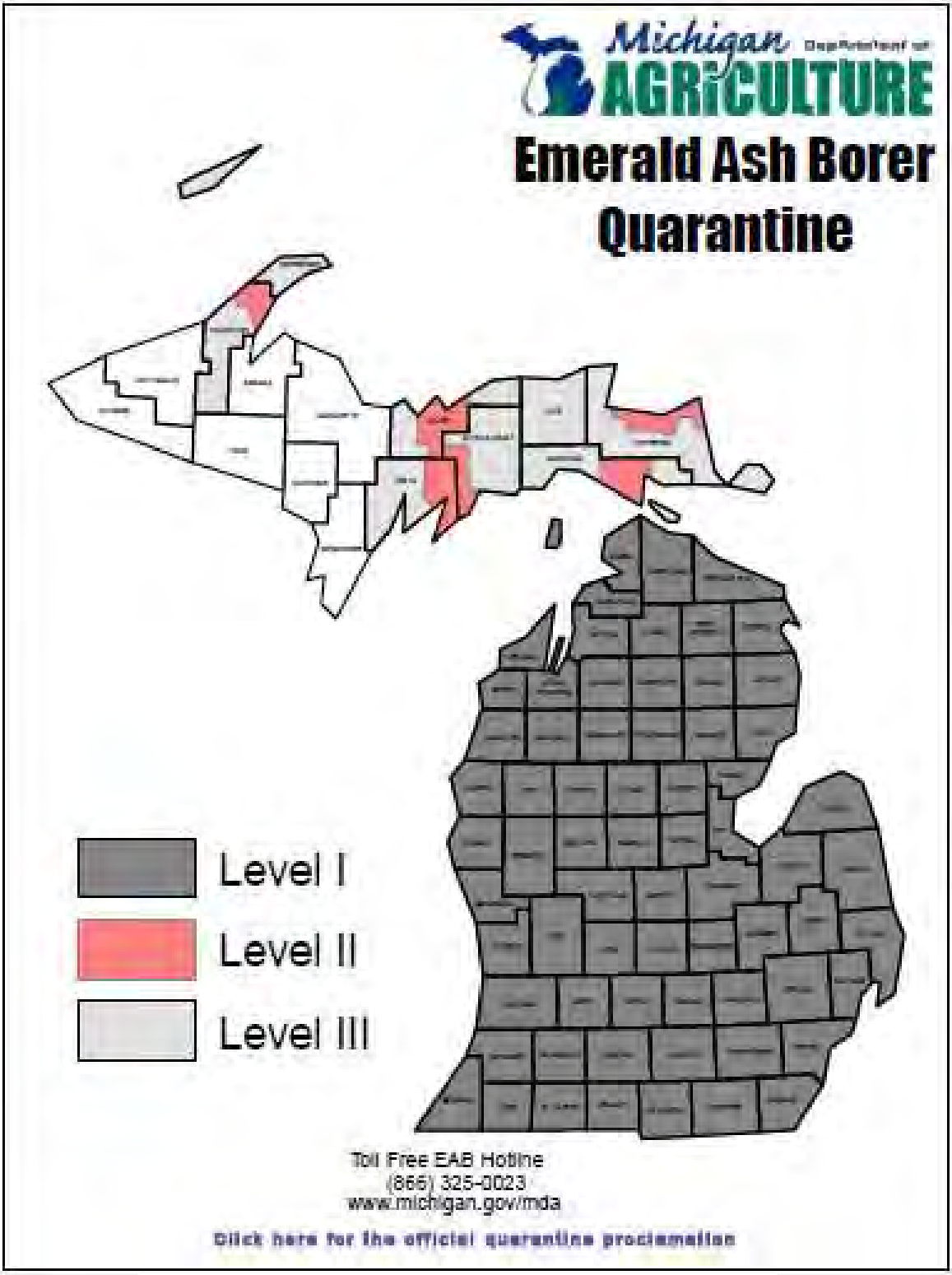
The main goal of the Cooperative Suppression Program is to provide technical and funding assistance to county governments. This allows them the opportunity to provide protection from severe gypsy moth populations. The objectives are 1) to reduce the risk of severe defoliation and 2) to reduce the nuisance created by large caterpillar numbers. A county, interested in participating in the Cooperative Suppression Program, enters into an agreement with MDARD to conduct the program. MDARD provides training, technical support and operational guidelines to the county. The training and guidelines are used to identify areas for treatment. The State of Michigan enters into a

contract with an applicant for treatment of the qualified areas and the county is granted up to 50% cost-share for the cost of conducting the program.

Aquatic Invasive Species Awareness Week

In a continued effort to raise public awareness about the negative impacts caused by aquatic invasive species, the State of Michigan has established the Aquatic Invasive Species (AIS) Awareness Week, usually the second week in June. An aquatic invasive species is defined as a waterborne, non-native organism that threatens the diversity or abundance of native species, the ecological stability of impacted waters, or threatens a commercial, agricultural, aquacultural, or recreational activity. The AIS Awareness Week recognizes that Michigan's expansive shorelines and inland waters draw millions of tourists and recreational users each year, and that appropriate preventive steps must be taken to protect the state's water resources from invasive aquatic species. The AIS Awareness Week is sponsored by the MDEQ's Office of the Great Lakes, working in collaboration with other state and federal agencies as well as private and nonprofit organizations.

Emerald Ash Borer Quarantine Area Map, as of late 2010



Source: Michigan Department of Agriculture and Rural Development

I. Natural Hazards
D. Geological Hazards

The following outline summarizes the significant geological hazards covered in this section:

1. Ground Movement
    a. Earthquakes
    b. Subsidence
2. Celestial Impacts

Although some states recognize "landslides" as an additional hazard, Michigan's geology and history tends to make it more prone to land subsidence instead. Michigan's two main vulnerabilities to ground movement are therefore identified in the sections on earthquakes and subsidence hazards. Erosion is not in itself typically considered an emergency event, except in cases involving encroachment into shoreline developments near a river or lake, and these have been dealt with in the Hydrological Hazards section of this plan. A new section of this plan, celestial impacts, deals not only with the impact of physical objects on property, but also with the effects of solar storms on our modern infrastructure. It will be seen that the systemic technological impacts of this hazard involve greater expected risks than the more well-known impacts of a meteoritic type. Although meteorite impacts are quite easy to understand and visualize, and do have a small potential to be catastrophic, it is the seemingly abstract and mostly invisible effect of "space weather" that has the greatest probability of causing widespread disruption and harm in the near future.

Overlap Between Geological Hazards and Other Sections of the Hazard Analysis

The most serious Michigan earthquakes would be expected to damage some of the utilities infrastructure in the southern part of the state, and could contribute to the occurrence of an energy emergency. Some flooding could result from broken water mains. There may be some potential for oil and gas pipeline operations to be disrupted, as well. A serious subsidence event may cause a key roadway to collapse and become unusable, and may also cause certain other types of infrastructure to become exposed and vulnerable. Transportation accidents that may result from these hazards could cause the release of dangerous hazardous materials. The real potential for a catastrophic incident exists in the event of a major seismic event involving the New Madrid fault line.

Celestial impacts involving solar flares can cause infrastructure failures and have the potential to cause major transportation accidents involving airplanes and/or seagoing vessels. Other types of celestial impacts, involving the impact of physical bodies upon the Earth and its atmosphere, are usually minor but rarely will have the potential to be catastrophic, capable of causing damage equivalent to a nuclear attack and the associated casualties, mass fires (including wildfires), infrastructure failure, severe winds, and physical damages associated with the nuclear attack hazard (but without as intense of radiological effects).

Earthquakes

A shaking or trembling of the crust of the earth caused by the breaking and shifting of rock beneath the surface.

Hazard Description

Earthquakes range in intensity from slight tremors to great shocks. They may last from a few seconds to several minutes, or come as a series of tremors over a period of several days. The energy of an earthquake is released in seismic waves. Earthquakes usually occur without warning. In some instances, advance warnings of unusual geophysical events may be issued. However, scientists cannot yet predict exactly when or where an earthquake will occur. Earthquakes tend to strike repeatedly along faults, which are formed where tectonic forces in the earth's crust cause the movement of rock bodies against each other. Risk maps have been produced which show areas where an earthquake is more likely to occur. Earthquake monitoring is conducted by the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, and universities throughout the country.

The actual movement of the ground in an earthquake is seldom the direct cause of injury or death. Most casualties result from falling objects and debris. Disruption of communications systems, electric power lines, and gas, sewer and water mains can be expected. Water supplies can become contaminated by seepage around water mains. Damage to roadways and other transportation systems may create food and other resource shortages if transportation is interrupted. In addition, earthquakes may trigger other emergency situations such as fires and hazardous material spills, thereby compounding the difficulties of the situation.

A fault line is where a fault meets the ground's surface, but many faults dip at an angle away from their surface location, and therefore earthquakes that occur at some depth will often not line up with the fault at the surface. Faults do not only occur at the boundaries of large geological plates. There are many small plates that exist, as well as faults that are internal to or perpendicular to plate boundaries.

Hazard Analysis

No severely destructive earthquake has ever been documented in Michigan. However, several mildly damaging earthquakes have been felt since the late 1700s. The exact number is difficult to determine, as scientific opinion on the matter varies. With most of these earthquakes, damage (if any) was limited to cracked plaster, broken dishes, damaged chimneys, and broken windows.

In recent years, attention has been focused on the New Madrid Seismic Zone. This zone extends from approximately Cairo, Illinois through New Madrid, Missouri to Marked Tree, Arkansas. During the winter of 1811-1812, a series of earthquakes shook the area. The three worst earthquakes destroyed the town of New Madrid, created a 17,000 acre lake in Northwestern Tennessee, caused ocean-like swells on the Mississippi River (which reportedly ran backwards), and rang church bells as far away as the eastern seaboard. Richter Scale estimates ranged around 8.0. The 1811-1812 earthquakes also included hundreds of aftershocks, some with magnitudes estimated to be between 6.5 and 7.6 on the Richter Scale.

The New Madrid Seismic Zone is significant because scientists predict that a catastrophic earthquake (between 6.0 and 7.6 on the Richter Scale) will occur within the zone sometime during the next few decades. Michigan may be somewhat affected by such an earthquake. A repeat of the 1811-1812 earthquakes is unlikely in the near future. However, should it occur, it could result in damage, disruptions, casualties, and injuries on a scale never experienced from an earthquake in the history of the U.S. The immediate and long-term relief and recovery efforts could place a significant, prolonged burden on the regional and national economies.

Fortunately, Michigan is not located in an area subject to major earthquake activity. Although there are faults in the bedrock of Michigan, they are now considered relatively stable. However, these faults are poorly mapped. According to the U.S. Geological Survey, although Michigan is in an area in which there is a low probability of earthquake occurrences, the area may be affected by distant earthquakes that occur in the New Madrid Seismic Zone and upstate New York. The New Madrid Seismic Zone poses the most significant threat. Based on recent scientific studies, portions of southern Michigan could be expected to receive minor damage were such an earthquake to occur (see the map at the end of this section).

The greatest impact on the state would probably come from damage to natural gas and petroleum pipelines. If the earthquake occurs in the winter, many areas of the state could be severely impacted by fuel shortages. Damage would probably be negligible in well-designed and constructed buildings. However, poorly designed and constructed buildings could suffer considerable damage under the right circumstances.

The following table has a list of earthquakes that have been felt in Michigan. The most severe event centered in Michigan was the 4.7 magnitude event of 1947, which caused some damage to (mainly residential) structures in the southwest region of the Lower Peninsula.

Tectonic Earthquakes Felt or Occurring in Michigan

Date	Origin	Magnitude
4-20-1793*	Porcupine Mt, MI	N/A
12-16-1811 (3 events)	New Madrid, MO	7.9, N/A., N/A
1-22-1812	New Madrid, MO	N/A
1-23-1812	New Madrid, MO	N/A
1-25-1812	New Madrid, MO	7.0
2-3-1812	New Madrid, MO	N/A
2-7-1812	New Madrid, MO	7.5
2-8-1812 (4 events)	New Madrid, MO	N/A
10-20-1870	La Malbaie, QUE	N/A
8-17-1877*	Greenfield, MI	3.2
9-19-1884	Lima, OH	4.8
9-1-1886	Charleston, SC	7.7
10-31-1895	Charleston, MO	6.7
5-26-1909	Aurora, IL	5.1
3-1-1925	La Malbaie, QUE	7.0
8-12-1929	Attica, NY	5.2
11-1-1935	Timiskaming, QUE	6.2
3-2-1937	Anna, OH	5.0
3-9-1937	Anna, OH	5.4
2-12-1938*	Porter, IN	4.0
3-13-1938*	Gibraltar, MI	3.8
3-14-1938*	Gibraltar, MI	N/A
3-9-1943	Lake Erie, OH	4.5
9-5-1944	Massena, NY	5.8
8-10-1947	Coldwater, MI	4.7
11-9-1968	El Dorado, IL	5.5
9-15-1972	Rock Falls, IL	4.5
4-3-1974	Lancaster, IL	4.7
2-2-1976	Pt. Pelee, ON	3.4
7-27-1980	Sharpsburg, KY	5.1
8-20-1980	Harrow, ON	3.2
11-29-1982	Scotts, MI	2.5
10-7-1983	Blue Mtn. Lake, NY	5.1
1-31-1986	Perry, OH	5.0
7-12-1986	St. Mary's, OH	4.6
6-10-1987	Lawrenceville, IL	5.2
11-25-1988	Saguenay, QUE	5.9
9-2-1994	Central Michigan	3.4
9-25-1998	Sharon, PA	5.2
10-23-2001*	Prairie Lake, MI	2.9
4-18-2008 (2 events)	West Salem, IL	5.4, 4.8
2-10-2010	Elgin, IL	3.8
6-23-2010	Val-Des-Bois, QUE	5.0

N/A means that the magnitude information was not available.
* May not have been a natural earthquake. Explosive blasting, mine collapse or other subsidence, and large meteorite impacts can all cause tremors to be felt that may give persons the impression that an earthquake has occurred.
Source: Michigan State University Earthquake Information Center / East Lansing Seismic Station

NOTE: This list has been adapted from the "Earthquakes in Michigan" source list found at https://www.msu.edu/~fujita/earthquake/eqinfo.html. Earthquakes that may not have actually been felt in Michigan were not included in the list.

Historical earthquake occurrences appeared to have an element of a cyclical nature about them, with some decades containing numerous events, surrounded by decades with only a few events, and followed by periods with nearly no occurrences at all. Over time it may be that (probably due to increases in population and development) the number of occurrences gradually increases within this cycle, although this is uncertain. (The pattern is not extremely clear and long, and may just happen to be a statistical artifact.) The potential pattern is illustrated through the listing of natural tectonic earthquake events by decade, with arrows pointing to small peaks of earthquake activity approximately every 50 years. (This is shown on the next page.)

The hypothesis that there may be a kind of cyclic trend is based purely upon the historical data. A recent text, Michigan Geography and Geology (editor in chief, Randall Schaetzl), includes a chapter on earthquakes and states that "about once every 50 years, a magnitude 3-4 event occurs within the state, south of a line between Grand Rapids and Pontiac." Although the event information (listed above) had fit pretty well into this pattern, the most recently updated information from the same source has not quite fit perfectly into the proposed pattern, for instead of the earthquake activity dropping to zero after a clear peak during the 1980s, it has instead fallen into a pattern of about two events per decade, and one of those decades (the 2010s) has only just begun! Thus, there seem to be more earthquakes being felt recently than might have been expected, according to the previous pattern. It is possible that this level of disturbance might be comparable to the periods that would have been marked with zeroes in the past, and that the next occurrence of a peak (in the 2030s?) may therefore involve a record number of events, if there is indeed a gradual trend toward an increased number of disturbances.

1790s:	0	
1800s:	0	
1810s:	12	←These were all New Madrid events and aftershocks, and may not fit into a cyclic trend for Michigan
1820s:	0	
1830s:	0	
1840s:	0	
1850s:	0	
1860s:	0	
1870s:	1	
1880s:	2	←Possible peak in a cyclic trend
1890s:	1	
1900s:	1	
1910s:	0	
1920s:	2	
1930s:	3	←Possible peak in a cyclic trend
1940s:	3	
1950s:	0	
1960s:	1	
1970s:	3	
1980s:	8	←Possible peak in a cyclic trend
1990s:	2	
2000s:	2	
2010s:	2	←Recent trend might not quite match the proposed 50-year cycle

Earthquake Risk Calculation

Although earthquakes are generally not considered a major hazard in Michigan, other states have had so many problems with this hazard that very detailed techniques have been developed to estimate earthquake risks. Each area of the country has been assessed by geologists (according to types of bedrock, fault line proximity, and other factors) and sorted into general zones of earthquake risk. (For a national map showing this, see the web site at http://earthquake.usgs.gov/research/hazmaps/.) These zones are expressed in terms of a probability that significant ground movements will be felt. For example, there may be a 10% chance of an area experiencing significant ground movement within a 50 year period, (which is similar to the "500-year" floodplain, since the annual probability of such an event calculates as roughly .0021). Another component of risk calculation would be to estimate the amount of damage that is likely when such an event occurs. Official measures use the concept of Peak Ground Acceleration (PGA, which is also abbreviated as %g). The key task is to translate the severity of (PGA) ground motion into estimates of structural damages and other economic costs. FEMA has developed a computer application (HAZUS) to give estimates of these earthquake effects.

Michigan has a comparatively low risk of experiencing damaging ground movements. Because of this low risk, however, many designers and developers did not take into consideration the possibility that an earthquake *might* occur. Some of Michigan's communities may actually be quite vulnerable to earthquake effects—especially Michigan's underground utilities—in cases where developed areas were not designed to withstand any ground movements.

Urban areas and active mineland/quarry areas may experience seismic effects as a result of blasting activities, subsidence, structural collapses, vibrations from trains and trucks, or explosions (such as from industrial accidents or terrorist activity). It is therefore worth considering a strengthening of infrastructure as well as interior design enhancements to resist both natural and other types of seismic impacts, vibrations, and stresses.

Impact on the Public

Earthquakes have the potential to cause impacts on an area's infrastructure and energy if a significant event occurs. Impacts could include higher prices for energy and supplies, and the potential for limited supplies of needed goods and resources. A major event, such as a large-scale temblor in the New Madrid Zone, may constitute a National Emergency event (on the scale of Hurricane Katrina), in which there is a need for mutual aid to be provided to states which were strongly affected, and the intake of evacuees from those states. There is a moderate potential for property damage to occur in areas of southern Michigan that are more prone to experiencing seismic activity, and these damages would clearly be inconvenient for homeowners and businesses, at the very least.

Impact on Public Confidence in State Governance

The public may perceive earthquake effects in terms of a governmental failure to plan for and maintain appropriate standards for infrastructure durability and hardening. Some questions may also be raised about whether sufficient

geological research had been conducted in the area, and about whether there was a successful means of providing advance warning that the area might experience an earthquake.

Impact on Responders

Response operations have the potential to include search and rescue activities, which involve special risks and requirements for training and equipment. Earthquake-related infrastructure failures or road subsidence may inhibit efficient and safe response to the incident, and may interfere with the access and use of resources needed for normal and emergency response activities.

Impact on the Environment

A significant earthquake has the potential to cause problems for the environment, both directly and indirectly. Ground movement may disrupt wildlife habitats and change an area's landscape. Secondary environmental impacts caused by a significant event may involve a hazardous materials release into the ground, air, or water from damaged buildings and infrastructure. Fortunately, it is unlikely that an earthquake, even a significant-magnitude New Madrid event, would cause great environmental impacts in Michigan.

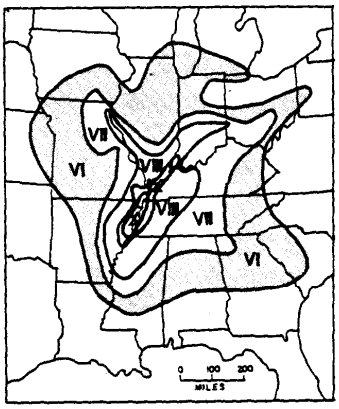
Programs and Initiatives

The Federal government has several programs and initiatives in place to help reduce the earthquake threat, two of which impact Michigan. The most recent, and perhaps most prominent, is the development of the National Response Framework (NRF) to coordinate federal assistance to a catastrophic earthquake or other similar disaster. Coordinated through the federal Department of Homeland Security (DHS), the NRF outlines the responsibilities of all federal agencies with a role in disaster response and/or recovery. Should a catastrophic earthquake ever impact Michigan, federal response and recovery assistance would be coordinated under the provisions set forth in the NRF.

In January 1990, Executive Order (EO) 12699, Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction, was signed into law. This EO requires that appropriate seismic design and construction standards and practices be adopted for any new construction or replacement of a federal building or federally regulated building receiving federal assistance. The purpose of this EO is to reduce risks from failure of federal buildings during or after an earthquake.

Earthquake Threat in Michigan

Source: U.S. Geological Survey



Regional map of maximum intensities that would result from a magnitude Ms=7.6, maximum intensity earthquake *anywhere* along the New Madrid Seismic Zone.

Subsidence

The lowering or collapse of a land surface, caused by natural or human-induced activities that erode or remove subsurface support.

Hazard Description

Subsidence is the lowering or collapse of a land surface, due to loss of subsurface support. It can be caused by a variety of natural or human-induced activities. Natural subsidence occurs when the ground collapses into underground cavities produced by the solution of limestone or other soluble materials by groundwater. Human-induced subsidence is caused principally by groundwater withdrawal, drainage of organic soils, and underground mining. In the United States, these activities have caused more than 17,000 square miles of surface subsidence, with groundwater withdrawal (10,000 square miles of subsidence) being the primary culprit. In addition, approximately 18% of the United States land surface is underlain by cavernous limestone, gypsum, salt, or marble, making the surface of these areas susceptible to collapse into sinkholes.

Generally, subsidence poses a greater risk to property than to life. Nationally, the average annual damage from all types of subsidence is conservatively estimated to be at least $125 million. The National Research Council estimate of annual damage from various types of subsidence is outlined in the table below:

Land Subsidence: Estimated Annual National Damage

Type of Subsidence	Annual Damage ($)
Drainage of organic soils	40,000,000
Underground fluid withdrawal	35,000,000
Underground mining	30,000,000
Natural compaction	10,000,000
Sinkholes	10,000,000
Hydrocompaction (collapsible soils)	N/A
TOTAL:	**$125,000,000**

Source: National Research Council; Multi-Hazard Identification and Risk Assessment, Federal Emergency Management Agency

Mine Subsidence

In Michigan, the primary cause of subsidence is underground mining. Although mine subsidence is not as significant a hazard in Michigan as in other parts of the country, many areas in Michigan are potentially vulnerable to mine subsidence hazards. Mine subsidence is a geologic hazard that can strike with little or no warning and can result in very costly damage. Mine subsidence occurs when the ground surface collapses into underground mined areas. In addition, the collapse of improperly stabilized mine openings is also a form of subsidence. About the only good thing about mine subsidence is that it generally affects very few people, unlike other natural hazards that may impact a large number of people. Mine subsidence can cause damage to buildings, disrupt underground utilities, and be a potential threat to human life. In extreme cases, mine subsidence can literally swallow whole buildings or sections of ground into sinkholes, endangering anyone that may be present at that site. Mine subsidence may take years to manifest. Examples of collapses occurring decades after mines were abandoned have been documented in several areas of the country.

Michigan's Mining Experience

Michigan's rich mining heritage has played a significant role in the State's development into a world economic power. Due to its diverse geology, Michigan has a wide variety of mineral resources, most notable of which are copper ore, iron ore, coal, sand, gravel, gypsum, salt, oil and gas. It is not surprising then that underground mining has occurred on a significant scale throughout Michigan's history. The principal types of underground mining that occurs, or has occurred in Michigan, include coal mining, metallic mineral mining, salt mining, gypsum mining, and solution mining.

Copper Mining

Copper mining, in particular, put Michigan on the map as a major mining area. Although native copper ore occurs in other parts of the world, at one time the quantity of Michigan's native ore was unsurpassed. From the mid to late 1800s, Michigan's Keweenaw Peninsula mines produced more native copper ore than any other mining area in North America. As those resources became depleted, copper mining began near White Pine in Ontonagon County. The target strata in the White Pine mining operations were on an anticline that was mined both at depths as shallow as 100 feet and as deep as 2900 feet. Over-mining of pillars in shallow parts of the mine caused collapse and subsidence at the surface, on mine property, during the 1980s. The "Copper County" area generally crosses Ontonagon, Houghton, and Keweenaw Counties.

Iron Ore Mining

Michigan's Lake Superior region has been home to significant iron ore mining operations since the mid-1800s. The iron producing areas are referred to as ranges, since the iron deposits generally occur on the slopes or at the base of remnants of ancient mountain ranges. Michigan has three ranges: 1) Gogebic Range, which extends from Gogebic County into Wisconsin; 2) Marquette Range, in Marquette County; and 3) Menominee Range, in Dickinson and Iron Counties. Most near-surface iron deposits in these three ranges have been exhausted, so underground mining has become the primary extraction technique. Nearly two billion tons of iron ore have been extracted from these areas. Unfortunately, economics have forced the closure of many of the underground iron mining operations, although one company still mines in the region. The "Iron Range" area generally includes the five counties of Baraga, Dickinson, Gogebic, Iron, and Marquette.

Salt/Solution Mining

Michigan also has one of the world's largest underground salt accumulations. The thickest salt beds lie under most of the Lower Peninsula. These formations are, in some places, over 3,000 feet thick and composed of layers of salt and other minerals. Michigan ranked first or second in national salt production from 1880 to the late 1920s. The bulk of the salt production was from natural brines pumped from six salt formations. Salt was also produced from artificial brines that were derived by injecting freshwater into salt formations and retrieving the resulting brines (called solution mining). The old Detroit salt mine produced rock salt using the "room and pillar" method until 1983. (The room and pillar method involves creating large underground expanses [rooms] in which to mine, supported by pillars [natural or artificial structural members] that held in place the roofs of these rooms.) The Detroit salt mine was approximately 1,100 feet below ground, and encompassed approximately 1,100 acres of subsurface land. The room and pillar method is being used only in the single salt mine that is still operating in Michigan, by the Detroit Salt Company, which has an excellent safety record. Salt is also being produced from brines extracted at various locations within the state.

Gypsum Mining

Gypsum has been mined in Michigan since 1841. In the Grand Rapids area, gypsum is mined by the "room and pillar" method. Open pit mining is used in the Alabaster region (Iosco County). In both of these areas, gypsum beds directly underlie thin layers of glacial drift. Closed topographic lows observed in both areas are believed to be due to groundwater solution of the gypsum and subsequent collapse of the overlying material.

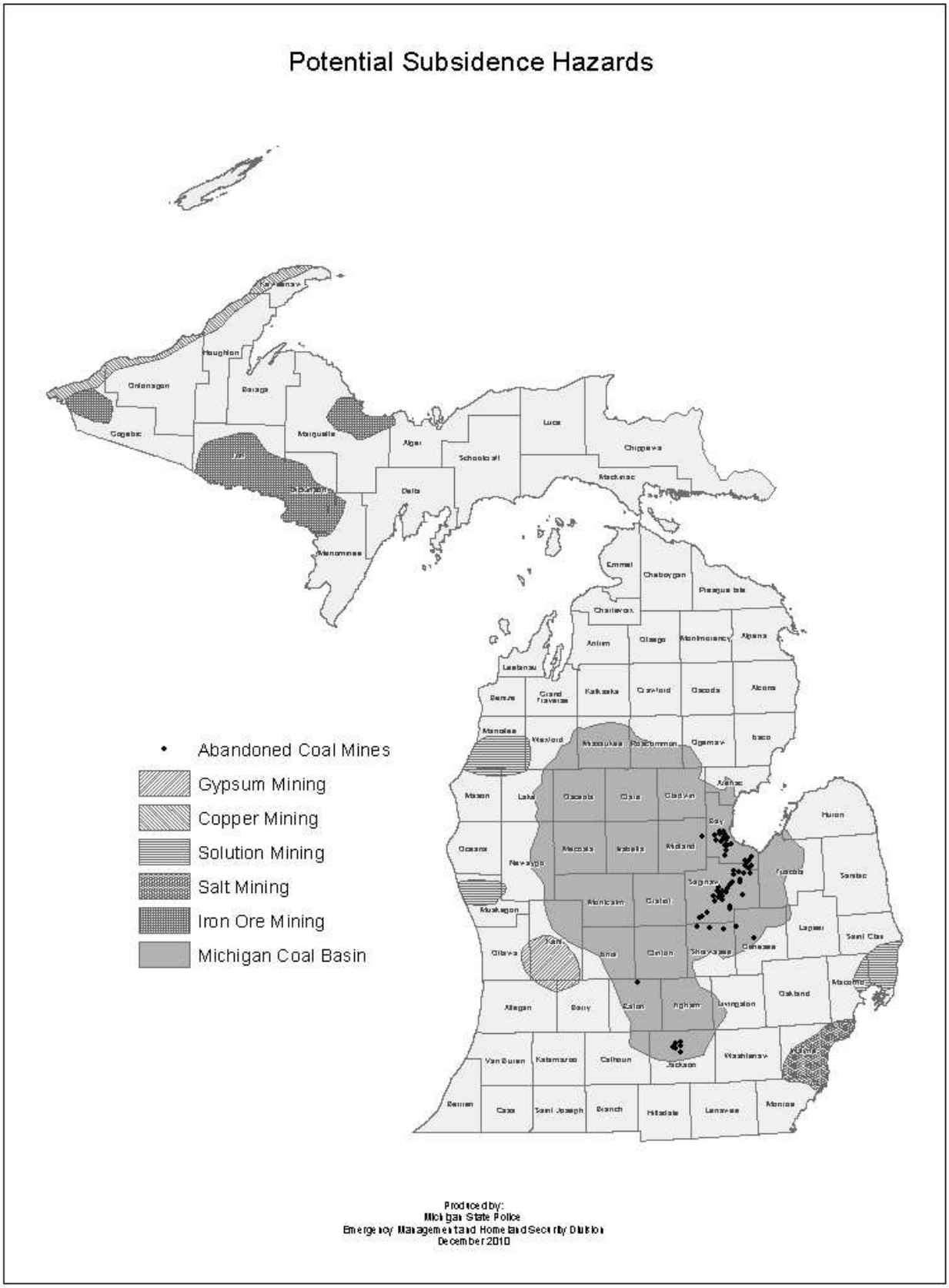
Coal Mining

Michigan also once supported a thriving coal mining industry. Records indicate that over 165 different coal mines operated in Michigan's coal-bearing region, which includes 31 counties in the south-central portion of the Lower Peninsula. Over 100 of the 165 known coal mines in the state were located in the Saginaw Bay area. (See the map on the following page for an outline of Michigan's Coal Basin.) Coal was first discovered in Michigan in 1835 in Jackson County. From that discovery, several small underground and surface coal mines were opened in that area of the state. In 1861, coal was discovered near Bay City, and in 1897 commercial coal mining began in Bay County. That led to the establishment of numerous additional mines in Saginaw, Tuscola and Genesee counties, which tended to be larger, deeper and more extensive mines. That was the start of Michigan's coal mining industry.

The state's underground coal mines were an average of 110 feet deep, and were worked by the "room and pillar" method. Michigan had continuous coal mining from 1897 to 1952, when the last underground coal mine near St. Charles, Saginaw County, closed. From 1860 (the year mine records were first kept) until 1975 (the year the last surface coal mine closed), the 165 commercial coal mines produced a total output of over 46 million tons of coal. The maximum coal output was achieved in 1907, when Michigan's 37 operating coal mines produced two million tons per year - enough to supply 16% of Michigan's then total demand for coal.

Mine-Related Subsidence Threats in Michigan

Source: Michigan Department of Environmental Quality, Office of Geological Survey



Mine Subsidence Problem in Michigan

The legacy of underground mining can be felt in numerous locations across the state. Many of the underground mining areas, whether active or abandoned, are vulnerable to subsidence in some form. The map on the previous page indicates the areas in the state that are potentially vulnerable to mine subsidence. Unfortunately, records of abandoned mines are often sketchy and sometimes non-existent. Therefore, it is often difficult to determine exactly where the mines were located. Many areas of Michigan may have developed over abandoned mines and may not even be aware of it. Oftentimes, the only way a community or home / business owner becomes aware of a potential hazard is when subsidence actually occurs and damage or destruction results.

Water-Related Subsidence

Compaction of soils in some aquifer systems can accompany excessive ground-water pumping and cause subsidence. Excessive pumping of such aquifer systems has resulted in permanent subsidence and related ground failures. In some systems, when large amounts of water are pumped, the subsoil compacts, thus reducing in size and number the open pore spaces in the soil that previously held water. This can result in a permanent reduction in the total storage capacity of the aquifer system. More than 80% of the identified subsidence in the United States is a consequence of human impact on subsurface water. Three distinct processes account for most of the water-related subsidence: compaction of aquifer systems, drainage and subsequent oxidation of organic soils, and dissolution and collapse of susceptible rocks.

Mining Ground Water

Groundwater in the pore spaces of an aquifer supports some of the weight of the overlying materials. When groundwater is depressurized or even removed from aquifers, where the materials are very compressible and pore pressures can be high, compaction may occur. This subsidence may be partially recoverable if pressures rebound, but much of it is not. Thus the aquifer is permanently reduced in capacity, and the surface of the ground may also subside. The picture on the next page shows the unconsolidated aquifer systems in Michigan

Drainage of Organic Soils

Land subsidence may occur when soils rich in organic carbon are drained for agriculture or other purposes. The most important cause of this subsidence is microbial decomposition, which, under drained conditions, readily converts organic carbon to carbon-dioxide gas and water. Compaction, desiccation, erosion by wind and water, and prescribed or accidental burning can also be significant factors. The picture on the next page shows the location of the organic soils in Michigan.

Collapsing Cavities

This type of subsidence is commonly triggered by ground-water-level declines caused by pumping and by enhanced percolation of ground water. Collapse features tend to be associated with specific rock types, such as evaporites (salt, gypsum, and anhydrite) and carbonates (limestone and dolomite). These rocks are susceptible to dissolution in water and the formation of cavities. Salt and gypsum are much more soluble than limestone, the rock type most often associated with catastrophic sinkhole formation. Evaporite rocks underlie about 35 to 40% of the United States, though in many areas they are buried at great depths. Collapse sinkholes may develop over a period of hours and cause extensive damage. The picture on the next page shows the location of the evaporite and carbonate rocks in Michigan.

Water-Related Subsidence Problems in Michigan

In the past there has been pressure for the Great Lakes states to export bulk quantities of water to various locations in the United States. If these plans to withdraw large amounts of water from the Great Lakes ever took place, it may have a major effect on the level of the ground water tables in Michigan, which may possibly make subsidence a more common occurrence. Currently, broken water pipes and the improper discharge of rainwater are the most common causes of water-related subsidence in Michigan. It most commonly occurs on sandy or silty ground when the water from the leak washes out the fine particles beneath the foundation, causing voids that result in collapse or subsidence.

Water-Related Subsidence Threats in Michigan

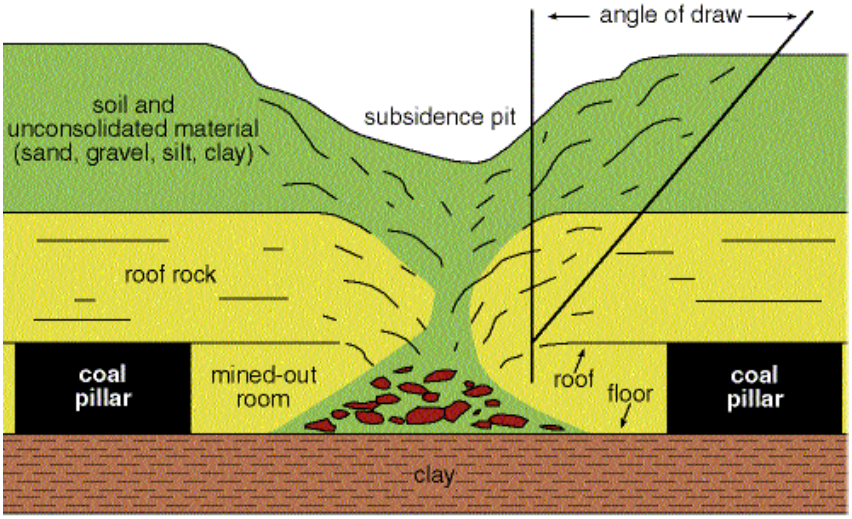
Unconsolidated Aquifer Systems	Organic Soils	Evaporite and Carbonate Rocks

Source: U.S. Geological Survey, *Ground Water and the Rural Homeowner, Pamphlet, 1982*

Overall, subsidence is not a very well-known hazard in most parts of Michigan, although it occurs with some regularity in parts of the state that have experienced past underground mining activity. The impacts of subsidence in Michigan tend to be limited in scope to individual sites and structures. Unlike some other areas in the country, such as Illinois, Ohio, Kentucky, West Virginia, Florida, Louisiana, and Pennsylvania, where subsidence is a serious concern, Michigan does not devote a great deal of state resources to the problem. Subsidence simply does not have the widespread impact potential of other natural and technological hazards that are prevalent in the state.

Underground mining has, in some respects, proved to be a double-edged sword for Michigan. On the one hand, it has fueled tremendous economic growth in many parts of the state, providing hundreds of thousands of jobs through direct mining or related industrial production activities. Mining helped put Michigan on the map as a world economic power, and even today it continues to be a major economic activity in some areas of the state. On the other hand, underground mining has also left a legacy of subsidence or threat of subsidence in some parts of Michigan. Old abandoned mines eventually begin to collapse under their own weight or human neglect, and oftentimes they swallow up whatever is built upon them. The following pictures show typical mine subsidence cross sections.

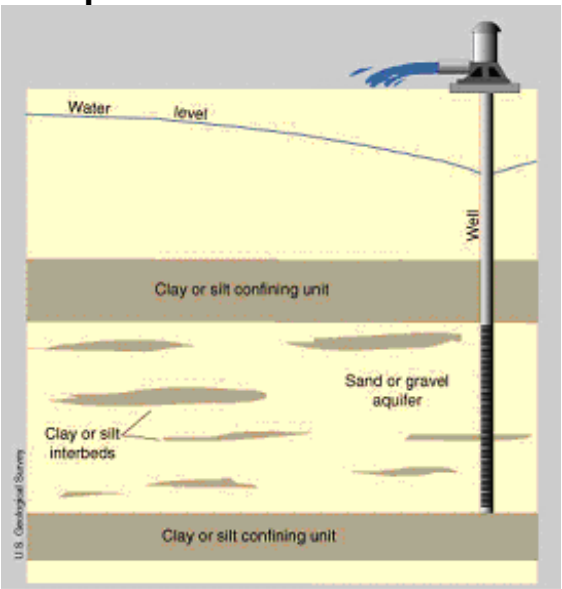
Typical Mine Subsidence Cross Section



Diagrammatic cross section of typical subsidence resulting from mine-roof collapse. No scale implied.

Source: State of Ohio, Department of Natural Resources web page

Typical Aquifer Subsidence Cross Section



Source: U.S. Geological Survey

In some areas where ground-water pumping has caused subsidence, the subsidence has been stopped by switching from ground-water to surface-water supplies. If surface water is not available, then other means must be taken to reduce subsidence. Possible measures include reducing water use and determining locations for pumping and artificial recharge that will minimize subsidence. Optimization models, coupled with ground-water flow models, can be used to develop such strategies. The picture above shows a typical aquifer-related subsidence cross section.

Because subsidence tends to be a more sporadic hazard, and because it poses a greater hazard to property than to life, it does not receive much attention from government agencies or the public. Other natural hazards, such as tornadoes, floods and severe storms receive much more attention because of their more widespread and severe impacts. However, subsidence will continue to be a hazard that a segment of the Michigan population will have to deal with in the future. Major incidents that lead to catastrophic damage are nearly unknown in Michigan, but smaller incidents occur with some regularity in old mining areas. Overall, about four moderate incidents per decade have been noted.

Probably the most effective way to mitigate subsidence hazards is through community education and awareness. Local officials in subsidence-prone areas need to be aware of their community's potential vulnerability to subsidence, and that awareness needs to be communicated to the public. Communities that have experienced mineral and water mining activity in the past, or that have ongoing mining operations, should conduct a thorough investigation of potential subsidence sites as part of their community's hazard analysis process. More often than not, local records of mining activity are the best (and sometimes only) source of information on the nature and potential extent of the problem. Local officials can use that information to make informed community development decisions so as to avoid, to the extent possible, areas potentially vulnerable to subsidence.

Ideally, information about the locations and subsurface conditions of all mines in an area would be found, and testing or inspection could then determine their stability and safety. However, the information that does exist has no guarantee of being comprehensive, and since many mines exist on private property, the owners of that property often have an interest in not allowing any mine details to be publicized (lest the information cause trespassers to be attracted to their property). MSP/EMHSD learned about valuable information that had been collected on this topic through an academic research process, but the information was not available to the general public. The information had been provided to the relevant counties as a part of their local hazard analysis process, and it was reported that the same type of information was also known to local Mine Inspectors. The best resource to consult for each local area is probably the relevant Mine Inspector for that area. Please refer to the list available at http://www.mg.mtu.edu/mine_inspectors.htm.

Impact on the Public

Although some incidents may cause private property damage and casualties, others may affect roadways or other public infrastructure, and thus cause a more general impact on the population of an area. (Please refer to the infrastructure failures subsection.)

Impact on Public Confidence in State Governance

The public may be prone to overestimate the amount of knowledge possessed by State government regarding areas and specific locations in which historic mines have existed. Subsidence events that involve damage to infrastructure or roadways may be attributed to poor maintenance or funding, rather than to the actual cause of subsidence that was responsible. Uncertainty about the extent of risk from subsidence may cause collective dissatisfaction with the area in which the hazard is present (or perceived to be present), and (at an extreme) may lower property values and cause or exacerbate emigration from the area.

Impact on Responders

Special hazards may be present in old mines or ground subsidence areas, which may present a risk of further collapses during emergency response. Areas that involve deep spaces, into which personnel and equipment may fall, necessarily entail a more complicated and dangerous situation for responders. Old mining tunnels may also contain toxic gases (as referred to in the oil and gas well subsections of this document).

Impact on the Environment

Environmental impacts stemming from subsidence are somewhat similar to those caused by an earthquake. Changes in an area's landscape, wildlife habitat and the natural ecosystem can all result from a sudden depression in the Earth's surface. In a severe event, infrastructure may be damaged and could release toxins into the air, soil, or waterways.

Significant Subsidence Incidents

Fortunately, Michigan has not had a catastrophic subsidence incident that involved death, injury or widespread property damage. However, smaller subsidence incidents have occurred that involved a single site or structure. The following incidents led to the implementation of reclamation projects designed to mitigate subsidence impacts. (Pertinent out-of-state incidents are also discussed.)

Various dates - U.S. Coastal States

In Florida, Louisiana, and some other coastal states, subsidence occurs with regularity, but for different reasons than it occurs in Michigan and other mining states. In Florida, subsidence is caused primarily by reductions in the water table caused by land development and groundwater withdrawal. Florida's cavernous limestone geology also plays a major role in its subsidence problem. A good example of that problem occurred on May 8-9, 1981 in Winter Park, Florida, when land collapsed, over a 36-hour period, into a sinkhole 324 feet wide and 100 feet deep. The collapse was caused in part by a prevailing drought. Damage was estimated at over $2 million and included a house, several cars, portions of several businesses, streets, and a municipal swimming pool. In Louisiana, subsidence is usually the result of a combination of oil and gas extraction, salt-water intrusion, and soil consolidation. Other coastal states face similar subsidence problems.

October 1984 - Jackson County

In October 1984, the abandoned Andrews Street Coal Mine in Jackson County partially collapsed, causing a detached garage, driveway and vehicle at a residence to collapse into a shallow sinkhole. A $12,000 emergency reclamation project was instituted in that subsidence incident.

October 1985 - Huron County

In October 1985, a subsidence incident occurred in Huron County that resulted in a sinkhole that swallowed up a portion of roadway. A $15,000 emergency reclamation project was instituted to mitigate the cause of the collapse.

May 1987 - Saginaw County

In May 1987, a subsidence incident in Saginaw County caused an attached garage and breezeway on a house to drop down several inches, damaging both structures. A $35,000 emergency reclamation project helped to mitigate the threat of future subsidence at that site.

March 1995 - Guernsey County, Ohio

In some other states around the country, subsidence has been a much more significant problem. For example, coal mining states such as Illinois, Kentucky, West Virginia, and Pennsylvania have large areas that are vulnerable to mine subsidence. In our neighboring state of Ohio, mine subsidence led to the collapse of a portion of Interstate 70 in Guernsey County in March 1995. That subsidence incident and the ensuing repair work closed the eastbound and westbound lanes of I-70 (a major national east-west highway) for several months, and final repair costs were $3.8 million. Fortunately, no deaths or injuries occurred as a result of the roadway collapse.

June 1999 - Philadelphia, Pennsylvania

Another dimension of the subsidence problem came to light in early June 1999 in Philadelphia, Pennsylvania, when several rowhouses were evacuated and torn down because they were sinking into the ground and in danger of collapsing. The homes had been built in the 1920s on old creek beds filled with a 21-foot layer of ash and cinders. Over time, the ground under the homes had slowly subsided, but then accelerated to the point where structural collapse was a real possibility. Officials suspect that sewer work done in the area in 1996 may have exacerbated and accelerated the problem. State assistance was provided to the evacuated homeowners to help offset the loss of their homes. (Homeowners insurance policies generally do not cover subsidence-related problems.) In 1987, the City had paid another $20 million to reimburse losses to 1,000 homeowners whose homes were also found to be sinking into the ground.

Although this problem occurred in Pennsylvania, it has implications for Michigan and other states. Building homes and businesses over streambeds and floodplains was a standard practice across the country during the early part of the 20th century. Home construction was lightly regulated during that period, and the regulations that were enforced were generally targeted more toward fire safety or other health and sanitation concerns. Hundreds of thousands of homes and

businesses across the country may have been built in these unstable areas. Local building records are often incomplete or non-existent, so the situation may not become evident until a home or business begins to sink into the ground.

June 1999 - Milan (Monroe County)

On June 29, 1999 northbound traffic on U.S.-23 at Milan was diverted for approximately 10 hours after the pavement sank eight inches over a 30-foot stretch of highway. The subsidence and traffic diversion caused traffic to back up for several miles throughout the day. Although a definitive cause of the subsidence was not established, officials believe a leaking storm sewer may have contributed to the problem.

July 1999 - Iron Mountain (Dickinson County)

On July 27, 1999 an abandoned mineshaft in Iron Mountain (Dickinson County) caved in, exposing a 50-foot diameter by 1,600-foot deep shaft. The cave-in occurred directly adjacent to the Cornish Pumping Engine and Mining Museum, a popular tourist attraction in the downtown area. The structure was in danger of collapsing into the opening until temporary stabilization measures were taken. Officials were also concerned that further subsidence could have damaged nearby infrastructure, including a roadway. Because the cave-in posed a significant threat to public safety, a Governor's Emergency Declaration was granted to provide state assistance in securing the site and permanently capping the opening.

February 2000 – Detroit (Wayne County)

On February 9, 2000 a 15-foot sinkhole opened up on Seneca near Mack, on Detroit's east side. The sinkhole swallowed up a half-ton pickup truck. Fortunately, the truck's two occupants escaped serious injury. Officials believe a leaking underground pipe may have caused the subsidence.

April 2001 – Gaastra (Iron County)

On April 19, 2001 the City of Gaastra in Iron County sustained a cave-in of 3,360 cubic yards of soil at the abandoned Baltic Mine Pit in the city, leaving four feet of ground between the mine pit and the City's main (and only) sewer line to the wastewater treatment plant. (When the sewer line was installed in 1984, there were 100 feet of ground between the line and the edge of the pit. From 1984 to 2001, the annual recession rate at the site was nearly six feet per year.) The April 2001 cave-in was the second major subsidence incident at that site in recent months, following on the heels of a similar cave-in that occurred in August 2000. Local and state officials feared that another subsidence incident at the site could cause the sewer line to break, resulting in significant public health, safety and environmental concerns due to lack of sewer service, contamination of nearby water wells, and contamination of the Iron River. In addition, a major subsidence incident could also have caused a partial collapse of County Road 424 (which runs parallel to the sewer line), negatively impacting the area's residents and tourist-oriented businesses.

To mitigate further damage to the threatened sewer line, the City of Gaastra applied for a Hazard Mitigation Grant Program (HMGP) grant to relocate the line outside the subsidence area. Work on that project was successfully completed, including appropriate steps to stabilize the roadway shoulder and prevent further ground collapse.

March 2004 - Detroit (Wayne County)

On March 25, 2004 a sinkhole about 20 feet wide and 14 feet deep opened in the westbound lanes of Six Mile Road. It was determined that water main work done in the area in the previous six months had not been completed properly. Leaking water apparently washed away the soil underneath and created the sinkhole.

August 2004 - Sterling Heights (Macomb County)

On August 22, 2004 a sewer line break caused a section of 15 Mile Road in Sterling Heights to collapse, prompting residents in six homes to evacuate and the street to close for several weeks. After the break, two sinkholes formed and eventually merged, forming one hole 150 long and 45 feet wide There were about 15 homes in the area that lost water service for several hours and around 1,000 Detroit Edison customers lost power because utility poles were being removed for excavations to reach the sewer. About 7 million gallons of raw sewage was diverted daily from the collapsed sewer into the Mount Clemens sewage treatment plant to prevent wastewater from entering basements or polluting county drains and streams. Eight families living on the edge of the sinkhole tried to claim $1 million each for damages to their homes and for health reasons. No outcome had been reached at the time of this writing.

May 20, 2010 – Detroit (Wayne County)

A sinkhole large enough to swallow a car appeared on May 20, 2010 in downtown Detroit and closed West Lafayette Street between Shelby and Griswald. The street began to crumble away after crews working to demolish the historic Lafayette Building punctured a water line.

October 4, 2010 – Stephenson (Menominee County)

A 600-foot long crevice suddenly opened up—in some places only a foot wide and a few inches deep, but in other places more than 2 feet wide and 5 feet deep. Fortunately, this took place in an undeveloped area on private property, where no injuries were caused and no damage to built property or physical infrastructure was reported. Vibrations were felt by nearly residents, who were uncertain whether they were feeling the effects of explosive blasting or some other force. Although this event resulted in no harm, the executive director of the Delta Conservation District (in Gladstone) was quoted in newspaper reports as stating that this type of phenomenon is not unusual in the Upper Peninsula. He stated that the cause of the fissure sounded like it was the result of rock fracturing below the surface—that areas containing fractured rock formations can result in fissures and sinkholes as the result of pressures generated by the annual freeze-thaw process (and that the same process could also form hills)

January 21, 2011 – Detroit (Wayne County)

A Detroit man was injured when the front end of his SUV went into a 10-foot-wide sinkhole caused by a water main break on Detroit's west side. The 52-year-old victim was taken to a local hospital, where he was treated for minor injuries. The sinkhole was on Pickford Street between Heyden and Vaughan.

March 23, 2011 – Ann Arbor (Washtenaw County)

A crack in a concrete retention system caused a 40 foot sinkhole to occur on March 23, 2011 in Ann Arbor, outside an underground parking structure construction site. The combination of the retention wall, the thawing of the ground and sandy soils could have caused an underground cavity behind the concrete retention system to bubble up vertically to open the hole. Two businesses were closed for the day after the ground opened in a shared parking lot used by both businesses.

Programs and Initiatives

Michigan Department of Environmental Quality, Office of Geological Survey

The Michigan Department of Environmental Quality, Office of Geological Survey (MDEQ/OGS), regulates metallic mining in Michigan. The OGS regulatory authority is granted under Parts 631, 635 and 637 of the Michigan Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. The Office's activities include issuing permits for metallic mining operations, maintaining maps and records on mining areas, and regulating mine reclamation. In terms of mine subsidence, the OGS works with local officials and the Office of Surface Mining Reclamation and Enforcement (OSMRE), U.S. Department of the Interior, to mitigate coal mine subsidence problems through special projects aimed at properly sealing mine shafts and otherwise ensuring the structural integrity of underground coal mined areas.

Surface Mining Control and Reclamation Act

There is very limited state funding for mine subsidence mitigation. Therefore, most of the funding for such projects comes from the federal government. The primary federal funding source is the Abandoned Mine Lands (AML) Reclamation Fund in the Surface Mining Control and Reclamation Act (SMCRA), P.L. 95-87, administered by the U.S. Department of Interior's OSMRE. AML funds are derived through a tax on coal production targeted at reclaiming land and water resources adversely affected by pre-1977 coal mining. These funds can also be used for mine subsidence mitigation measures and salt sealing, which Michigan has done on numerous occasions. Normally, priority is given to those emergency projects that involve mine lands that present an immediate danger to the public health, safety or general welfare. Typically, such emergencies include landslides near homes and across roads, subsidence occurring under houses and public buildings, mine and coal waste fires, and open mineshafts discovered near populated areas.

Subsidence Insurance

Unlike states such as Illinois, Ohio, Pennsylvania, Kentucky and West Virginia, which have state insurance programs for homes and businesses in subsidence-prone areas, Michigan does not have such a program. As a result, home and business owners and communities that are affected by subsidence must rely on whatever private insurance payments they can collect for subsidence-related damages, or they must pay for damages out-of-pocket. (Subsidence-related damage is generally not covered under a standard homeowner's insurance policy.)

National Association of Abandoned Mine Land Programs

Michigan is a member of the National Association of Abandoned Mine Land Programs, a national advocacy group that provides a forum and clearinghouse for addressing issues and problems pertaining to mine subsidence and reclamation. Michigan's participation is beneficial in that it gains tremendous knowledge of the experiences of other states in reclaiming mine sites and mitigating subsidence. In addition, Michigan also gains knowledge about current reclamation and mitigation technologies that could be applied to problem areas in the state.

CELESTIAL IMPACT

An impact or threatened impact from a meteorite, asteroid, comet, satellite, space vehicle, space debris, solar storms, or similar phenomena that may cause physical damages or other disruptions.

Hazard Description

The celestial impact hazard primarily concerns the effects of large forces (from objects or energy) upon the Earth or its atmosphere. Most such forces are extraterrestrial in origin—**meteors** (which burn up in the atmosphere) or **meteorites** (which impact physically upon the ground) that were originally **asteroids** or **comets** from elsewhere in the solar system. It must be noted that even in cases where no meteorite actually strikes the ground, the explosive energies from the meteor's impact upon the many layers of atmosphere can create an intense heat and blast area, along with very strong winds, and can release more energy than even the largest nuclear bombs. Massive or fast moving bodies that impact upon either the ground, the oceans, or the atmosphere can cause widespread destruction and disruption of both human and natural systems, including secondary hazards such as earthquakes, volcanoes, tsunamis, and severe winds, although events of that magnitude are extremely rare.

Much more common is the flare-up of energy and charged particles that are emitted and ejected by the Sun and impact upon the Earth's atmosphere. These **solar geomagnetic storms** (also known as **space weather**) can cause widespread failures of important satellite, electronic, communication, navigation, guidance and electric power systems—which have all formed a very important part of our modern technology and lifestyles. Because of the amount and complexity of information concerning the potential impacts from space objects, a great deal of this section has been devoted to an explanation and analysis of that hazard. However, it is important to note at the outset that the solar storm hazard is far more likely in the near term to cause disruptive effects, large economic impacts, and risks to human life. The smaller amount of text dedicated to space weather in this document should not mislead readers into a sense that it is considered less important, or that it is expected to cause less impact in the near future. Rather, the conclusion of the analysis presented here is that the effects of space weather have already had, and are much more likely to have, strong impacts upon Michigan within the normal historical timeframe that is typical for this type of plan. By contrast, the extensive discussion of impacting physical objects is given primarily to be "on the safe side" so that readers and emergency managers can be well-informed in the unlikely event that a very serious incident does occur, or threaten to occur.

Although it has been estimated that a major impact from a physical body upon the Earth occurs approximately once per century, recent discoveries (and the fact that much more of the Earth has been covered by human developments within the recent past) have caused increasing concern over this hazard. Although most meteorites would be expected to strike an ocean rather than a continent, the effects of a large enough ocean strike can still be widely damaging, through resulting tsunami and seismic activities.

An important type of celestial impact involves the interference or disruption of modern electronic and communications systems, including those upon which our modern aviation networks rely. Solar flares and storms (also known as "space weather") are highly relevant for their potential impacts and possible disruption of these complex modern communication systems—satellites, television, radio, GPS, power supply networks, and the extensive human and technological infrastructure that relies upon those communication and utility networks.

Extensive evidence of previous celestial impacts upon Earth has been discovered, including evidence of a historic crater site located in southwest Michigan, but the vast majority of historical Earth impacts have had their evidence erased from normal observation by the ongoing geological processes that take place over time. Even the largest of impact sites would no longer be evident to normal observation after a period of about 200 million years (usually much, much less). Such an amount of time is less than 5% of the Earth's overall age, but it has been found that impacts used to occur much more frequently during the earlier periods in Earth's history (i.e. nearer to the period of planetary formation) than they do in recent geological periods. Clearer evidence of the many historical impacts can be seen on other celestial bodies that are less geologically active, such as Earth's own Moon.

Asteroids

Most asteroids are located in the main asteroid belt and have well-defined orbits there between 200 and 310 million miles from the Sun, but thousands of asteroids also exist in other parts of the solar system. There are groups of "Trojan" asteroids that share an orbit with Jupiter, for example, located 60 degrees both ahead of and behind that planet itself while going around the Sun. Asteroids that have paths which cross over Earth's orbit are classified as

Near-Earth Objects (NEOs), and are called Apollo asteroids. Two other types of NEOs are Amor asteroids, which approach the Earth's orbit from positions outside of it, and Aten asteroids, which approach the Earth's orbit from the direction of the Sun. As of January 2009, there were 6,021 NEOs identified, of which 1,026 were classified as posing the possibility of threat (having the potential to come within 466,000 miles of the Earth's orbit). The typical asteroid would impact upon the Earth at an angle of 45 degrees and a speed of 10 miles per second.

Comets

More than 99% of all meteorites come from asteroids, but some comet impacts have also been confirmed (9 are known, constituting less than 0.03% of all meteorites). The main difference between comets and asteroids is that comets tend to have elliptical orbits that carry them out beyond the "nebular frost line" (located in the main asteroid belt, about 250 million miles from the Sun) and thus their composition includes a substantial amount of icy and frozen matter. Comets usually lose about 0.1% of this matter each time they pass by the sun, due to the effects of warming and the pressure of solar radiation, and this matter trails behind them in their long "tails," which include charged particles (with associated magnetic fields) and can stretch across many tens of millions of miles of space. Where such tails cross the Earth's orbit, this matter (typically small and harmless to us) generates sometimes spectacular "meteor showers" as it periodically burns up in the Earth's atmosphere at regular times during the year. After a certain number of orbits, however, the comet simply breaks apart. Even if less dense than the average asteroid, a comet's heavy nucleus can be sizeable (from several hundred meters to over 40km in diameter), and a comet impact upon the Earth would typically occur at a speed of 31 miles per second—about three times as fast as the average asteroid, with a proportionally larger momentum of destructive energy if the amount of mass is the same. (It is worth noting here that the maximum impact upon the Earth for any object orbiting the Sun would be no more than 44.5 miles per second—160,000 miles per hour.)

Comets are classifiable by their orbital period, with long period comets taking more than 200 years to travel around the Sun, and short period comets taking less than that. The short period comets are further subdivided into Halley-type comets with orbital periods between 30 and 200 years, and Jupiter-type comets with orbital periods of less than 30 years. Long period comets originate in the farthest reaches of the Solar System (the Oort Cloud) and approach the Sun and Earth from every direction, while short period comets originate from the "Kuiper Belt" that exists beyond Neptune and is approximately in the same plane as all of the major planets. Short period comets thus would approach us from more predictable, shallow angles. The comet only begins to glow, though, when it approaches to within 3 and 5 Earth-distances from the Sun (3 to 5 astronomical units). Since short-period comets tend to last for only a matter of hundreds or perhaps thousands of orbits, their number seems to be replenished by a reservoir in our solar system (whose orbits eventually become shifted by gravitational perturbations). The Oort Cloud probably contains about a trillion comets, but most of these remain so far away that we remain unaware of them. The Kuiper Belt contains billions of comets, and the average diameter of one that comes near to the Sun is about 10 km.

If advance notice of an approaching meteor, asteroid, or comet is available, then widespread alerts might be prompted by this information, much as the explosive breakup of the Space Shuttle Columbia in 2003 had required warnings and alerts across multiple southwestern states, due to the possibility of persons and property being affected by falling debris. (See the event descriptions that appear later in this chapter.) In the case of the Cosmos 954 and Space Shuttle incidents, such debris needed special handling, both for purposes of investigation and out of concern for personal safety, since some of it could have contained hazardous substances. The threat of a celestial impact could be much more dangerous and far-reaching. One clear example of the potential damage was seen in the impact of the comet Shoemaker-Levy 9 on the planet Jupiter, in 1994, which resulted in blasts that were estimated as the equivalent of ten million megatons of explosives. In comparison, the 1979 Mount St. Helens eruption was roughly 5 megatons, and the 1885 Krakatoa eruption in Indonesia was about 100 megatons. Following the Shoemaker-Levy comet impact, Congress authorized new research to analyze this type of celestial impact hazard.

Space Weather

The Sun does not "burn" in the sense that we usually experience that common heat-generating process on Earth, but rather emits huge amounts of energy from the continuous processes of nuclear fusion that take place in the Sun's core. The gravitational pressures of the Sun's enormous mass, pulling toward itself, are thus generally offset by outward pressures from the fusion processes that take place at its core. Enormous amounts of energy are radiated from the Sun, including the spectrum of electromagnetic waves up through gamma wave frequencies. These include infrared (heat) radiation, ultraviolet, all colors of visible light, x-rays, microwaves, and radio waves. The intensity of these forms of radiation varies, and gamma waves are normally only emitted during solar flare events (to be explained shortly). It

should also be understood that in the midst of all these solar interactions of matter and energy are powerful magnetic forces, which also affect the distribution of heat energy in and around the Sun and sometimes cause cooler areas, called **sunspots**, to form for a while, readily visible even with crude forms of observational equipment. (Although an observer should never look directly at the Sun, a pinprick of solar light projected onto a surface provides one basic means of seeing a Solar image). The relatively low temperatures of sunspot areas, however, are coupled with a rise in energy above the Sun's surface. **Solar prominences** are arches of plasma that soar above the Sun's surface, in a pattern that is itself shaped by the powerful magnetic fields present. In some cases, these magnetic fields have become too twisted to maintain such forces within these ordinary patterns, and a **solar flare** is generated, which releases a huge amount of energy from the Sun. Normally, a **solar wind** exists in the form of milder pressures exerted by emitted photons, ions, and other particles that flow outward from the Sun until they are eventually halted (beyond the orbit of Neptune, at an area called the heliopause) by the pressure of interstellar gases. Within the realm of the Sun's planets, however, the solar wind is an ongoing feature of the space environment, constantly sending energy and charged particles outward.

Space weather is a term that denotes the impacts of the Sun's activity upon the bodies within this sphere inside the heliopause, including our own Earth. As with the weather on Earth, there are some clear patterns that are exhibited by space weather. More turbulent space weather is produced during times when more sunspots are present (called a solar maximum), and space weather is calm during times when sunspots are rare and small (or not even seen to be present at all, called a solar minimum). A **sunspot cycle** exists, in which sunspot activity regularly shifts between a minimum and maximum level. As with our Earthly seasons, however, it cannot be known in advance exactly how turbulent or calm things will be at a given moment during the sunspot cycle—only that calmer periods regularly give way to more turbulent periods. As to the regularity of the sunspot cycle itself, although it has been found that the average amount of time between a solar minimum and a solar maximum is about 11 years, the actual length varies quite a bit within each cycle. The interval is sometimes as long as 15 years and sometimes as short as 7 years. In addition, it has been observed that long periods can occur with little or no sunspot activity. The "Maunder minimum," which occurred between the years 1645 and 1715, is the primary example of such long-term variation from the normal cycle, but it is not yet known what caused it, or when it might recur. The Earth's atmosphere serves as a shield for us against many types of particles and radiation zipping across space, and Earth also has a **magnetosphere** that similarly provides protection against most of the charged particles traveling through space. There are some weak spots in the Earth's magnetic field, however, that exist near its two magnetic poles and allow many ions to penetrate, where they collide with atoms in the Earth's upper atmosphere and glow to produce the beautiful auroras in the skies of the arctic regions of the north and south. In addition, the Earth is surrounded by "belts" of charged particles (called Van Allen belts) which are hazardous to spacecraft and astronauts. These are known and predictable conditions of calm space weather, however, and the actual hazard is the turbulence that is generated by large solar flares, causing problems with radio communications, damage to satellites, and even disruptions in power delivery networks on the Earth. Currently, as of early 2012, sunspot cycle number 24 is proceeding, from a solar minimum that was reached in December 2008 and is projected to transition to a solar maximum by early 2013 (a relatively short cycle).

Another type of solar disturbance is a **coronal mass ejection** (CME), in which built-up pressures cause a sudden burst in gases and magnetic fields at tremendous speeds, with impacts that reach far across interplanetary space. Like solar flares, CME events are a cause of geomagnetic storm events on Earth (usually 1 to 4 days after the solar event), and they occur more frequently during periods with more sunspots. One of the additional effects of space weather involves increased exposure to ionizing radiation (e.g. x-rays), especially among those in aircraft at high altitudes and along polar flight paths. Extra costs, in fuel and delays, are imposed upon airlines during periods of harmful space weather.

Hazard Analysis

A couple of scales have been developed to numerically summarize the extent of risk associated with extraterrestrial celestial bodies, such as comets, asteroids, and meteoroids. One scale is called the Palermo scale, but since that is tricky to interpret, the Torino Scale has instead been featured in media reports since its initial presentation at a United Nations conference in 1995, and it was adopted by the International Astronomical Union in 1999. Both scales take into consideration the amount of destructive energy that an impact could cause, and the probability of such an impact occurring. It is common for newly discovered objects to have their initial classifications on these scales subsequently downgraded, as additional information is collected that more precisely defines the exact path of the object. In other words, an object that is initially classified as having the potential for impact, and thus being worthy of closer study, is often later reclassified as additional information reveals that little or no significant impact potential exists. The lower

numbers on the scale should not be interpreted as indicating any particular concern, and in the previous 15 years, only one object (99942 Apophis) had temporarily been classified as high as a 4 on the Torino scale. Being an asteroid large enough to cause regional devastation if it struck, Apophis had initially been estimated to have a 1 in 45,000 chance of striking the Earth on April 13, 2036, but as more information was obtained about its trajectory, that estimate was downgraded to only a 4 in 1 million probability. Although the asteroid's approach will be spectacular to observe, it is predicted to come as close as 18,300 miles away from the Earth's surface as it passes. (In Celestial terms, this is a very near miss, because that distance is smaller than the circumference of the Earth.)

The official explanation of Torino Scale ratings are provided below. In addition to numerical categories from 0 to 10, the scale is also color-coded in five categories, from white to red.

THE TORINO IMPACT HAZARD SCALE:

No Hazard (White Zone)

0: The likelihood of a collision is zero, or is so low as to be effectively zero. Also applies to small objects such as meteors and bodies that burn up in the atmosphere as well as infrequent meteorite falls that rarely cause damage.

Normal (Green Zone)

1: A routine discovery in which a pass near the Earth is predicted that poses no unusual level of danger. Current calculations show the chance of collision is extremely unlikely with no cause for public attention or public concern. New telescopic observations very likely will lead to re-assignment to Level 0.

Meriting Attention by Astronomers (Yellow Zone)

2: A discovery, which may become routine with expanded searches, of an object making a somewhat close but not highly unusual pass near the Earth. While meriting attention by astronomers, there is no cause for public attention or public concern as an actual collision is very unlikely. New telescopic observations very likely will lead to re-assignment to Level 0.

3: A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of localized destruction. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by public and by public officials is merited if the encounter is less than a decade away.

4: A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of regional devastation. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by public and by public officials is merited if the encounter is less than a decade away.

Threatening (Orange Zone)

5: A close encounter posing a serious but still uncertain threat of regional devastation. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than a decade away, governmental contingency planning may be warranted.

6: A close encounter by a large object posing a serious but still uncertain threat of a global catastrophe. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than three decades away, governmental contingency planning may be warranted.

7: A very close encounter by a large object, which if occurring this century, poses an unprecedented but still uncertain threat of a global catastrophe. For such a threat in this century, international contingency planning is warranted, especially to determine urgently and conclusively whether or not a collision will occur.

Certain Collisions (Red Zone)

8: A collision is certain, capable of causing localized destruction for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 50 years and once per several 1000 years.

9: A collision is certain, capable of causing unprecedented regional devastation for a land impact or the threat of a major tsunami for an ocean impact. Such events occur on average between once per 10,000 years and once per 100,000 years.

10: A collision is certain, capable of causing global climatic catastrophe that may threaten the future of civilization as we know it, whether impacting land or ocean. Such events occur on average once per 100,000 years, or less often.

Note: This is the Torino Scale as revised in 2005. A graphic of the Torino Scale is also available at http://neo.jpl.nasa.gov/images/torino_scale.jpg .

The Palermo Technical Impact Hazard Scale is a bit different, with values less than -2 reflecting events for which no consequences are likely, values between -2 and 0 indicating situations that merit careful monitoring, and values above zero indicating situations that merit some level of concern. This document presents only the Torino scale in its entirety, since that scale was developed for general public informational uses.

About 40,000 to 60,000 tons of extraterrestrial material falls onto the Earth each year, but most of it is mere dust. Larger materials fall during regular cycles called meteor showers, but again most of it is small enough to harmlessly burn up (through ablation) as it hits the Earth's atmosphere at high speeds (typically about 67,000 mph). During meteor showers, the material is typically leftover debris from comets that had crossed the Earth's orbit, and most such material is very small and harmless to us. Material that does survive ablation to strike the Earth's surface lands in random locations, and since 70% of the Earth's surface is water, these meteorites mostly go unnoticed by ordinary people. The risk to Michigan is calculable in general terms, by considering the proportion of the Earth's total surface area that is occupied by Michigan's land area. This is approximately 2.9×10^{-4}, or 0.00029. The frequency of global impact events can then be multiplied by this factor to estimate the frequency of impact events directly upon Michigan's land area. This results in the following estimates, on average, for different sizes of impacts upon Michigan's land itself:

- About 1 to 5 impacts per year that are larger than 100g (golf-ball size) – This may kill an individual that is struck, but since most space is not occupied by a person at any particular moment, such a thing is exceptionally rare, and there have only been a couple of confirmed meteorite injuries worldwide. Instead, such incidents are more likely to simply cause limited property damage to a car or home, although their appearance in the sky can appear impressive and be accompanied by a sonic boom. (Example: the Washtenaw County strike of 1997.)
- About one impact per century involving an object of more than 100kg (220 pounds), and about one impact every 1700 years involving an object of more than 1000kg (about 2200 pounds) – These types of events would result in loud sounds and bright flare-ups in the sky, leaving a field of fragments strewn across an area that is miles across, but actual damages are likely to be only moderate unless a dense urban area or critical facility happens to be struck. (Example: the Park Forest, IL event of 2003.)
- About one impact every 350,000 years involving an object of more than 100,000kg (about 220,000 pounds) – This is the type of impact that resembles an atomic blast, exploding brightly in the sky and producing a very strong blast wave and severe winds that would cause extensive building damages and collapse at ground level, would flatten forest lands, and could start a large wildfire. (Example: the Tunguska, USSR event of 1908.)

Although that last type of event is so rare that it need not be of general concern for Michigan, the probability of such an event affecting some part of the U.S. and potentially causing a national emergency is a bit larger, but still remote. It is most probable that the next such event will occur elsewhere in the world (on the order of about 1 event per century) and, although potentially devastating to that area, Michigan's role would probably only involve the voluntary donation of humanitarian aid to the disaster area. One foreseeable scenario could involve an asteroid impact in the ocean, which causes tsunami impacts upon the associated coastline of the U.S.—waves could be more than 100 feet high from the impact of an asteroid with a diameter of 1300 feet, although that scale of event would only be expected about once in 80,000 years. These type of large events, of the type that would actually form sizeable craters and cause catastrophic national or global impacts (including major seismic and volcanic effects and global cooling from gaseous effects and dust, smoke, and particulates deposited into the atmosphere), are rare enough that no extensive description will be provided here—past events of that type are well-established in a geological timeframe but not in a human historical timeframe. (Reference will be made to such events primarily in the description of mitigation strategies.)

Since meteors flare up brightly in the sky, some persons have speculated about whether meteorites could then cause wildfires to start up. As it turns out, this is generally not the case. The flaring fireballs are caused by ablation, as the very fast meteors encounter the atmosphere and friction generates heat, but a great amount of material typically burns away in this process, followed by miles of additional falling before ground impact, during which time the contact with blowing air exerts a cooling effect. The vast majority of meteorites are actually cool when they strike the ground. It would take a very large impact to bring a degree of heat that is capable of igniting a forest fire, and impacts of that size are very rare. That type of rare, large impact would also tend to flatten forest lands at the same time, with blast pressure and wind effects that could offset much of the fire risk. A large (Tunguska-sized) event would cause forest fires, along with huge amounts of other damage, and it is conceivable that a smaller-sized (but still very rare) impact might cause wildfire ignition if there are already drought conditions present that have increased the natural wildfire risk. In general, wildfires will not be caused by meteorites, and there is no good evidence that any of Michigan's historic wildfires were of meteoritic origin.

Space weather can be very expensive for those who use or rely upon satellites. During a solar maximum, the Earth's upper atmosphere expands and increases the drag upon satellites within low orbits, which will then require boosting in order to remain aloft. Electronic circuits can malfunction and cause interruptions or complete losses in operational capacity. Space missions may also need to be delayed, in order to ensure their safety and success. Special design features may require additional expenses, to mitigate the effects of space weather. Communication disruptions can inhibit navigation and hinder the safe management of air and sea traffic. Electric currents are induced by the relative motion of magnetized material, and these can affect power supply and pipeline infrastructure, potentially causing weakening and damage in these systems as well as electronic malfunctions. Three space weather scales are in use by NOAA/NWS to summarize the intensity and potential impact of three different types of space weather effects. Each uses a 5-category classification scheme, and the three scales denote (1) geomagnetic storm intensity, on a G-scale, (2) solar radiation storms, on an S-scale, and (3) radio blackouts, on an R-scale. Weaker events are given a number of 1 on the scale, and extreme events are rated as a 5. In this document, selected material is summarized below. For more detailed information, please refer to the NOAA web site at http://www.swpc.noaa.gov/NOAAscales/.

NOAA Space Weather Scales

NOTE: Each type of space weather may occur separately. Descriptions of all three types of space weather warnings are here combined into one table merely to conserve space.
HF means high frequency (radio waves), but other radio frequencies may also be affected by these events. LF means low frequency (radio waves). F: refers to event frequency.

Category Labels	Geomagnetic Storms (effect & frequency)	Solar Radiation Storms (effect & frequency)	Radio Blackouts (effect & frequency)
Minor G1 S1 R1	G1 events can cause weak power grid fluctuations, minor impacts on satellite operations, effects on migratory animals, and widely visible auroras seen in Northern Michigan. F: about 900 days per solar cycle.	S1 events result in minor impacts on HF radio in polar regions. F: about 50 such events per solar cycle, each of which can last more than 1 day.	R1 events cause weak or minor degradation of HF radio communication on the sunlit side of Earth, and occasional loss of radio contact. LF navigation signals used by maritime and general aviation systems may be degraded for brief intervals. F: about 950 days per solar cycle.
Moderate G2 S2 R2	G2 events can cause high-latitude power systems to experience voltage alarms. Long-duration storms may cause transformer damage. Corrections to satellite orientation and orbital drag prediction may be required. HF radio propagation can fade at higher latitudes. Auroras may be visible throughout Michigan. F: about 360 days per solar cycle.	S2 events may expose persons in high-flying aircraft to an elevated radiation risk* in areas of high latitude. Infrequent single-event upsets of satellite operations are possible. Possible effects on HF propagation and navigation through polar regions. F: about 25 events per solar cycle, each of which can last more than 1 day.	R2 events cause a limited blackout of HF radio communications on the sunlit side of Earth, and loss of radio contact for tens of minutes. LF navigation signals may also be degraded for tens of minutes. F: about 300 days per solar cycle.
Strong G3 S3 R3	G3 events may require voltage corrections at power systems and may trigger false alarms on their protection devices. Satellite orientation problems may need correction. Increased atmospheric drag and component surface charging may occur. Intermittent LF radio navigation problems may occur. F: 130 days per solar cycle.	S3 events can expose persons in high-flying aircraft to a radiation risk* in areas of high latitude. Satellite operations may experience single-event upsets, imaging system noise, and slight solar panel inefficiencies. Degraded HF radio propagation in polar regions. Navigation position errors are likely. F: about 10 events per cycle (each can exceed 1 day).	R3 events cause a wide area blackout of HF radio communication and loss of radio contact for about an hour on the sunlit side of Earth. LF navigation signals may be degraded for about an hour. F: about 140 days per solar cycle.
Severe G4 S4 R4	G4 events may cause widespread voltage control problems for power systems, and mistaken exclusion of key assets from a power grid by some protective systems. Satellites may experience surface charging, tracking and orientation problems that may need correction. Pipelines may experience induced currents. HF radio propagation sporadic. LF radio disrupted. Satellite-based navigation may be degraded for hours. F: about 60 days per solar cycle.	S4 events can expose persons in high-flying aircraft to a radiation risk* in areas of high latitude. Satellites may experience memory device problems, imaging systems noise, orientation problems, and degraded solar panel efficiency. A blackout of HF radio communications is likely through the polar regions. Increased navigation errors over several days are likely. F: about 3 events per solar cycle (each can exceed 1 day).	R4 events cause an HF radio communication blackout on most of the sunlit side of Earth for 1 to 2 hours, with HF radio contact lost during this time. LF navigation signals cause increased errors in positioning for 1 to 2 hours. Minor disruptions of satellite navigation are possible on the sunlit side of Earth. F: about 8 days per solar cycle.
Extreme G5 S5 R5	G5 events may cause widespread voltage control and protective system problems in power systems, with some grid systems completely blacking out or collapsing, and possible damage to transformers. Satellites may experience extensive surface charging, orientation, tracking, and linkage problems. Pipelines may receive induced currents reaching hundreds of amps. HF radio may be out for 1 to 2 days in many areas. LF may be out for hours. Satellite-based navigation may be degraded for days. Bright auroral lights visible at night. F: about 4 days per solar cycle.	S5 events can expose persons in high-flying aircraft to a radiation risk* in areas of high latitude. Satellites may be rendered useless, may receive permanent solar panel damage, or may experience memory problems, loss of control, serious imaging data noise, and navigation problems. Complete HF radio communications blackouts are possible throughout the polar regions. Navigation operations will be extremely difficult and error-laden. F: less than 1 event per solar cycle should occur, although an event may exceed 1 day in duration.	R5 events cause a complete HF radio blackout on the entire sunlit side of Earth for a number of hours. No HF radio contact with mariners and aviators in this sector. LF navigation signals experience outages for many hours on the sunlit side of Earth, causing loss in positioning. Satellite navigation errors in positioning increase for several hours on the sunlit side and may spread into the night side of the Earth. F: fewer than 1 event per cycle.

*** Pregnant women are particularly susceptible to radiation risk.**

Meteors are commonly observed, illuminating briefly in the sky as the force of friction with the Earth's atmosphere burns away the solid matter they contain. Some meteors partially survive this process and thus become meteorites by striking the Earth's surface and potentially causing great amounts of damage. However, there are cases in which huge fiery blasts occurred in the sky (bolides) without any meteorite remnants being found. Enormous damage can still occur at ground level from the effects of the heat, blast force, and strong winds that result from the atmospheric impact (see the description provided for the 1908 event at Tunguska, Russia, later in this section).

Part of the usefulness of this analysis is meant to involve the presentation of information that might alleviate confusion throughout Michigan's communities and residents, in case some event actually does occur, or should some warning of an impending impact eventually be given out. In the former case, those who already have some information about meteors, and the potentially spectacular appearance of either sky or ground impacts, would have a means to make sense of an unusual bolide or impact event and would be less likely to mistake the event for a nuclear explosion. A greater general awareness of the variety and nature of Michigan's hazards should eventually translate into a lessened demand for emergency services and information. For example, it might take only 30 seconds to explain to a knowledgeable citizen that a meteor impact caused a huge explosion in the sky (and an impact on the ground), whereas a less-knowledgeable citizen might seek 20 minutes of reassurance that the explosion was not nuclear, that the incident was not connected with a crashing airplane or a confidential military experiment, and so on. The provision of advance information that realistically describes and assesses the nature of unusually severe events can help to provide a framework in which the correct interpretation and response actions can be undertaken more quickly and efficiently.

In the latter case, involving an alert about an impending impact or potential impact, many persons would need information that allows them to understand the nature of the threat, and the techniques that may be used to prevent or mitigate its impacts. For example, there is an enormous difference between an alert that provides only a few weeks of notification, and one that has identified a need for action over the course of several decades.

It should be realized that although the atmosphere and air around us seems to be "light" and only a small obstacle to movement (mostly at high speeds or during strong wind gusts), the air nevertheless has enough substance to sustain heavy aircraft in flight, to hold aloft huge thunderstorm clouds full of rain, and so on. A meteor crashing into the atmosphere thus releases tremendous amounts of energy, as the result of friction from plunging through large quantities of air at enormous speeds. This energy can result in large (and loud) blast waves, even if the meteor's trajectory is oblique enough to cause it to "bounce off" the atmosphere, rather than plunging through it and hitting the ground. For example, if a towel is wrapped around a bowling ball, a baseball can easily be bounced off the top of the bowling ball without leaving a dent or scratch in the bowling ball's surface, but it would still make a clearly audible noise and could crush any small insect that happened to be crawling underneath the towel. The towel can be seen as an analogy for our ecosphere on the surface of the planet, and the visible results of such an atmospheric impact could include great bursts of flame, damaging shock waves, severe winds, deafening noise, and disrupted weather patterns.

While this section does is not intended to focus upon planetary life-ending scenarios (which are remotely possible but <u>extremely</u> unlikely to occur within our lifetimes), it does consider the possibility of a major (averaging once per century) impact that may cause either an area of widespread destruction within the United States, or an impact somewhere else in the world that may cause unusual effects to be felt in distant locations. If a Tunguska sized event (see the 1908 entry in the list of Significant Events later in this section) were to affect a densely populated area, the results could be extreme enough to constitute a National Emergency. (Please refer to the new section describing "Catastrophic Incident," for more discussion about this, as well as the Nuclear Attack section, for more information about problems such as mass fires, which may arise from large blasts.)

This section also considers more common events that have fairly limited effects and damages, but may be associated with a significant degree of uncertainty about the area and population that could be struck by such impacts. Even though the number of celestial impact events has probably not increased in recent times, certain types of vulnerability have increased (see for example the description of the 1859 Carrington Solar Flare event, in the section describing Significant Events). Our public awareness of these possibilities has also increased, resulting in a need for additional information to inform citizens about the actual risks, effects that different types of celestial impact may have, and present-day means to prevent or mitigate some of the worst possible impact scenarios. Most significantly, the size of the human population, and the amount of land area it occupies, has changed greatly during the past century. The global population is nearly four times what it was a century ago, and (especially in the richer nations) this population

growth has been accompanied by a much larger portion of the land area that has been built-up for urban uses. Just since World War II, the population of the United States has more than doubled, and even in areas with a relatively stable population, residential neighborhoods take up a lot more space today than they previously had in the period of time before the suburban "explosion." A random impact point today is more likely to affect lands that are developed to at least a moderate residential capacity, which could result in thousands of casualties.

Although most comets and asteroids have very consistent trajectories that change only very slowly, in terms of human history, Earth-threatening space bodies may still remain undiscovered by humans. There is also the possibility that their traditional orbits may be unexpectedly disrupted by collisions with other bodies, or by gravitational effects such as that exerted by Jupiter on Comet Shoemaker-Levy 9, which caused that comet's eventual impact into the planet. "Jupiter-family comets" are those in which a normal (safe) orbit of a comet or asteroid may be "suddenly" altered in a manner that causes it to become a threat to Earth. In either case (a newly discovered object or one whose course is changed), the possibility exists that a serious impact threat may suddenly be discovered. However, extensive observations and calculations have been taking place to identify and track all potential threats of this kind.

It is likely that the next major celestial impact will occur somewhere in the world other than Michigan, and that Michigan's role as part of the United States would at most involve the provision of support to the impacted area and its surroundings. If a major impact happens to occur in North America, then state-level mutual aid may result, and possibly even the intake of evacuees, as had taken place during the Katrina and Rita hurricane disasters of 2005. Several recent bolide events have been documented in the Great Lakes area, but have caused no known damage to the state's area during its European historical era over the past four centuries. It is possible that certain unexplained seismic events reported in the Upper Peninsula more than two centuries ago may have been caused by celestial impacts. For the most part, however, the meteorite hazard is important to know about mainly for preparedness and informational usefulness, rather than due to an actual pattern of damaging effects upon Michigan.

The space weather hazard, by contrast, is likely to cause one or more serious infrastructure failures in the near future, due to the extent of our reliance on complicated electronic and satellite systems that are vulnerable to disruption. In addition to power failures and phone communication breakdowns, it is also quite possible for the disruption of radio and navigational systems to cause risks for air and marine traffic. Even if cautious transportation providers are diligent about maintaining safety during such events, considerable economic impacts and delays can result from the electronic breakdowns caused by solar geomagnetic storm events.

Impact on the Public

A celestial impact from an object that is either sufficiently massive or fast-moving can have an effect that is comparable to nuclear blasts, in terms of the amount of energy released in the form of pressure (shock) waves and thermal effects (heat/fire). Additionally, major earthquake activity would be felt in areas that normally wouldn't have had to worry about such effects. An impact into major water bodies can cause intense tsunamis to occur, and severe winds could also result in extensive physical damages many miles (or hundreds of miles) away from the main impact site. Depending upon the mass and velocity of the meteorite, the impact on the public may range from the barely noticeable to the complete destruction of the entire area, with the most powerful impacts having effects similar to those described for nuclear attack (minus the radioactive fallout and electromagnetic pulse), earthquake, severe winds, wildfires, and storm seiches (shoreline flooding), all described in their own sections in this document. Space weather impacts will result in transportation delays and communication interference, and some cases may result in fatal transportation accidents, large economic losses, and widespread power supply interruptions.

Impact on Public Confidence in State Governance

If a major impact occurs in Michigan or the Great Lakes, many persons may feel disgruntled if no advance warning was able to be provided. There is probably not a widespread familiarity with this type of hazard, and popular conceptions may be rooted in televised or cinematic portrayals in which it was considered that part of the government perhaps "should have known" about a potential impact and been able to prevent it. One of the reasons that this hazard is now being included in state plans is to help provide information that will improve people's understanding of it. Moreover, since a significant celestial impact event could easily be mistaken for a nuclear blast by many persons, an educational process could be useful in overcoming the possible harm caused by such assumptions. For example, if a large bolide is seen, or actually damages an area, it will be helpful for people to have been familiar with what the event actually might be, rather than assuming that it was a deliberate hostile action that may involve secondary radiation and

security impacts, or assuming that a mass evacuation or escalated level of security alert may be needed. Rather, if it is understood that there is a natural phenomenon that in some cases may resemble that of an atomic blast or explosive attack, then people's behavior and attention can be more properly guided toward activities and attitudes that are appropriate for a natural disaster rather than those for a homeland security alert. The potential impacts of space weather will require greater public awareness in order to build an understanding about existing weaknesses and the expense involved in correcting those weaknesses, where possible.

Impact on Responders

A small impact incident would not be likely to cause much risk for responders, unless the impact was upon a structure that became weakened to the point of potential further collapse. Larger impact incidents would be extremely unusual, but may be expected to require extensive search and rescue operations, as well as various firefighting operations and probable infrastructure failure impacts to be dealt with simultaneously. The presence of hazardous materials could also be expected at an impact site that had been urban in nature, or had involved key agricultural or infrastructure facilities. A catastrophic impact event could require extensive use of mutual aid and state/federal disaster and emergency assistance, with the possibility that all normal response resources would be disabled within the area of impact, and would need to be replaced by resources from adjacent local areas, or even from beyond the state. Underground sheltering would be a useful way to increase the odds of survival from the wind/shock/frame effects of a huge bolide event, which would likely pass quickly and then enable responders to deal with rescue operations, fires, infrastructure failures, and the organization of mutual aid. The impacts of space weather include interruptions in the function of radios, satellites, electronics, and even power supply systems that may be needed for emergency response. Response activities that involve electronic navigation technologies and Global Positioning Systems may need to fall back upon the use of less technologically advanced means to accomplish their mission.

Impact on the Environment

An extremely large impact, even if not in Michigan, could cause a National Emergency situation to arise, which Michigan may have to help to respond to and recover from (please refer to the chapter on catastrophic incidents). A direct meteorite impact on land could destroy an entire area, and cause fires, earthquakes, and other hazards for a large area around the impact. The same types of effects can also result from the atmospheric blast and heat impacts of a large bolide event, even if the celestial body itself does not strike the ground. A large impact in one of the Great Lakes could cause substantial flooding, seiche, and erosion impacts along areas at or near the lake's coasts. It has been speculated that space weather may be connected with global climate, but this is primarily due to the possibly coincidental occurrence of a "Little Ice Age" (lower average temperatures in America and Europe) during the same time that the Maunder minimum in solar activity was observed. The specific mechanisms that would underlie such a connection have not yet been figured out and therefore such a link should probably still be considered to be purely speculative. On the favorable side, solar activity helps to shield us from some of the cosmic rays that come from throughout the universe.

Significant Events

NOTE: Although many of the events listed here occurred out of state, some of them were nevertheless large enough to have direct impacts upon Michigan, due to the sheer magnitude of the impacts. Other events are included from a very long time ago, as well as smaller more recent events, to give an indication of the magnitude of what is possible. Some events describe "close calls" and events whose limited impact at the time could have been much greater had they affected a more densely developed location (for our current circumstances involve much greater population density and physical/infrastructure developments than had been present in the past). Some events are included because they help to indicate the range of threat posed by the hazard—events outside of Michigan usually represent the largest known events or threats, while events involving Michigan tend to represent the typical level of recorded impacts in the state.

<u>Ancient-Archaic Events</u>

Approximately 1.8 billion years ago – Sudbury, Ontario

One of the largest known impacts took place around Sudbury, Ontario, leaving impact effects that measure 155 miles in diameter. The impact site's geological structure had been discovered in 1883 but not fully explained until 1964. Debris ejected from the impact site was thrown as far as the Midwestern U.S., including Michigan. This was an impact of global significance. The heat directly generated by this cataclysmic impact would have killed any humans within at least 500 miles from the impact site (which includes all of Michigan), if humans had been living in the area at the time.

Approximately 450 million years ago – Cass County

An impact, now designated Calvin 28, struck what is now southeastern Cass County, Michigan, and left effects that are still geologically detectable today. The Calvin impact area is about 5 miles in diameter, and is located mid-way between the Village of Vandalia and the Michigan-Indiana State Line. About the same time (in geological terms), a much larger impact occurred on what is now the northern coast of Lake Superior (the Slate Islands in Ontario) and formed an impact structure about 19 miles in diameter. The following map shows the Cass County impact area (Source: University of New Brunswick's Earth Impact Database website).

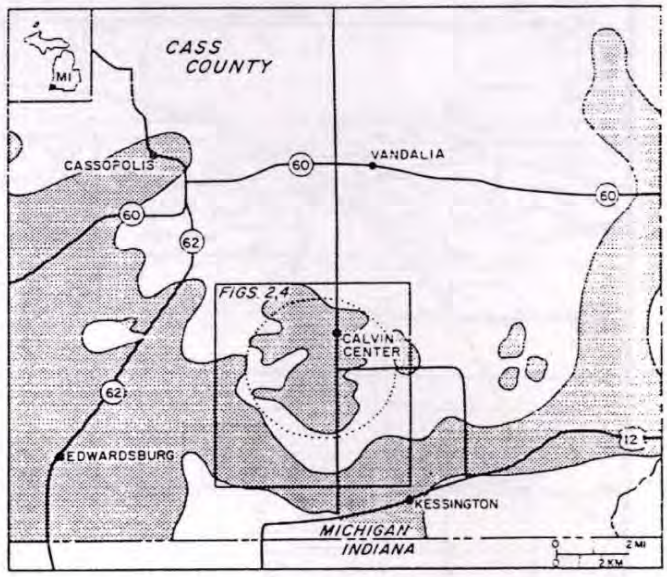


Figure 1. Map of the southeastern part of Cass County, Michigan, showing location of the Calvin 28 cryptoexplosive disturbance (dotted circle). Shaded area, Ellsworth Shale; unshaded area, Coldwater Shale.

Several hundred million years ago – Indiana and Ohio

A Kentland, Indiana impact leaves a crater estimated to have originally measured 8 miles in diameter. A smaller (5 mile diameter) Ohio impact later had Native American burial mounds built on its site, and is now known as the Serpent Mounds.

Approximately 65 million years ago – Global

A large impact on the Yucatan peninsula of Mexico (the impact area is now known as Chicxulub) took place at the end of the Cretaceous (geological) period, and thus has been considered to be a direct or contributing cause of the extinction of many prominent species of life on Earth at the time, including the large reptilian dinosaurs. There may be galactic cycles that make major, species-threatening impacts more likely during certain periods of time than others, with mass extinctions seeming to correlate with intervals of between 26 and 32 million years in length (over the past 250 million years), perhaps caused by some celestial event that sweeps Oort Cloud or Kuiper Belt objects from the outer parts of the Solar System toward Earth, or by the effects of a nearby star going supernova. Certain regions of the Milky Way Galaxy, which the Sun passes through on a grand cycle that repeats every 225 to 250 million years as it orbits the galaxy's center, may expose the Earth to more celestial bodies than are normally seen in the Solar System during the more stable, intervening time periods. Since the most recent mass extinction period was about 11 million years ago, there is no expected threat of this type during our lifetimes. The Chicxulub impact structure measures about 100 miles in diameter. Recently, evidence has been claimed for an even larger impact site, at around the same time, off the west coast of India. A surge in volcanic activity took place in the same geological time frame as the impact events and thus may have been a result of them.

About 37 million years ago – Ontario

Another impact occurred near the huge Sudbury, Ontario site (mentioned previously) and today is known as Lake Wanapitei, which is just under 5 miles in diameter.

About 50,000 years ago – Arizona

An impact forms the Barringer Meteor Crater in Arizona, which currently measures 570 feet deep and 1.2 miles in diameter. Evidence suggests that it was formed by an iron-nickel asteroid measuring about 100 feet in diameter, moving with an original velocity of 45,000 miles per hour. The impact probably caused hurricane-force winds more than a dozen miles from the impact site, the formation of a huge cloud of dust and debris, and the displacement of more than 300 million tons of rock.

Circa 900 C.E. or later – Alberta

An impact ("Whitecourt") at Alberta, Canada, leaves a crater that is more than 100 feet wide (now called the Brenham Crater).

Circa 1000 C.E. or later – Kansas

A Haviland, Kansas impact leaves a crater about 50 feet wide. (Also, during the same approximate time period, an impact occurred at Sobolev, Russia, leaving an impression about 3 times as wide.)

Modern Events

July 1, 1770 – International

Lexell's comet (D/1770 L1) was computed by astronomers as having passed only about 1.4 million miles from Earth (less than 6 times the average distance of the Moon, or about 1.5% of the distance to the Sun). This was the nearest such Earth encounter to be measured astronomically rather than in terms of its actual impact effects as a meteorite (until the very recent tracking of smaller and slower objects). Now considered to be a "lost comet," its orbital period had been calculated at the time (by Lexell) to be 5.6 years, eventually leading to the idea that space objects may be propelled toward Earth by a gravitational encounter with Jupiter—a circumstance that is one of the potential sources of comet/asteroid impact threats that would provide little or no advance warning. The comet was initially observed on June 15, 1770, and was last observed moving away from the Sun on October 3 of the same year.

September 1, 1859 – International

A large solar flare was briefly observed by astronomer Richard Carrington. Just before dawn of the next day, however, brilliant auroras were visible in skies around the world, telegraph systems severely malfunctioned, and various damages (and minor injuries) resulted from sparks and equipment failures. This was the first solar flare observation and it was also clearly seen that the phenomenon was connected with malfunctions in electronic communications systems on Earth. No solar flare of this magnitude has been seen in the 150 years since this occurred. Based upon evidence from arctic ice, it was estimated that the 1859 solar geomagnetic storm was the most intense in the past 500 years, nearly twice as much as the second-largest event. (Even though certain intensities have since been matched, no storm since has been able to simultaneously match this one, on all types of intensity measures.) Were such an event to happen again today, it has been estimated that tens of billions of dollars in damage would be done to the more than 900 satellites that orbit the Earth. These satellites are essential for the safe and smooth operation of airlines, spacecraft, and various communications systems.

1863 – Arabian Peninsula

An event more than 300 miles southeast of Riyadh, Saudi Arabian, left an impact site of probably at least five craters (Wabar Craters) in the desert, one of which was more than 100 meters in diameter. The impact compressed desert sand into rock. The date of the event is approximate, because the impact site itself was not reported until 1932, but was then considered in retrospect to match up with fireball reports that had come from the city of Riyadh in 1863. It has been calculated that the impact occurred with the force of a Hiroshima-sized atomic bomb, but fortunately in this case, it affected only an uninhabited desert area.

June 30, 1908 – Russia

A large impact event occurred in Tunguska, Russia (in Siberia), in which a large object blasted into the atmosphere in a manner that created a forceful, spectacular, and destructive impact. Although the object was evidently destroyed in the air (leaving no impact crater like so many rocky meteoroids have), the force of this destruction has been estimated as equivalent to between 5 and 30 megatons of TNT, flattening an estimated 80 million trees over an area of approximately 830 square miles (a surface area equivalent to that of a disc 32½ miles in diameter). Brilliant meteor impacts like this have been termed "**bolides**," since they can resemble fireballs and are observed as explosive, incendiary events. Unusual levels of acid rain followed the event. Recent research from Cornell University concluded that the event was "very likely" a comet impact (with most of its mass in the form of ice that would dissipate in the atmosphere), since high-altitude noctilucent clouds (which normally occur only with certain types of icy, high-altitude conditions) were sighted across Europe for several days (as much as 3,000 miles away), and caused the night skies to glow. Estimates about the frequency of this scale of impact vary from once every thousand years to once per century.

May 1921 – International

An extremely strong geomagnetic storm occurred—the strongest such storm since 1859. According to one study, if a storm of this magnitude were to occur today, it could result in large-scale electrical blackouts that would affect more than 130 million persons across the northwestern U.S. (including Michigan) and the Pacific Northwest. These estimates were based upon estimates of regions susceptible to power grid collapse, and the 1921 storm was considered to be about 10 times as strong as the one that did cause power failures in 1989. Extra-high-voltage transformers were considered to be a particular vulnerability in these projected blackout areas, with places like New Hampshire, New Jersey, and Pennsylvania at particularly high risk in the interconnected grid.

February 12, 1947 – Russia

A bolide event that included many meteorites took place in far-eastern Russian Siberia (Sikhote-Alin), fortunately occurring in a relatively isolated and undeveloped area, between China and Japan. The event was reported as a fireball, brighter than the Sun, at 10:38 am (local time). As the bolide descended at an angle of 41 degrees, it left a trail of smoke and dust 20 miles long that remained visible for several hours. The meteorite was broken into fragments as it fell at roughly 31,000 miles per hour. Upon reaching an altitude of about 3.5 miles, the bolide culminated in a giant explosion, scattering its remaining debris over an impact area of about one-half square mile. The largest impact crater in this area measured 85 feet wide and 20 feet deep. The total mass of all the meteorites from this event has been estimated as just under 1,000 tons, with the largest fragment later weighed at 1,745 kilograms and displayed in Moscow.

September 17, 1966 – Lake Huron

A bolide event occurred over Lake Huron, Michigan, involving an air blast estimated as the equivalent of 1/3 ton of TNT, approximately 8 miles above the surface of the water. Although no material from a meteorite was found to help determine more information about the size and characteristics of this meteor, this is not surprising since the location of the event probably placed any meteorite remnants at the bottom of Lake Huron. The bolide illuminated the whole of south-western Ontario and adjacent regions at about 8:48 pm, as it was seen traveling northwest across Lake Erie and the tip of Ontario, toward Lake Huron. At least a dozen loud "detonations" were reported from the Ontario area near the lake a few minutes after the fireball's passage. Astronomers later calculated that the meteor was about 8 miles up as it crossed over Lake Huron, and probably reached the lake's surface fewer than 18 miles west of the city of Kincardine, Ontario. The meteor was traveling about 10.6 miles per second (38,000 miles per hour) and was brightly luminous for at least 10 seconds.

February 8, 1969 – Pueblito de Allende, Mexico

A large shower of stony meteorites fell near a village in the Mexican border state of Chihuahua. More than two tons of meteorites fell in that incident.

August 4, 1972 – Illinois

A huge solar flare ended up causing the failure of long-distance telephone communications across Illinois. AT&T redesigned its power system for transatlantic cables as a result of this event.

August 10, 1972 – Western U.S. and Canada

Since the angle of approach varies widely, some meteors simply graze or bounce off of the atmosphere. In 1972, such a fireball was seen from Utah to Alberta.

January 1978 – International

A Soviet satellite, Cosmos 954, which had been launched in September of 1977, was being monitored by U.S. agencies and by November was found to have a decaying orbit. By January, it had become apparent that the satellite had lost its attitude stabilization system. Such satellites were known to be powered by small nuclear reactors, using fuel that was 90 percent enriched Uranium-235. Thus, whenever and wherever this satellite fell to Earth, it had the potential to contaminate things and persons who came into contact with it. The U.S. National Security Council arrived at an estimate that there was only about a 1 in 10,000 chance that a human would be injured in the crash, but because of the political aspects of an enemy nation's nuclear satellite crashing onto friendly territory, it became important to treat the incident with more weight than what that small risk might normally be credited with. Operation Morning Light was thus created, in December of 1977, with the Department of Energy given lead responsibility for the possibility of a domestic crash site. Even though a crash site for the projected landing orbit was only supposed to have an 8% chance of being on land, plans were made for such a contingency, which would involve the finding of radioactive debris, decontamination of affected land areas, and the treatment of any persons within an unsafe distance of such debris. After about 10 days of careful inquiries with the Soviet government, various types of confirmation were received about the satellite's nature and condition. On January 24, the satellite entered the atmosphere over Queen Charlotte Island, British Columbia, and at 6:53 am, finally crashed near the Great Slave Lake, just north of the Province of Alberta, in Canada. Aircraft and Nuclear Energy Search Teams were then dispatched to Canada, to assist with clean-up operations.

July 11, 1979 – International

The Skylab Space Station, which had been put into orbit in 1973 but abandoned in 1974, had its orbit finally deteriorate to the point where it plunged to Earth. Delays in the launch of the Space Shuttle program prevented the station from being salvaged by restoring it to a sustainable orbit. Instead, considerable uncertainty was expressed in the media about where the station might return to Earth, and with what potential for destructive impacts. Skylab re-entered the atmosphere on July 11 and the calculated area at-risk turned out to be in the Southern Hemisphere around the Indian Ocean. Debris impact areas on land were identified in Western Australia, the largest being a heavy metallic fragment (perhaps 5 feet in length).

March 13, 1989 – Canada and Eastern United States

Geomagnetic storms caused by a huge solar flare caused widespread disruptions in the transmission of electrical power, causing a widespread blackout across most of Quebec and affecting 6 million persons for a period of up to 9 hours. Specifically, when five transmission lines went down, the system was unable to withstand the loss of their 21,350 megawatt load, and collapsed within the subsequent 90 seconds. The blackout closed schools and businesses, shut down the Montreal Metro Airport, and delayed flights from other airports. Street traffic backups took place, since traffic signals and traffic control systems no longer functioned smoothly. Workers in downtown Montreal were stranded in dark offices, stairwells, and elevators. Elsewhere, power surges caused by the geomagnetic storm (geomagnetically induced currents, or GICs) caused power transformers in New Jersey to be overloaded and damaged. The functioning of long-distance telephone cables were also affected by auroral currents, major power substations experienced voltage swings, generators went offline, and the U.S. Air Force temporarily lost its ability to track satellites. Costs from the loss of power exceeded $100 million, including stalled production processes, idled workers, and spoiled products. This was considered to be the strongest geomagnetic storm of the space age.

October 9, 1992 – New York

The "Peekskill Meteorite" damaged a parked car in Peekskill, New York, after creating a bright fireball in the sky that was seen across several states. The original meteor (estimated to be 1 to 2 meters wide) had fragmented at a height of about 41.5 km, then again about 20 seconds later, until it was under a foot in diameter.

January 1994 – Canada

Inclement space weather caused electric charges to build up and then discharge within the electronic components of two expensive communications satellites. One satellite was disabled for about 7 hours, due to damage to its control electronics. A second satellite went out of service entirely, when its backup systems also became damaged, requiring 6 months of service before its functions were restored. The satellite disruptions prevented news information from being electronically delivered to 100 newspapers and 450 radio stations. Television and data services to more than 1,600 remote communities broke down with the second satellite failure. Telephone service in 40 communities was also interrupted. Total costs of the event were estimated at between 50 and 70 million U.S. dollars.

July 15 to 24, 1994 – International

Comet Shoemaker-Levy 9 crashed into the planet Jupiter, after being broken into 21 fragments by gravitational forces, and caused enormous impacts, which quickly became visible to telescopes on Earth. (The impact took place on the far side of Jupiter, but the planet quickly rotated and allowed the impact points to be visible). The energy released by this impact was estimated as greater than many thousands of 50-megaton nuclear bombs, as the comet's debris was vaporized and released enormous amounts of heat, temporarily exceeding the amount given off by the entire (exothermic) planet as a whole and also exceeding the temperature of the surface of the Sun. The impacts caused atmospheric spots to appear that were comparable in size to the diameter of the Earth. The comet had first been detected by astronomers only 17 months prior to its impact. It was calculated that on the comet's previous approach toward Jupiter on July 7, 1992 (which tore it into fragments), its distance from the planet was only 16,000 miles (less than the circumference of the Earth). It was estimated that the largest fragment of the comet may have exceeded 2 miles in diameter. As a result of this impact, the U.S. Congress asked NASA to propose how to identify and track all large space objects with the potential to impact the Earth.

March 19, 1996 – International

A celestial "close call" involved asteroid 1996 JA1 (large enough to cause catastrophic damage), which came within 280,000 miles—nearly as close as the Moon.

January 11, 1997 – International

A satellite that had cost $200 million was incapacitated by the impact of a Coronal Mass Ejection. After efforts to restore the satellite's function failed, it was officially decommissioned.

September 1, 1997 – Salem Township (Washtenaw County)

After numerous persons reported a bright daylight meteor and sonic booms, the object broke up into at least three parts. One meteorite (called the "Worden Meteorite") then struck a residential garage roof (in Salem Township, midway between the villages of Salem and Brookville), as the family was nearby working in their back yard. They had heard a whistling sound passing overhead, and then investigated a boom and crash, finding the garage full of plaster dust, pieces of drywall, and insulation. There was a dent in the roof of a car that was parked in the garage, and the meteorite itself was found on the floor nearby, along with a couple of associated fragments. The large meteorite weighed about 1.5kg, and its dimensions were about 6 inches long, 4 inches wide, and an inch thick.

April-May, 1998 – International

The failure of the attitude control system of an expensive Galaxy IV satellite (the cost of such satellites is usually on the order of $200 to $250 million) disrupted the function of about 45 million pagers. Various other satellite problems were noted, and researchers eventually concluded that these problems were "caused, or at least exacerbated by" the impacts of geomagnetic conditions originating from "highly disturbed" solar conditions. Although the satellite problems occurred in May, weeks of problematic space weather that had started back in April was considered to have eventually led up to May's events.

June 14, 2002 – International

Another "near miss," in celestial terms, as asteroid 2002 MN passed within 75,000 miles of the Earth, but wasn't spotted until three days after it had already passed. An impact from the asteroid would have been of Tunguska-like force.

Feb 1, 2003 – National

The Space Shuttle Columbia broke apart violently when returning from a mission, causing a widespread alert about the potential for falling debris across the southwestern United States. More than 2,000 debris impact sites were eventually reported, but fortunately these were predominantly in sparsely populated areas. NASA issued warnings that the shuttle debris could contain hazardous materials and that it should remain untouched (and instead be reported to authorities upon discovery).

March 26, 2003 – "Park Forest event" in Suburban Chicago, Illinois

Hundreds of meteorites fell across residential areas in the suburbs of Chicago. Although meteors were visible from Michigan and the meteorites landed fairly close to Michigan territory, it must be noted that this event is highly unusual, having been described as "the most densely populated region to be hit by a meteorite shower in modern times." Coincidentally, the area of impact was in the midst of numerous highly-trained experts associated with the University of Chicago and other scientific institutions. The original meteoroid was calculated to have been between 1 and 7 thousand kilograms (possibly more) before it broke apart in the atmosphere. About 30 kilograms of meteorite fragments were recovered, the largest of them weighing 5.26kg. Numerous holes were punched through windows, roofs, and ceilings in homes, and also a fire station. One roof hole was caused by a meteorite that weighed only 545 grams. There were about 18 documented fragments of about that size or larger across a couple of square miles of neighborhoods.

October and November, 2003 – International

Geomagnetic storms took place in late October and November, and although power grids had learned from the March 1989 event and were better able to withstand the storms' effects, there were some heavy impacts upon the aviation sector from this event. The FAA had implemented a WAAS (Wide Area Augmentation System) to better guide navigation and aviation system control, and a part of what WAAS supports is the ability of air traffic to maintain safe distances from each other. The vertical navigation component of WAAS was disabled for approximately 30 hours across most of the United States during the late October storms.

January 2005 – International

Space weather at this time included solar radiation storms. In addition to the loss of HF radio communications, such storms can cause elevated radiation exposure to persons in aircraft flying at high latitudes (e.g. across polar regions). The use of polar routes has increased dramatically since the 1990s, since such routes can reduce travel time and fuel costs (by avoiding strong wintertime headwinds). Aircraft must divert to lower-latitude routes during such storm events, resulting in delays, increased flight times, missed connections, higher costs, and greater fuel consumption.

December 2005 – International

A geomagnetic storm caused the disruption of satellite-to-ground communications and GPS (Global Positioning System) navigational signals. Although this disruption only lasted about 10 minutes, it threatened the safety of commercial air flights and marine traffic during that time.

December 6, 2006 – International

A burst of solar radio wave energy caused a disruption in the function of GPS units across the entire sunlit side of the Earth (the Western hemisphere in this case). Some users of navigation systems found their capacities disrupted for many minutes, which was of particular significance for military aircraft.

September 20, 2007 – Southern Peru

After a loud explosion was heard, residents of an isolated village found a large crater measuring 41 feet in diameter near Lake Titicaca and filled with water. A 1.5 magnitude earthquake was detected in the area. The unusual aspect of this incident is that many villagers subsequently reported symptoms such as headaches and nausea. It has been proposed that the impact of a meteorite, along with the heat that was generated, caused the release of toxic fumes from the ground.

February 4, 2011 - International

An asteroid designated as 2011 CQ1 was the closest "near miss" on record so far, as this object came only about 3,400 miles away from Earth. Earth's gravitational pull at that distance was strong enough to change the asteroid's trajectory by 60 degrees, indicating just how close the object was, in astronomical terms.

June 27, 2011 - International

An asteroid designated as 2011 MD passed only 7,600 miles above the Earth's surface. It was discovered by LINEAR and its size was less than 20 meters in diameter. The object was close enough to markedly change its trajectory as it passed.

Image showing identified impact crater sites across the United States and Canada

(Map based on information from the Impact Database website – http://www.unb.ca/passc/ImpactDatabase/NorthAmerica.html)

Programs and Initiatives

In recent decades, a number of programs and research projects have examined this hazard, sought additional information about near-Earth objects (NEOs), and developed models of the potential risks and effects of an impact. Although most historic meteors went unnoticed (or unrecorded as such) in earlier times, today's satellite systems allow practically every meteor to be detected as it ignites in the atmosphere.

Near-Earth Object Detection Programs

Various agencies and universities have set up or coordinated in the creation of detection programs designed to locate and measure the characteristics of Near-Earth Objects such as "Apollo asteroids" that cross the orbit of the Earth. (It has been estimated that there are about 200 such asteroids with diameters of at least 1km, which would thus be capable of catastrophic damage if an impact were to occur. It has also been estimated, by NASA, that fewer than 10% of the estimated NEOs larger than a half-mile in diameter have yet been detected.) Most of these detection programs involve

systematic telescope surveillance, measurements, complex modeling and orbital projection. Programs include the following:

- Lincoln Near-Earth Asteroid Research (LINEAR) project – at MIT, funded by NASA and the USAF.
- Lowell Observatory NEO Survey (LONEOS) program – in Flagstaff, Arizona.
- Near-Earth Asteroid Tracking (NEAT) system – operated by NASA's Jet Propulsion Laboratory in conjunction with the U.S. Air Force on Mt. Haleakala, Hawaii. The goal of NASA's 1998 Near-Earth Object Program was to locate at least 90 percent of all NEOs that are at least 1km in diameter.
- Palomar Planet-Crossing Asteroid Survey
- Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) – Hawaii program supported by the U.S. Air Force.
- Raptor – a stereoscopic observation system operated by Los Alamos National Laboratory.
- The Sentry System – of the NASA Jet Propulsion Laboratory
- Spaceguard – started by NASA in 1998, a global survey devoted to asteroid analysis.
- The Spacewatch program – run by the University of Arizona in Tucson at Kitt Peak, Arizona.
- Various space missions have occurred to gather more information about asteroids and comets, and more are planned for the future. Some past missions have included Vega 1, Vega 2, Giotto, Suisei, and Sakigake (1986 flybys of Halley's Comet); Galileo (1995 observations of the Shoemaker-Levy comet impact); Near-Earth Asteroid Rendezvous (NEAR—asteroid investigations from 1997 to 2001); Deep Space 1 (comet rendezvous in 2001), Stardust (comet material collected and returned for analysis in 2006); Hayabusa (aka MUSES-C – asteroid landing and probing form 2005 to 2010); Rosetta (asteroid flybys from 2008 to 2010, and comet interception mission scheduled for 2014-2015); and Deep Impact/EPOXI (comet rendezvous in 2005 and flyby in 2010). Additional missions can be expected to provide even more information.

More information about these programs can be found at their associated web sites on the internet.

Solar Monitoring and Measurement Programs

Various spacecraft are gathering data on solar flares, coronal mass ejections (CMEs), and charged-particle emissions (solar storms and space weather). These include:

- The Solar and Heliospheric Observatory (SOHO) (http://sohowww.nascom.nasa.gov/) is a collaborative international project between the U.S. National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA). It was launched in 1995. Among its solar studies, it tracks the intensity of solar winds and flares, and has also been responsible for the discovery of 2000 comets.
- Hinode – A Japanese satellite that engages in solar missions coordinated with other space agencies around the world, Hinode employs optical, ultraviolet, and X-ray equipment that measures the Sun's magnetic field, the Sun's corona (turbulent outer atmosphere), and the solar particles that are radiated.
- Solar Terrestrial Probes (STP) – Currently, the Solar Terrestrial Relations Observatory (STEREO) is the third of NASA's Solar Terrestrial Probes program and has been engaging in 3-D observations, imaging, and measurements of solar activity since 2006. Using a pair of spacecraft, the combined views cover most of the solar surface at all times, including the far side of the Sun, and make use of extreme ultraviolet waves to better detect and analyze coronal activity. A phone application is available from NASA that allows solar monitoring and the receipt of alerts to be transmitted to users' phones. The STEREO web site is located at http://www.nasa.gov/mission_pages/stereo/main/index.html. On February 3, 2011, the two STEREO craft reached positions directly opposite each other, 180 degrees apart on each side of the Sun, allowing the entire surface to be monitored simultaneously. A Magnetosphere Multiscale (MMS) mission is planned for 2014, and will study three important plasma processes in the Earth's magnetosphere, to better understand space weather processes.
- Advanced Composition Explorer (ACE) – Launched in 1997, NASA's ACE provides solar wind monitoring and measurement in nearly real-time. From its space location at a point of gravitational equilibrium between the Earth and the Sun, ACE provides one hour of advance notice about impending geomagnetic activity that can disrupt communications and/or overload power grids. ACE instruments provide information about energetic ions and electrons, magnetic field vectors, high energy particle flux, and solar wind ions. The ACE web site is found at http://www.swpc.noaa.gov/ace/.
- Solar Dynamics Observatory – This program was designed by NASA to help understand the causes of solar variability, and its impacts on Earth. Launched in 2010, the mission focuses on the Sun's magnetic field, solar

coronal activity and plasma, space weather, and the irradiance underlying planetary ionospheres. The SDO web site is at http://sdo.gsfc.nasa.gov/mission/about.php.

NOAA/NWS Space Weather Prediction Center

A web site at http://www.swpc.noaa.gov/ allows continuous access to information about space weather, including the convenient classification of space weather into NOAA's convenient 5-category schemas (e.g. from G1 to G5). Alerts and warnings are also accessible through this web site, along with a number of Space Weather User Groups, covering topics such as navigation, radio, electric power, and satellite operators.

Grid Reliability and Infrastructure Defense Act (GRID)

In 2010, the U.S. House of Representatives passed an act that included the following language specifically directed toward mitigating some of the impacts of geomagnetic storms:

"Geomagnetic storms.--Not later than 1 year after the date of enactment of this section, the Commission shall, after notice and an opportunity for comment and after consultation with the Secretary and other appropriate Federal agencies, issue an order directing the Electric Reliability Organization to submit to the Commission for approval under section 215, not later than 1 year after the issuance of such order, reliability standards adequate to protect the bulk-power system from any reasonably foreseeable geomagnetic storm event. The Commission's order shall specify the nature and magnitude of the reasonably foreseeable events against which such standards must protect. Such standards shall appropriately balance the risks to the bulk-power system associated with such events, including any regional variation in such risks, and the costs of mitigating such risks."

The full text of the act can be found at http://www.fas.org/irp/congress/2010_cr/grid.html.

II. Technological Hazards
A. Industrial Hazards

The following outline summarizes the significant industrial hazards covered in this section:

1. Fires
    - a. Structural Fires
    - b. Scrap Tire Fires
2. Hazardous Material Incidents
    - a. Hazardous Material Incidents – Fixed Site (including industrial accidents)
    - b. Nuclear Power Plant Emergencies
    - c. Hazardous Material Incidents – Transportation
    - d. Petroleum and Natural Gas Pipeline Accidents
    - e. Oil and Natural Gas Well Accidents

This section covers many related types of events that stem from breakdowns or weaknesses in industry and the built environment. The starting section, structural fires, considers various types of large fires that occur in the midst of important buildings or structures. Since a frequent cause of structural fires involves natural gas explosions, the chapters involving natural gas (pipelines and wells) appear nearby, to make easier a more thorough reading about this shared source of risk. Although small residential fires are common, and can be the cause of larger urban conflagrations, this hazard analysis focuses in particular on those larger-scale fires that have greater potential to affect an entire community—either through a fire's sheer magnitude or through the vital nature of the facilities or resources it affects. For this 2012 edition of the Michigan Hazard Analysis, new consideration and detail is provided for "urban conflagrations" in which dense urban development may allow fires to spread over many blocks, or even the entire core of the built-up area.

Scrap tire fires are a special case of industrial hazard, for although they do not typically affect a specific structure, these types of fires do involve toxic smoke and chemical residues that have more in common with hazardous material incidents than with ordinary residential and wildfire events. The following chapters, specifically dealing with hazardous material incidents, cover a wide array of extremely hazardous substances across diverse situations that typically involve industrial or warehousing operations. The section on fixed site incidents includes a consideration of fire-related industrial accidents and explosions, even if these did not involve extremely hazardous substances. Again, the emphasis is on events of a relatively large magnitude—those that resulted in community states of emergency, evacuations, impairment or loss of economically significant or critical facilities, or multiple casualties. A separate chapter deals with nuclear power plant emergencies, and then consideration is given to various forms of transportation incidents that may involve hazardous materials, including separate chapters about pipeline infrastructure and wells that have been dug for production purposes.

Overlap Between Industrial Hazards and Other Sections of the Hazard Analysis

Various types of structural, scrap tire, and industrial fires and incidents may stem from deliberate actions, rather than accidental causes. In such cases, the incidents tie in with the terrorism and civil disturbance chapters, in the Human-Related hazards section of the hazard analysis. Large scale disaster events may also cause these types of fires to occur—lightning strikes have actually caused the direct ignition of structural fires, and the destruction caused by tornados can lead to fires as well. Wildfires have a clear potential to ignite structures, and may also come to involve scrap tire storage areas. Although the chances are slim, earthquakes and celestial impact events might also result in the occurrence of structural or industrial fires. There might be certain conditions under which infrastructure failures are connected with fires. An indirect link also exists between extreme temperatures and winter weather, as various means of heating indoor areas have been known to increase fire risks. A major transportation incident has the potential to start a fire, and certain kinds of catastrophic incidents (such as nuclear attack) would certainly create fires.

A structural fire involving one or more critical facilities has the potential to cause infrastructure failures, energy emergencies, flooding, wildfires, dam failures, transportation accidents, and nuclear power plant emergencies. Hazardous materials incidents of any type (including scrap tire fires) may lead to public health emergencies if they are large enough, or if the involved substances are hazardous enough. If a fire or hazardous materials incident stems from some sort of systematic official negligence then there may be a potential for civil disturbance or sabotage/terrorism to take place.

STRUCTURAL FIRES

A fire, of any origin, that ignites one or more structures, causing loss of life and/or property.

Hazard Description

In terms of average annual loss of life and property, structural fires—often referred to as the "universal hazard" because they occur in virtually every community—are by far the most common hazard facing most communities in Michigan and across the country. Each year in the United States, fires result in approximately 5,000 deaths and 25,000 injuries requiring medical treatment. According to some sources, structural fires cause more property damage and loss of life than all types of natural disasters combined. Direct property losses due to fire exceed $9 billion per year, and much of that figure is the result of structural fires.

In 2008 alone, there were 3,320 civilian deaths and 16,705 civilian injuries as a result of fire in the United States, along with 118 firefighters killed while on duty. There were an estimated 1.5 million fires in 2008, and direct property loss due to fires was estimated at $15.5 billion. This figure includes the 2008 California wildfires, with estimated losses of $1.4 billion. There were 515,000 structure fires in the United States in 2008 that resulted in 2,900 civilian deaths, 14,960 civilian injuries, and $12.4 billion in property damage. Every 22 seconds, a fire department responds to a fire somewhere in the nation. A fire occurs in a structure at the rate of one every 61 seconds, and in particular a residential fire occurs every 78 seconds. Nationwide, there is a civilian fire injury every 31 minutes. In 2008, structure fires represented 34% of the total fires across the United States.

Unfortunately, although the United States has made great strides in lessening deaths and injuries caused by other types of disasters, structural fires are worse problems in this country than in many other industrialized countries (even those with a more densely-developed population pattern). The United States Centers for Disease Control (CDC) figures indicate that fire-associated mortality rates in the United States are approximately 2-3 times greater than those in many other developed countries. According to the Federal Emergency Management Agency's National Fire Data Center, residential fires represent 78% of all structural fires and cause 80% of all fire fatalities. Approximately 83% of those fatalities occur in single-family homes and duplexes. Perhaps the most tragic statistic of all is that over 40% of residential fires and 60% of residential fatalities occur in homes with no smoke alarms. (Studies have repeatedly shown that a working smoke alarm dramatically increases a person's chance of surviving a fire.)

Michigan's fire experience generally mirrors the national fire situation. According to statistics compiled by the Fire Marshal Division of the Michigan Department of Licensing and Regulatory Affairs for 2003, nearly 19,000 structural fires occurred in Michigan, resulting in 161 deaths and 624 injuries. The dollar loss for all fires was estimated at over $230 million. The Fire Marshal Division estimated that a structural fire occurred in Michigan about every 28 minutes in 2003. Michigan's fire death rate of 15.4 persons per million puts it toward the middle of all states in the nation in 2006. As the following table indicates, Michigan is ranked 19th in terms of fire deaths per million population. Michigan's fire death rate is ranked third in the Midwest, behind Missouri and Indiana as of 2007.

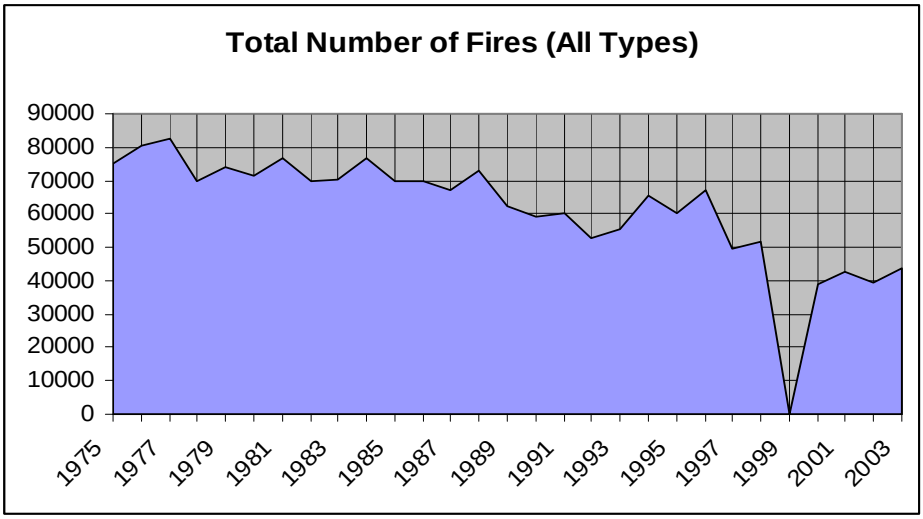
During the period from 1975-2009, the number of reported fires in Michigan (both structural and nonstructural) has trended downwards from a high of just over 80,000 to the current low of around 40,000, with yearly numbers fluctuating within this range. The number of structural fires represents approximately 35-40% of those yearly totals. Although fire risks are clearly a major concern, most of the incidents are of a limited scale and do not threaten or harm an entire community. This analysis will focus on major fires that do cause a severe impact to local communities—as disaster events.

Fire Death Rate per Million Population: 2007

State	Fire Rate	State	Fire Rate	State	Fire Rate
District/ Columbia	39.2	Indiana	15.6	Wyoming	9.6
Mississippi	28.4	**Michigan**	**15.4**	Montana	9.4
Arkansas	26.0	Vermont	14.5	Connecticut	9.2
Alaska	25.1	Nevada	14.4	Washington	8.8
Oklahoma	24.9	Illinois	14.2	Iowa	8.7
West Virginia	24.8	Delaware	13.9	Idaho	8.7
Louisiana	23.8	Virginia	13.3	Minnesota	8.7
Alabama	22.6	Wisconsin	12.7	Colorado	8.3
Tennessee	22.5	Ohio	12.5	California	8.2
Missouri	20.1	Nebraska	12.4	Arizona	7.9
North Carolina	19.5	Utah	11.6	New Jersey	7.5
Pennsylvania	19.2	South Dakota	11.3	Massachusetts	6.9
Georgia	18.8	Texas	11.2	Maine	6.8
Kentucky	18.6	New Mexico	11.2	New Hampshire	6.8
South Carolina	17.4	New York	10.7	North Dakota	6.3
Kansas	17.3	Florida	9.8	Rhode Island	5.7
Maryland	16.2	Oregon	9.6	Hawaii	3.9

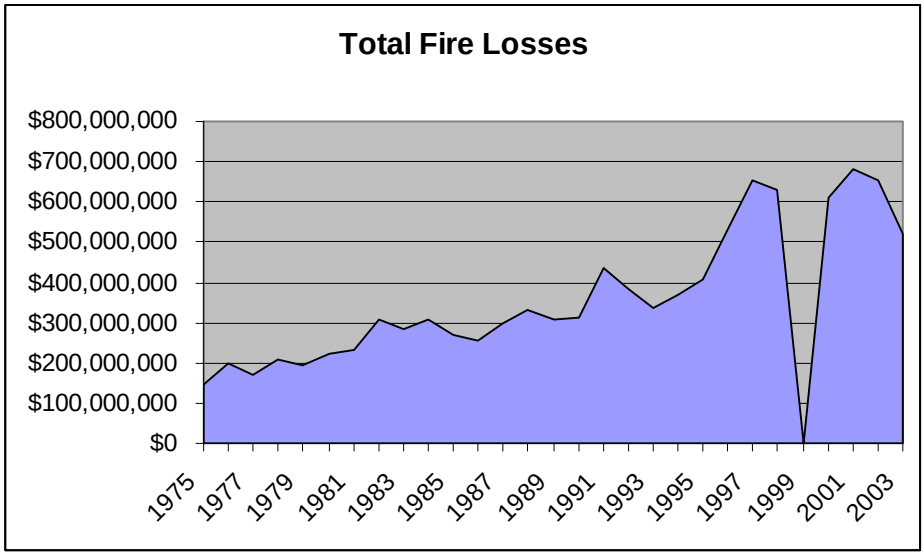
Source: U.S. Fire Administration web page, Federal Emergency Management Agency (National Fire Data Center)

Total Number of Fires (all types) in Michigan: 1975-2003



Note: There was no annual report of fires in 1999 due to the transfer to NFIRS
Source: Michigan Department of Licensing and Regulatory Affairs (LARA), Fire Marshal Division / MFIRS
(Note: Approximately 35-40% of the total number of fires are structural fires.)

Total Fire Losses in Michigan: 1975-2003



Note: There was no annual report of Fires in 1999 due to the transfer to NFIRS
Source: Michigan Department of Licensing and Regulatory Affairs (LARA), Fire Marshal Division / MFIRS
(Note: Approximately 75% of the total losses are structural fire-related.)

The State Fire Marshal, Department of Licensing and Regulatory Affairs / Bureau of Construction Codes and Fire Safety, and local fire departments are proactive in attempting to reduce the number, scope, magnitude, and impacts of structural fires in Michigan. State and local fire service efforts in the areas of training, public education, incident tracking, construction plan review, site inspection and fire analysis are all oriented toward, and contribute to, structural fire mitigation and prevention. However, like most programs, the amount of work that can be done is directly related to funding and programmatic priorities.

Nature/Composition of Michigan Fire Service

The primary challenge facing the State Fire Marshal, in particular, and the State of Michigan, in general, is the nature and composition of the Michigan fire service. The high proportion of fire fighters that are either volunteer or paid part-time (roughly 3/4 of the fire service) presents significant challenges for sustaining adequate code enforcement and inspection efforts. In addition, the relatively high level of turnover within this group places additional demands on state and local training resources. Also, with the effects of recession, especially in the State of Michigan, many fire fighters have been laid off or had their positions cut due to a lack of funding. For example, in March 2010, the city of Flint laid off 23 firefighters and 46 police officers, and closed two fire stations due to budget deficits.

The lack of full-time professional fire fighters in many areas of the state means that less time is available to conduct fire inspections and take other preventive measures necessary to lessen the structural fire threat. In many small towns and rural communities, local efforts in fire prevention are almost non-existent, due to lack of personnel and time to devote to such activities. Out of necessity, efforts in these communities are directed primarily at fire suppression. Clearly, the lack of full-time paid fire professionals in many areas across the state poses great challenges for maintaining a sustainable fire prevention and inspection program.

Lack of State Fire Safety Code

The other major challenge facing the Michigan fire service is the lack of a state-mandated fire safety code and code enforcement program for all occupancy types. Although the State enforces fire safety codes in schools, dormitories, health care facilities, and correctional facilities, plus some businesses, the remainder of the job is left to local officials. Because there is not a uniform, mandated fire safety code for everyone to adhere to, a plethora

of local ordinances have emerged. In some communities, fire safety codes do not exist at all. This contributes to Michigan's structural fire problem by allowing serious fire safety violations to go unchecked, often for years at a time. This problem manifests itself more seriously in rural areas and small towns, which typically have few, if any, paid full-time fire fighters. In Michigan's larger cities, full-time fire departments with qualified inspectors are the rule rather than the exception. As a result, fire safety inspections are performed on a more regular basis, but not necessarily as often as they should be.

Even if a mandated fire safety code were instituted statewide, it wouldn't totally solve the problem of structural fire prevention because the costs of compliance in existing buildings would often be prohibitive for business owners. Such a measure would, however, help to ensure that new construction doesn't compound the problem.

Impact on the Public

Structural fires can cause displacement and homelessness, in addition to serious injuries, death, and economic losses. Beyond the small-scale structural fires that only affect a single home or two at a time, emergency management authorities are primarily focused on disaster-level events involving multiple or major structures such as hotels, college residence halls, and major employers and community facilities (such as schools and hospitals). The impacts upon local services and economies can be severe in such cases, due to the number of residents served and the diversity of needs being met by these facilities. Structural fires occur more frequently than other Michigan hazards, and also cause more deaths, injuries, and property damage.

Impact on Public Confidence in State Governance

Structural fires may raise questions about code enforcement and other regulations that may be connected with state government. Some fires may originate from utility malfunctions (e.g. natural gas explosions) or wildfire events, and thus call into question the capacity of the state to foresee, regulate, or manage such situations. Emergency management personnel are particularly interested in structural fires that can produce disaster-level events involving major or multiple structures, major employers, or community facilities. Examples include hotels, college residence halls, schools, hospitals, factories, and "main street" commercial areas. If severe economic or service disruptions result from such fires, the viability and reliability of government operations, design standards, and procedures may be called into question. The fact that regulatory controls may be created and implemented at the local level does not necessarily absolve State government from responsibility, since municipalities are legally considered to be "creatures of the state" and could potentially have their safety policies formulated by state legislation, and implemented by state agents.

Impact on Responders

The structural fire hazard, from the perspective of emergency management, does not generally involve common residential fires that primarily affect a single home, but instead deals with large-scale events that involve critical, large, or multiple structures, utilities infrastructure, industrial facilities, nursing homes, dormitories, hospitals, hotels, and other locations that involve greater risk and complexity due to the potential numbers of vulnerable people involved, the vital nature of the site for the community, or the potential for exposure to hazardous materials. Extensive search and rescue operations may be warranted under major structural fire conditions. Special training, staffing, and equipment is often useful or necessary to effectively deal with such events.

Impact on the Environment

Air pollution issues are inherent to structural fire events, including vast amounts of carbon released from the flames, various chemicals burning within the building's materials, other forms of air pollution, and ash spread widely around the area. Large, dark, and thick smoke plumes from large burning structures can alter atmospheric conditions and lead to shifting wind patterns that affect other areas. Fires may spread to other structures and to natural vegetation, negatively affecting the environment. The burning of nearby native forests, trees, and grasslands can be some environmental consequences of structural fires. Chemicals from combustion may contaminate nearby water in lakes, reservoirs, rivers, and swamps. Agricultural structural fires can also affect farm animals and ruin agricultural products. The waters used to quell fires can spread the combustion products

(chemicals, soot, ash) into nearby areas, and into municipal sewer systems where they may affect the environment at system outlet locations.

Significant Structural Fires

Unfortunately, Michigan has not been immune to large structural fires that resulted in a significant loss of life. Michigan has not had a catastrophic structural fire disaster in recent years that resulted in a significant loss of human life or significant injury. However, in any given year it is not uncommon for several multiple-casualty residential structural fires to occur throughout the state. Despite the best efforts of fire officials in fire safety education and prevention, deadly residential fires continue to occur year after year.

For example, a January 10, 2002 arson fire at an apartment complex in Detroit killed two women and left over 100 people homeless. An August 29, 2002 house fire in Detroit killed three adults and a baby girl and also left one man injured. An October 16, 2002 fire at an unlicensed adult care facility in Flint killed five elderly residents. On January 26, 2003, a kitchen fire in a Detroit home spread through the house, killing five people trapped in by bolted burglar bars around the windows. On July 29, 2003, six persons (mostly children) perished in a house fire in Pontiac. A December 17, 2003 house fire in Grand Rapids killed all seven people inside, ranging in age from two to seventy. On January 25, 2004, burglar bars also trapped one adult and four children during a house fire at a home in Mount Morris Township, Genesee County, killing everyone inside. On July 10, 2007, two persons died in a Livingston County house fire. On Thanksgiving November 22, 2007 two people were killed in an Otsego house fire as a result of non working smoke detectors. On January 20, 2008 a massive structural fire in Grand Rapids resulted in the destruction of over 100 condominium units in two adjacent buildings. Around 200 individuals escaped the building, and although nobody was injured, four persons had to be rescued. On February 12, 2008 a fire raced through a home in rural northern Michigan before dawn, killing a man and his four children and sending the children's mother to the hospital. On September 29, 2008 a house fire in Coopersville resulted in four deaths. On April 25, 2009, a fire at a house in Texas Township, Kalamazoo County killed four young children and one adult. In May 2009 about 777 acres and 33 structures, including houses and outbuildings, burned in Marquette County, southwest of Ishpeming, and caused about 500 persons to be evacuated. On December 31, 2009, two fatalities and several injuries occurred during an apartment complex blaze in Detroit. A townhouse fire in Flint killed four children on February 14, 2010. On March 3, 2010 three children were killed during a Detroit house fire and another four survived by jumping out of a window to be caught by men who were providing assistance. On April 14, 2011 two people died in a house fire in Grand Rapids.

Fires in congregate facilities such as hotels, entertainment venues, schools, and hospitals pose an even greater risk due to the larger number of persons involved. As the following tables indicate, when catastrophic fires occur in congregate facilities, the human toll can be severe.

Catastrophic Structural Fire Disasters in the United States

HOTELS:

Structure	Date	# Fatalities	Structure	Date	# Fatalities
Newhall House (Milwaukee)	1883	71	Lane (Anchorage)	1966	14
Hotel Royal (New York City)	1892	28	Hotel Fire (Seattle)	1970	19
Windsor Hotel East (NewYork)	1899	35+	Pioneer Intl. (Tucson)	1970	28
Kerns (Lansing)	**1934**	**34**	Ponet Sqr. (Los Angeles)	1970	19
Terminal (Atlanta)	1938	35	Hotel Vendome (Boston)	1972	9
Marlborough (Minneapolis)	1940	19	Washington House (W .V.)	1974	12
Gulf (Houston)	1943	55	Pomona (Portland)	1975	12
LaSalle (Chicago)	1946	61	Path Finder (Nebraska)	1976	20
Canfield (Dubuque)	1946	19	Coates House (Kansas C.)	1978	16
Baker (Dallas)	1946	10	MGM Grand (Las Vegas)	1980	87 (700+ inj)
Winecoff (Atlanta)	1946	119	Stouffers Inn (New York)	1980	26
Thomas (San Francisco)	1961	22	Hilton (Las Vegas)	1981	8 (252 inj)
Surfside (Atlantic City)	1963	25	Royal Beach (Chicago)	1981	19
Roosevelt (Jacksonville)	1963	22	Alexander Hamilton (N. J.)	1984	15

ENTERTAINMENT VENUES:

Structure	Date	# Fatalities	Structure	Date	# Fatalities
Richmond Theatre (Virginia)	1811	160	Circus (Connecticut)	1944	169(700+inj)
Brooklyn Theater (New York)	1876	295	Restaurant (Ohio)	1965	22
Theater (Chicago)	1903	602	Lounge (Gary, IN)	1968	13
Rhoads Theater (PA)	1908	170+	LA Cocktail Lounge (L.A.)	1973	32
Dance Hall (Louisiana)	1919	25	Social Club (New York)	1976	25
Dance Hall (Mississippi)	1940	207	Supper Club (Kentucky)	1977	167
Strand Theater (Massachusetts)	1941	13	Happy Land (New York)	1980	87
Nightclub (Massachusetts)	1942	492	The Station (Rhode Island)	2003	100

SCHOOLS:

Structure	Date	# Fatalities	Structure	Date	# Fatalities
Collinwood (Ohio)	1908	176	New London (Texas)	1937	295-500?
Peabody (Massachusetts)	1915	22	Cleveland (New York)	1954	15
Cleveland (South Carolina)	1923	77	Chicago (Illinois)	1958	93
Babbs Switch (Oklahoma)	1924	36	-	-	-

HEALTH CARE:

Structure	Date	# Fatalities	Structure	Date	# Fatalities
Hospital (Oklahoma)	1918	38	Nursing Home (Missouri)	1957	72
Manhattan State (New York)	1923	25	Hospital (Connecticut)	1961	16
Clinic (Ohio)	1925	125	Nursing Home (Ohio)	1963	63
Little Sisters of Poor (Pitt., PA)	1931	48	Nursing Home (Indiana)	1964	20
St. Anthony's Hospital (Illinois)	1949	77	Nursing Home (Ohio)	1970	31
Mercy Hospital (Iowa)	1950	41	Nursing Home (P.A.)	1971	15
Nussing Home (Florida)	1953	35	Mental Hospital (M.S.)	1978	15
Nursing Home (Missouri)	1956	12	Wayside (Missouri)	1979	25

INDUSTRIAL/ FACTORIES:

Structure	Date	# Fatalities	Structure	Date	# Fatalities
New York City (New York)	1911	146	Texas City (Texas)	1947	561
Pittsburgh (Pennsylvania)	1927	28	**Livonia (Michigan)**	**1953**	**6**
Los Angeles (California)	1947	15 (150+ inj)	Hamlet (North Carolina)	1991	25

PRISONS:

Structure	Date	# Fatalities	Structure	Date	# Fatalities
Columbus (Ohio)	1930	329	Jacksonville (Florida)	1967	37

Source: ***The Public Health Consequences of Disasters - 1989,*** U.S. Department of Health and Human Services; Lansing State Journal

December 24, 1913: Not an actual fire, but the threat of a fire caused the suffocation deaths of 73 persons (mostly children) in Calumet's Italian Hall when someone attending a party there yelled "Fire!", sending masses of party goers in a mad rush for the exit. Although there was no fire, 73 persons died while attempting to escape down a stairwell that had doors that opened inward. The perpetrator of the tragic false fire alarm was never identified.

A 1927 fire at the Briggs Manufacturing Plant in Detroit resulted in 21 deaths. A 1934 fire at the Kerns Hotel in downtown Lansing killed 34 and injured 40.

February 8, 1951: Although it did not result in any loss of life, the arson fire at the State Office Building in Lansing was another significant structural fire that had a profound impact on Michigan. That fire, which caused close to $7 million in damage and burned for a week—destroyed thousands of irreplaceable state records and archives, including the Michigan Library. The fire was started by a young employee who thought having a criminal record would prevent him from being drafted into the Korean War.

August 2005: Another example of a catastrophic fire that did not result in any loss of human life is the blaze at a poultry farm in Berlin Township, Ionia County. The fire destroyed an egg-production building at one of the state's largest poultry farms, causing the death of over 250,000 chickens and $5 million in damage. Sixteen fire departments from four counties responded to the fire that destroyed the 150-by 600-foot building, which housed egg-laying hens.

Urban Conflagrations

It seems important to mention some of the major historical fires that have been so destructive to cities in the past, because many historical sections of Michigan's current cities remain at risk, due to their development densities and original designs that would not meet current construction and fire safety requirements. Events such as the Great Chicago 1871 fire, San Francisco's 1906 earthquake-related conflagration, and others should serve as reminders that older sections of cities may be more vulnerable to the spread of structural fires.

The following list refers to significant structural fires in Michigan communities, especially those that affected major facilities or downtown business districts, caused tremendous physical damage, death, loss of tax base due to business closures, and negatively impacted other important aspects of those communities.

Additional major urban conflagrations or significant structural fire events in Michigan

6/11/1805 Detroit

All but one of the town's 300 buildings were destroyed. Territorial governor William Hull then authorized the 1807 plan of Detroit, with a less compact and crowded urban design less amenable to catastrophic fires—a kind of hazard mitigation planning.

5/10/1848 Detroit

A fire broke out in Detroit that destroyed 107 buildings, including two large warehouses on the river. The burnt district covered over 10 acres of ground. Damage estimates were between $200,000 and $300,000. The number of families deprived of houses was about 200, or nearly 1000 persons.

7/31/1874 Muskegon

A fire destroyed a quarter of the business district and about 200 homes.

6/11/1881 Ludington

A fire destroyed almost the entire downtown (67 buildings).

8/5/1881 "Great Thumb Fire"

Nearly all, if not all of the entire buildings were destroyed in towns from the Michigan "thumb" counties of Huron, Tuscola, and Sanilac. Many Lapeer County buildings were also destroyed. 282 people lost their lives and damage was over $2 million. Over one million acres were burned, and this was also the first disaster served by the American Red Cross.

1/18/1884 Lowell

20 downtown buildings were destroyed by a fire.

9/17/1887 Ironwood

Over half of the downtown's buildings were destroyed by a fire.

12/22/1888 Hermansville

A fire destroyed the entire town of 400+ people; $250,000+ in damages.

5/16/1891 Muskegon

A fire destroyed about 250 buildings / homes, including the court house.

7/25/1892 Bay City

A fire destroyed nearly 350 homes and businesses in a 40 block area, resulting in around 1,800 people going homeless. Strong gale force winds along with the burning of timber-constructed structures contributed to the great spread.

6/28/1893 Augusta

Nearly the entire village of Augusta, with a population of 600+, was destroyed.

11/24/1893 Detroit

One building destroyed; several buildings damaged; 8 fatalities; $700,000 in damages.

7/5/1897 Lake Ann

A fire destroyed all but one building in a village of about 1,000 people.

5/10/1900 Fruitport

A fire wiped out over half of the downtown business district.

5/15/1901 Detroit

Several buildings were destroyed in a fire, resulting in about $1,000,000 in damages.

7/5/1908 Kalkaska

Nearly the entire town was wiped out by a fire.

12/9/1909 Kalamazoo

Several buildings were destroyed in a fire, resulting in about $1,000,000 in damages.

4/3/1910 Rose City

A fire destroyed the entire town of 30+ buildings, except for two concrete structures.

7/11/1911 Oscoda / Au Sable

A fire destroyed about 600 buildings in Oscoda / Au Sable; five fatalities.

7/6/1913 Perry

A disastrous fire consumed nearly the whole downtown area.

10/21/1930 Dewitt

A fire destroyed the downtown business district and several historic buildings.

1/24/1938 Marquette

A fire destroyed downtown buildings during a snow blizzard; $400,000 damages.

3/17/1951 Owosso

One large industrial factory destroyed; $2,000,000 in damages.

2/20/1954 Hartford

One senior citizen home destroyed; seven fatalities.

2/11/1955 Owosso

One large industrial factory destroyed; $2,500,000 in damages.

1/2/1958 Lowell

Seven businesses destroyed in a massive fire.

7/23-30/1967 Detroit

One of the most infamous riots ever in the United States occurred in Detroit from July 23-30, 1967, resulting in over 2,500 buildings damaged. This uprising resulted in the greatest loss of life and the largest destruction of property of any of the national riots of the 1960s. Over 7,000 arrests were made, 43 people were killed, and over 1,000 were injured. Many stores and buildings were set on fire during the riot, as much as six to seven miles out from the initial starting point. Over 150 fires consumed a 15 block area and burned uncontrolled when firefighters were forced to withdraw after being pelted by objects. About 5,000 were left homeless and over 400 structures were burnt or damaged enough to be demolished. Over $50 million in damage had been incurred, due to fires and looting.

10/29-31/1984 Detroit (Note: the event occurred annually but with varying severity)

The Halloween tradition known as “Devil’s Night” reached its peak destruction level as 810 fires were intentionally set over a three day period in late October, in Detroit. The arson destruction during this time period had roots dating back to the 1930s, and it was very common to have hundreds of fires each year before Halloween. In the late 1990s city of officials created “Angel’s Night” where volunteers and law enforcement officials patrol neighborhoods and monitor abandoned buildings, generally starting the night of October 29.

2/8/1987 St. Johns

One business destroyed; $350,000 in damage.

2/10/1987 Ithaca

Four businesses destroyed, two others damaged; $750,000 in damages.

3/6/1987 Ovid

Three businesses destroyed; $175,000 in damages.

3/13/1987 Detroit

Two industrial buildings destroyed; three fatalities; six other injuries.

1/26/1988 Alma

One business destroyed; one death; $150,000 in damages.

3/2/1988 Webberville

One business destroyed; public library destroyed; $200,000 in damages.

6/2/1988 Corunna
Four businesses destroyed; one other damaged; $2.4 million in damages.
11/8/1990 Ovid
One business destroyed; one other damaged; $100,000 in damages.
1/20/1991 Perry
One business destroyed; three others damaged; $225,000 in damages.
2/28/1993 Ludington
Two apartment complexes damaged; nine fatalities; $50,000 in damages.
6/1/1993 Owosso
One factory destroyed; $30,000,000 in damages.
7/18/1993 Grand Ledge
Three businesses destroyed; four others damaged; $525,000 in damages.
4/25/1995 Flint
One business destroyed; over $1,000,000 in damages.
6/26/1999 Suttons Bay
One business destroyed; $700,000 to $1,000,000 in damages.
11/10/1999 Flint
One convalescent home destroyed; five fatalities.
10/5/2000 Oakland
One building destroyed; two buildings damaged; 50 evacuated; $1,800,000 damages.
12/1/2000 Detroit
One apartment complex damaged; six fatalities.
4/2/2001 Detroit
One apartment complex destroyed (all 50 units); three injuries.
4/30/2001 Wixom
One apartment complex destroyed.
5/25/2001 Detroit
Five buildings destroyed.
6/1/2001 Highland Park
Three houses damaged; two buildings damaged; one apartment damaged.
7/3/2001 Detroit
One large downtown building destroyed; other buildings threatened.
8/26/2001 Detroit
One industrial building destroyed; nine injured.
4/16/2002 Detroit
One apartment complex destroyed; 100+ left homeless; two injuries.
5/20/2002 Detroit
One apartment complex destroyed, leaving dozens homeless.
7/5/2003 West Bloomfield
One building destroyed; $2,500,000 in damages.
7/24/2003 Ann Arbor
Four buildings destroyed.
8/18/2003 Inkster
One apartment complex destroyed (all 18 units); one injury.
9/22/2003 Detroit
A natural gas explosion blew up a vacant home and caused two occupied homes to catch on fire. Up to 30 nearby homes may have been damaged by debris.
12/29/2003 Detroit
One apartment complex destroyed (all 34 units); one injury.
1/6/2004 Grosse Pointe
Three businesses destroyed; six apartment units destroyed.
1/20/2004 Springfield Twp
One building destroyed; eight salt trucks destroyed; seven graders destroyed.
3/4/2004 Lake Orion
Six businesses destroyed (some dating back to the 19th century).
8/24/2004 Southfield
One apartment complex destroyed; residents evacuated.
5/13/2005 Highland Park
Block fire with several houses burned—set by an arsonist.

6/20/2005 Detroit
Large vacant industrial plant destroyed; 150 responders; three injuries.
7/12/2005 Detroit
Six units in apartment complex destroyed; six units damaged.
8/10/2005 Ionia
One building destroyed; $3,000,000 in damages; 250,000 chickens killed.
9/13/2005 Hartford
One business destroyed, one apartment complex damaged.
9/23/2005 Utica
One historic building destroyed.
10/16/2005 Detroit
Large vacant industrial building destroyed.
3/3/2006 Ann Arbor
One apartment complex damaged; one fatality; two injured, 100+ evacuated.
5/23/2006 Bay City
One apartment building destroyed (all eight units); several shops destroyed.
12/7/2006 Detroit
One apartment complex destroyed; one fatality; 51 families left homeless.
2/8/2007 Ypsilanti
One apartment complex damaged (six units destroyed); three fatalities.
3/7/2007 Cedar Springs
Fire devastates homes and businesses downtown.
5/7/2007 Presque Isle
Five buildings of a single industry were destroyed in Millersburg.
5/18/2007 Linden
Three businesses destroyed.
7/4/2007 Owosso
Apartment complex destroyed; two businesses damaged; one fatality.
9/16/2007 Mount Pleasant
Three businesses destroyed.
1/20/2008 Grand Rapids
Two buildings destroyed (100+ condominiums destroyed); 200+ evacuated.
1/23/2008 Van Buren Twp
One apartment building destroyed (all 32 units)
2/6/2008 Detroit
One apartment complex destroyed; 100+ left homeless; one fatality; two injuries.
4/3/2008 Bay City
One apartment building destroyed (all 18 units).
6/17/2008 Mount Clemens
10 apartment units destroyed in apartment complex fire.
8/31/2008 Ontonagon
Seven buildings destroyed; $250,000 in damages.
8/21/2008 Harrison Township, Macomb County
One apartment complex destroyed (all 37 units).
10/2/2008 Clare
One business destroyed in large fire; downtown evacuated.
12/10/2008 Shepherd
One business destroyed in a large fire that impacted responders.
2/3/2009 Kalamazoo
One apartment complex destroyed (all 36 units).
2/13/2009 Fenton
One apartment complex destroyed (all 18 units).
3/7/2009 Cedar Springs
Three businesses destroyed; two apartments destroyed.
5/20/2009 Marquette County
33 structures destroyed by wildfire; 500+ evacuated.
6/30/2009 Muskegon
One apartment complex destroyed (all 10 units); five injuries.

7/25/2009 Hancock
One building destroyed; two apartment floors destroyed; four fatalities.
8/5/2009 Big Rapids
One business destroyed; $4,000,000 in damages.
10/25/2009 Ann Arbor
One business destroyed; four apartments damaged; 600+ evacuated.
1/22/2010 Grand Blanc
One apartment complex destroyed (all 24 units).
1/30/2010 Potterville
Four businesses destroyed.
3/19/2010 Wyoming
A fire destroyed a 32 unit apartment complex displacing all 30 residents.
5/17/2010 Homer
Historic 19th Century community mill destroyed.
5/19/2010 Gaylord
One business destroyed; three businesses and two apartment complexes damaged.
9/7/2010 Detroit
At least 85 fires destroyed more than 70 homes in Detroit; strong winds gusting up to 40-50mph, hot and dry conditions, downed power lines, and lack of equipment and man power contributed to the rapid spread.
10/14/2010 Alma
Two businesses destroyed; four other businesses damaged.
3/26/2011 Jackson
Historic 19th Century large factory building destroyed as a result of arson.
5/9/2011 Grand Rapids
One large factory building destroyed.

Although structural fires occur every day in both large cities and small towns in Michigan, what was significant about these particular fires was the level of impact they had on the communities. In some cases, the very lifeblood of the community's business and retail districts was destroyed or severely damaged, affecting not only the structures themselves, but also the community's economy as well. Some of the affected businesses never re-opened. (Note: please refer also to the section on Wildfires, for more information about some of these events.)

State Facility Fire Safety

A February 1999 fire in the G. Mennen Williams Building in Lansing (which houses the Michigan Department of Attorney General) caused $4.2 million in damage and forced the temporary relocation of many employees. The fire is believed to have started in a photocopy machine. Fortunately, the fire occurred over the Presidents Day holiday when the building was mostly vacant, so no injuries occurred. The Williams Building, like many state facilities, was built before sprinkler systems were routinely recommended as a fire safety measure. As a result of this fire, the State Fire Safety Board of the Michigan Department of Licensing and Regulatory Affairs is considering adopting stricter fire safety standards for all state owned and leased facilities—including the installation of fire sprinkler systems in all new facilities and those undergoing major renovation.

A December 22, 2001 fire at the Murray D. Van Wagoner Building in Lansing (which houses the Michigan Department of Transportation) severely damaged the third floor, causing smoke and water damage throughout all of the building's four floors. Fortunately, the building was empty at the time the fire occurred. The fire forced the temporary relocation of several hundred workers until the building could be cleaned up and restored.

College Dormitory Fire Safety

The fire safety of college dormitories across the country was called into question on January 19, 2000 when a predawn fire at a Seton Hall University (New Jersey) dormitory killed 3 students, injured 62, and forced the evacuation of hundreds more students into the freezing cold outside. The Seton Hall tragedy set off a national re-examination of fire safety measures and practices in dormitories and similar congregate housing facilities at colleges and universities. Sensing the need for additional financing of fire safety measures on college campuses,

Congress occasionally considers legislation that would authorize appropriations for nationwide competitive grants to help provide fire sprinkler systems in student housing and dormitories.

In Michigan, fires in two college dormitories in March of 2000 provided a reminder that what happened at Seton Hall University in New Jersey could also happen here given the right circumstances. On March 16, an early-morning fire at a Western Michigan University dormitory in Kalamazoo destroyed a first-floor room and forced the evacuation of more than 400 students. No one was injured in that fire. Three days later, on March 19, a fire in a third floor room at a 175-student Ferris State University dormitory hospitalized one person and left two others with minor injuries. The building's second and third floors sustained extensive fire and water damage.

Michigan colleges do have a history of significant fire incidents, such as in 1986 when 34 students were injured in a Michigan State University dorm fire. Also, on March 9th, 1989 a massive fire gutted 50 percent of Sherzer Hall at Eastern Michigan University. It was classified as one of the most devastating events in the University's history.

In 1998/99, state, local and university officials in Michigan had already begun to take a closer look at the fire safety standards and requirements for Michigan's college and university dormitories. That re-examination resulted in the adoption of new fire safety rules that took effect in December 1999. (See the Programs and Initiatives section below for more details.) Below is a chart showing the statistics of U.S. dormitory fires from 1980-2006. It should be noted that dormitories include school, college and university dormitories; nurses' quarters; convent, monastery and other religious dormitories; and bunk houses and worker's barracks.

U.S. Dormitory Fires: 1980-2006

Year	Fires	Civilian Deaths	Civilian Injuries	Property Damage (in millions)
1980	3,200	13	122	$9.2
1981	2,960	4	118	$12.6
1982	2,420	0	103	$9.4
1983	2,490	9	156	$23.9
1984	2,510	5	50	$11.1
1985	2,440	0	68	$7.8
1986	2,350	5	55	$46.9
1987	2,560	0	76	$10.5
1988	2,430	3	91	$8.1
1989	2,650	0	109	$17.4
1990	2,330	2	80	$24.5
1991	2,270	8	61	$37.1
1992	2,470	2	147	$7.4
1993	2,270	0	73	$8.8
1994	2,320	0	75	$12.6
1995	2,330	0	143	$20.3
1996	2,050	0	78	$10.2
1997	2,200	9	73	$12.2
1998	1,810	5	143	$9.7
1999	1,380	0	190	$5.0
2000	1,780	7	168	$23.0
2001	2,940	6	67	$104.0
2002	3,110	1	19	$20.0
2003	3,350	1	50	$23.0
2004	3,380	3	48	$18.0
2005	3,270	1	59	$37.0
2006	4,290	2	58	$40.0

Source: National Fire Incident Reporting System

Programs and Initiatives

Michigan Fire Prevention Act

The Michigan Fire Prevention Act (1941 PA 207), the State's primary fire enabling legislation, provides for the prevention of fires and the protection of persons and property from exposure to the dangers of fire and explosion. The Act gives the State Fire Marshal (Michigan Department of Licensing and Regulatory Affairs) and local fire chiefs broad authority to take actions necessary to prevent fires and stop the spread of fires once they have started. This includes: 1) requiring the razing, repair, alteration or improvement of buildings and premises that constitute a fire hazard; 2) controlling the use and occupancy of such buildings and premises; and 3) engaging in public education activities aimed at preventing or mitigating the effects of fire and explosion.

Michigan Department of Licensing and Regulatory Affairs, Michigan Fire Fighters Training Council

The Michigan Fire Fighters Training Council, housed within the Michigan Department of Licensing and Regulatory Affairs, performs a number of tasks aimed at developing, improving, and enhancing the training of fire fighters in Michigan. This includes, but is not limited to: 1) developing standards for training and fire fighter selection; 2) establishing courses of study and instructor qualifications and certification; 3) evaluating instructors and schools; and 4) assisting fire departments with training. All of these functions contribute to structural fire mitigation by enhancing the skills of fire fighters in preventing and suppressing fires.

The Michigan Department of Licensing and Regulatory Affairs, in conjunction with local fire departments, conducts a number of other important fire-related initiatives, including: 1) statewide public education programs aimed at preventing fires; 2) investigating fires, explosions and hazardous material incidents; and 3) collecting, compiling and analyzing fire-related data (through the National Fire Incident Reporting System) to determine fire frequency, causes, and impacts; 4) membership association and union membership organization for both fire fighters and fire chiefs.

Michigan's Office of Fire Safety

The Michigan Department of Licensing and Regulatory Affairs' Office of Fire Safety is responsible for conducting fire safety and prevention inspections in state-regulated facilities and certain other facilities. Specific services provided include: 1) fire safety inspections of adult foster care, correctional and health care facilities, and hotels/motels; 2) plan review and construction inspections of the regulated facilities in item (1), as well as schools, colleges, universities, and school dormitories; 3) coordination of fire inspector training programs; and 4) coordination of fire alarm and fire suppression system installation in regulated facilities. These activities are important mitigation activities designed to save lives and protect property from structural fire hazards. The State Fire Safety Board, also housed within the Michigan Department of Licensing and Regulatory Affairs, Bureau of Construction Codes and Fire Safety, promulgates rules covering the construction, operation and maintenance of schools, dormitories, health care facilities, and correctional facilities. These rules are designed to protect life and property at these facilities from fire, smoke, hazardous materials and fire-related panic.

National Fire Protection Association

Established in 1896, the National Fire Protection Association (NFPA) conducts research on fires and fire-related issues, develops codes and standards for fire prevention and protection, and disseminates fire safety information to fire departments and the public. The cornerstone of the NFPA's fire prevention activities is its consensus standards development system. The NFPA's consensus process involves over 6,000 volunteers from a wide range of professional backgrounds who serve on more than 200 technical committees, each reflecting a balance of affected interests. This consensus standards development system resulted in the creation and maintenance of the National Fire Codes, over 300 codes and standards covering all areas of fire safety. Used throughout the world, virtually every building and construction process in place today is affected, in one way or another, by the codes and standards developed through the NFPA system. Even when not written into law, the Association's standards and codes are typically accepted as a professional standard, and are recognized by many courts as such. The NFPA codes and standards help to reduce the structural fire threat in Michigan, and elsewhere.

U.S. Fire Administration

Established by P.L. 93-498, the Federal Fire Prevention and Control Act of 1974, the U.S. Fire Administration (USFA) provides leadership, coordination and support for the nation's fire prevention and control, fire training and education, and emergency medical services activities. The USFA, a branch of the federal Department of Homeland Security, conducts training for firefighters through the National Fire Academy (NFA), located in Emmitsburg, Maryland. Many Michigan firefighters have attended those training courses. In addition, the USFA administers a number of national fire programs aimed at fire prevention, with a particular emphasis on structural fire prevention. The USFA also supports the National Fire Incident Reporting System (NFIRS), administered and implemented in Michigan by the State Fire Marshal (Department of Licensing and Regulatory Affairs). The NFIRS provides the vehicle for collecting and analyzing information on fire frequency and causes, as well as deaths, injuries and property losses associated with fires. Over 900 local fire departments in Michigan participate in the NFIRS. The NFIRS data is used by the State Fire Marshal and other state and local fire agencies to assess and combat the fire problem in Michigan.

Local Fire Service

Over 1,000 local fire departments and roughly 30-35,000 fire fighters constitute the bulk of Michigan's fire service forces. By and large, these local forces are either volunteers or paid part-time (approximately 56% paid part-time; 16% volunteer; 28% paid full-time). According to statistics from the State Fire Marshal, local fire departments in Michigan respond to a fire call, on average, every minute and 17 seconds, and to a structural fire call roughly every 28 minutes. In addition to fire suppression, local fire departments in Michigan also conduct vitally important public education, code enforcement and fire investigation activities within their respective communities. Local fire departments are the lifeblood of Michigan's fire prevention and suppression system.

The Hotel and Motel Fire Safety Act of 1990 (PL101-391)

The Hotel and Motel Fire Safety Act of 1990 was passed into law by Congress to save lives and protect property by promoting fire and life safety in hotels, motels and other places of public accommodation. The law mandates that traveling federal employees must stay in public accommodations that adhere to the life safety requirements in the legislation's guidelines. PL101-391 also states that federally funded meetings and conferences cannot be held in properties that do not comply with the law. The United States Fire Administration (USFA) has been charged with carrying out FEMA's responsibilities with respect to the Hotel and Motel Fire Safety Act of 1990. In addition to compiling, maintaining and publishing the National Master List, the USFA is also responsible for taking steps to encourage states to promote the use of automatic sprinkler systems and automatic smoke detection systems.

Fire Safety Rules for Michigan Dormitories

Even before the Seton Hall University dormitory fire in January, 2000, the State Fire Safety Board took action to enhance the fire and life safety protection of Michigan's college and university dormitories. On December 21, 1999 two new sets of rules took effect governing the construction, operation, and maintenance of school, college and university instructional facilities and dormitories. These sets of rules were updated to meet the most current nationally recognized standards from the National Fire Protection Association. The new rules adopted the 1997 edition of NFPA 101, Life Safety Code. NFPA standards provide the minimum requirements necessary to establish a reasonable level of fire and life safety and property protection from hazards created by fire and explosion.

The new rules require, among other things, that fire sprinklers be installed in newly constructed dormitories or those undergoing major renovations. However, existing dormitories don't fall under the new rules and therefore do not have to be retrofitted unless they are being renovated.

U.S Fire Corps

In 2002, President George W. Bush announced the creation of the USA Freedom Corps, which is an effort to foster a culture of service, citizenship, and responsibility, building on the generous spirit of the American people.

One of the initiatives of USA Freedom Corps is Citizen Corps. Citizen Corps programs share the common goal of helping communities prevent, prepare for, and respond to natural disasters, and other emergencies, at various levels of government. One of the Citizen Corps partner programs is Fire Corps. This program is a partnership between the International Association of Fire Chiefs' Volunteer Combination Officers Section (VCOS), the International Association of Fire Fighters (IAFF), the National Volunteer Fire Council (NVFC), and the White House's USA Freedom Corps Office. The program's ultimate goal is to support and supplement resource-constrained fire departments at all levels, volunteer, combination, and career. This will be accomplished through the use of civilian advocates for non-operational related activities. The program will educate fire departments on how to implement a non-operational citizen advocates program, or improve existing programs. Fire service input to the program is provided through the Fire Corps National Advisory Committee which gives strategic direction and important feedback from the field to Fire Corps.

Michigan Fire Service Coalition

Various websites provide services regarding information, training and news about issues within fire services in Michigan. In October 2005, the Michigan Professional Fire Fighters Union, the Michigan Fire Inspectors Society, the Michigan Fire Service Instructors, the Michigan Association of Fire Chiefs and the Michigan State Firemen's Association united to form the Michigan Fire Service Coalition. Michiganfireservice.com is a site dedicated to the men and women who serve throughout the State as fire fighters, company officers, fire chiefs, fire marshals, training instructors, or permit technicians. The site intends to provide quality information about fire service news, training, and issues that affect Michigan's Fire Service. Michigan Safety News is a similar site for safety professionals across Michigan to discuss contemporary safety issues as a discussion forum to share ideas on success, lend expertise, ask questions, discuss contemporary issues and monitor important news.

Michigan Fire Inspectors Society (www.mfis.org) is a code-related organization in the State of Michigan. With almost 600 members, the organization represents the wide interests of Michigan's Fire Inspectors. Committees include members serving to provide updated rules or to monitor code changes. MFIS works to educate members on current trends and practices at conferences which include the fall educational seminar and winter educational conference. The Michigan Association of Fire Chiefs provides leadership and a voice for the fire service and its providers to government residents, fire service members, and other organizations, to protect and improve the safety of Michigan residents.

SCRAP TIRE FIRES

A large fire that burns scrap tires being stored for recycling or re-use.

Hazard Description

With the disposal of an estimated 290 million vehicle tires annually in the United States, management of scrap tires has become a major economic and environmental issue. Michigan generates approximately 10 million scrap tires each year. Although responsible means of storage and disposal have become more common, tire dumps of the last forty years still present environmental and safety hazards. In November 2009, the State of Michigan has identified a total of more than 990,400 tires (those that pose the greatest fire danger) in outdoor stockpiles scattered around the state. Since the MDEQ Michigan Scrap Tire Program began in 1991, the total amount of Michigan's scrap tire stockpile has gone from 31 million to about 3,400,000. The department estimates that most of the remaining tires could be disposed of before the program's ending date in December 2012.

Scrap Tire Disposal Sites in Michigan: November 2009

County	Sites	Tires	County	Sites	Tires
Alpena	2	100,250	Livingston	1	1,000
Arenac	1	37,341	Marquette	1	3,000
Bay	1	700	Mecosta	1	8,000
Benzie	1	10,000	Menominee	1	2,000
Calhoun	2	5,700	Midland	2	121,100
Cass	1	37,000	Monroe	2	7,500
Chippewa	1	500	Montcalm	1	2,000
Clare	1	700	Newaygo	2	27,000
Crawford	1	10,000	Oakland	2	20,633
Dickinson	1	499	Oceana	1	11,000
Eaton	1	300	Osceola	2	2,385,000
Genesee	2	152,000	Ottawa	1	100,000
Grand Traverse	1	1,499	St. Clair	3	9,400
Gratiot	1	2,500	St. Joseph	2	48,000
Hillsdale	1	1,300	Sanilac	2	11,000
Houghton	2	117,500	Shiawassee	1	1,000
Ingham	1	500	Tuscola	2	12,700
Iosco	1	4,800	Wayne	22	168,977
Ionia	1	3,000	Van Buren	2	3,000
Jackson	2	6,600	**Total**	76	3,435,499

Source: Department of Environmental Quality, Waste and Hazardous Materials Division.

NOTE: Inventory totals compiled for tire quantities are approximated and will vary from year to year, as new tires are brought in and others are recycled or otherwise disposed of.

Issues pertaining to the management of scrap tire disposal sites are difficult and diverse. Whole tires are difficult to landfill because they tend to float to the surface. Whole tires are banned from disposal in Michigan landfills due to their associated problems. Scrap tires are breeding grounds for mosquitoes, which can reproduce at thousands of times their natural rate in a scrap tire disposal site, and these mosquitoes can carry and transmit life-threatening diseases. Stockpiles also are home to snakes and small mammals such as rats, opossums, skunks, and raccoons. Stockpiled tires are often soiled with mud, dirt, or other foreign materials that limit potential markets and increase processing costs. From an emergency management perspective, the most serious problem that scrap tire disposal sites pose is that they can be a tremendous fire hazard if not properly designed and managed.

Tire disposal sites can be serious fire hazards due to the sheer number of tires typically present at a site. This large quantity of "fuel," coupled with the fact that the shape of a tire allows air to flow into the interior of a large tire pile, renders standard fire fighting practices nearly useless. Flowing burning oil released by the tires spreads the

fire to adjacent areas. Some scrap tire fires have burned for months, creating acrid smoke and an oily residue that can leach into the soil, creating long-term environmental problems.

Deep stockpiles of compacted tire shreds can undergo a progressive series of exothermic reactions that increase pile temperatures and generate combustible gases. Surface symptoms of this phenomenon can be subtle, such as a slight sulfur odor, vapor steaming from isolated sections of the pile surface, or a slight oil sheen on adjacent standing water after rainfall. Due to the potential for auto-ignition, surface fires can ignite on a shredded tire stockpile, especially as shreds are removed from the area near the hot zone. Gases and shreds are then exposed to air and may ignite.

Scrap tire fires differ from conventional fires in several respects: 1) even relatively small scrap tire fires can require significant resources to control and extinguish; 2) the costs of fire management are often far beyond that which local government can absorb; 3) the environmental consequences of a major tire fire are significant; and 4) as alluded to earlier, the extreme heat converts a standard passenger vehicle tire into about two gallons of oily residue, which can leach into the soil or drain into streams.

Current technologies are sufficient to address the reuse of newly generated scrap tires, but some waste tires still migrate to the least expensive disposal method, which usually means they end up in a scrap tire disposal site (sometimes illegally). Lightning strikes, equipment overheating or sparks, unattended burning of debris/refuse, and arson are the leading causes of tire fires. Fires are also sometimes started by site operators or local residents in the wake of publicity over clean-up activities. This publicity can include enforcement proceedings or initial abatement activities, suggesting that a landowner may be acting out of frustration or attempting to avoid costs associated with tire abatement.

Much work still needs to be done to mitigate the impacts of scrap tire fires. Incident management planning, recognition of the hazardous material potential of fires at scrap tire sites, and improving and enhancing disposal site selection and design processes are all critical pre-incident preparedness factors that must be addressed by government and the private sector. In light of the potential consequences of scrap tire fires, prevention must become a primary goal in the treatment of scrap tire disposal sites. The Rubber Manufacturers Association has put together a document on the Prevention and Management of Scrap Tire Fires that can be printed and used by local fire officials. This document can be found at:
http://www.rma.org/scrap_tires /scrap_tires_ and_the_ environment/fireprevention.cfm .

Impact on the Public

Scrap tire fires often involve extensive smoke and pollution that may prompt evacuations from, and lingering odors in, nearby residences. In addition to the disruption and inconvenience of even a temporary displacement (especially on the elderly, disabled, and very young), negative health effects may result from smoke exposure, and considerable time and expense may be involved in the process of cleaning and deodorizing homes afterward. Nearby local roads, businesses, and facilities may be closed during a fire event. Scrap tire piles also tend to serve as breeding grounds for mosquitoes, which cause additional health and nuisance problems for area residents.

Impact on Public Confidence in State Governance

Some of the public may have an idea that governmental regulations and environmental policy/enforcement should be able to entirely prevent scrap tire piles and fires from presenting a significant hazard. Scrap tire storage/disposal sites, plus any associated fires, can affect an area's property values, reputation, and environment. Local impacts from scrap tire sites should be viewed in terms of the larger-scale, specialized economic functions being served by these sites and their associated businesses. Abstractions such as economic need/demand are not easy for all residents of an area to immediately understand and accept. The "not in my backyard" (NIMBY) problem is involved in this issue, for although tire disposal <u>must</u> occur (i.e. it is a necessary function) many residents see it as undesirable in their vicinity and would prefer that the service take place at a different location.

Impact on Responders
Scrap tire fires can involve excessive response costs and time/resource commitments that may strain local budgets and staff workloads. Responding personnel are exposed to unusually thick and toxic smoke from these events. Potential problems may also arise involving access to crowded or poorly-organized sites (tire sites with storage arrangements that didn't sufficiently conform to established regulations and restrictions).

Impact on the Environment
Stockpiles of tires may catch fire and the environmental consequences of a major tire fire include air, surface water, soil, groundwater, and residual contamination that have negative impacts on humans, wildlife, and natural vegetation. Scrap tire fires generate dense, black smoke containing partially combusted hydrocarbons. The smoke plume can negatively impact residences and businesses in its path as well as the air quality in a broad area for a significant time period. In addition to smoke, some tire fires produce large quantities of oils that contain hazardous compounds. Under certain conditions, these oils can penetrate porous soils to contaminate groundwater that is a source of the area's drinking water. The oils can also reach surface waters and cause substantial fish kills, due to the oils' depletion of dissolved oxygen levels. Finally, the residuals (ash, wire, and unburned rubber) from a tire fire often require special handling and disposal. Processing equipment can be damaged by handling heavily contaminated or partially burned tires, slowing the abatement process.

Significant Scrap Tire Fires

Scrap tire fires have occurred in Michigan in the past. Over the past several years, there has been a decrease in both the frequency and severity of fires at scrap tire disposal sites due to the cleanup of existing stockpiles and an increase in compliance at collection sites. Unfortunately, fire departments are generally ill-equipped and untrained to handle these incidents when they do occur. This is especially true in rural areas where many scrap tire disposal sites are located. Scrap tire fires occur often enough to present a major concern to those communities that have quantities of tires stored at disposal sites within or adjacent to their borders. Given the right set of circumstances, the potential is always there for a major fire that may require evacuation, sheltering, large amounts of fire suppression assistance, and both short and long-term environmental monitoring. Large scrap tire fires can also be very costly for the owner/operator and the affected local jurisdiction(s), as the fires are difficult to extinguish and typically require a large emergency response personnel presence at the fire scene (often for an extended period of time).

In recent history, the following incidents stand out as examples of the adverse impacts that can occur when fire breaks out at a scrap tire disposal site.

Significant Scrap Tire Fires in Michigan

October 30, 1987 – Kent County
A large fire broke out at a scrap tire disposal site in Kent County containing over one million tires. It was estimated that the blaze was contained to about a fifth of the ten-acre site and a fire break was established with bulldozers. Firefighters ultimately concluded that the best course of action was to allow the contained portion of the fire to burn, and that applying water would add no benefit. Nearby residents were evacuated during the early stages of the fire.

December 29, 1995 to January 20, 1996 – Grand Traverse County
A tire fire burned at a re-treading facility in Grawn near Traverse City. Initial fire response was delayed due to attempts by employees at the recycling center to extinguish the blaze without outside assistance. Over the course of the event, surrounding subdivisions were evacuated. The fire engulfed 100,000 tires spread over a three-acre site. Personnel from numerous area fire departments, as well as the U. S. Environmental Protection Agency (EPA) and U. S. Coast Guard, were involved in the containment and suppression effort. In all, 451 responders from 30 separate agencies assisted with the fire over its 22-day duration. The long duration of this fire was testimony to the difficulty of extinguishing fires of this nature.

July 30, 1996 – Clare County
A fire broke out at a scrap tire storage facility located in Redding Township in Clare County. Over the course of the fire, 14 fire departments responded, along with representatives from the EPA and Michigan Department of Environmental Quality (MDEQ). Fortunately, the fire was contained to 250,000 of the 4.2 million tires on the ten-acre site, and was extinguished the following day, some 32 hours after it began.

April 16, 1997 – Osceola County
The worst tire fire ever in Michigan occurred in Osceola County. The salvage yard where the blaze started contained over 6 million tires. All of the fire departments in a five county area were contacted. Residents within a three-mile radius were evacuated. The fire was extinguished in about two and one-half days by digging a trench around the perimeter of the fire to prevent its spread, and capping the fire with sand. In all, 478 firefighters from 34 different departments fought the blaze. The final cost of putting the fire out came to approximately $300,000. Over 1.5 million tires, two buildings and some trailers were lost in the fire.

March 26, 1998 – Monroe County

A grass fire spread to a scrap tire pile in London Township, setting fire to between 3,000 and 5,000 tires. The pile was 50'x 30' and about 6 to 10 feet high. Soil samples were obtained afterward, showing no signs of contamination and no surface or ground water effects. The fire was put out by local fire departments.

February 24, 2000 – Mecosta County

A fire broke out at a tire recycling plant located in Hinton Township in Mecosta County. The fire had started in a pole barn that contained approximately 50,000 shredded tires. Nearby structures that also contained scrap tires were in danger of catching fire as well. Approximately 150 fire personnel from 13 local fire departments fought the blaze. Eventually, sand was brought in by a local contracting firm to smother the flames. Investigators determined that the apparent cause of the fire was a machine that had caught fire earlier and had not been adequately extinguished. The fire had then spread from the machine to the tires.

October 31, 2000 – St. Joseph County

In the early morning hours, a fire broke out at a tire recycling plant located in Colon Township in St. Joseph County. The 250-foot diameter fire – apparently set by an arsonist – consumed approximately 10,000 of the 350,000 tires at the site. The tires were piled 20 feet high in some places, hindering fire suppression efforts. A total of 10 fire agencies assisted in containing the blaze. Local residents were advised to either evacuate the immediate area or close their doors and windows and stay indoors to avoid breathing the acrid, black, choking smoke from the fire. Although the site was located only 300 feet from the St. Joseph River, a dirt berm around the tire pile prevented runoff from the fire from contaminating the river. The fire was extinguished 12 hours after it had begun.

June 13, 2003 – Clare County

A large fire broke out at a scrap tire disposal site in Clare County. It was estimated that 135,000 of the 850,000 tires at the site had caught on fire. The fire response and pollution control efforts would have been much more difficult without the $250,000 in funds awarded to Clare County through the DEQ Scrap Tire Grant Program in 2002. The lanes constructed between the tire piles had bought firefighters enough time to prevent the fire from spreading into the remaining piles. Otherwise, they would have been dealing with a much larger fire. This fire occurred at the same location as the scrap tire fire of 1996, when 250,000 tires were involved.

August 5, 2004 – Ogemaw County

A fire occurred at an old junkyard where tires were in a pile 100 feet wide and 8 feet tall. The fire involved the tire pile and part of some adjacent woods. The fire was fought using water and foam, and by burying the burning tires with soil. The fire was extinguished after about 3 hours. The owner was issued a ticket for failing to control a fire he was using to burn brush and solid waste that had been intermingled with the tires.

August 17, 2005 – Wayne County

Three firefighters were injured while battling a tire fire early in the morning of August 17, 2005 in southwest Detroit. After a few hours, the fire was under control, but the tire sales and repair building was destroyed.

April 21, 2006 – Washtenaw County

A man was burning brush in a barrel at a salvage yard and then left the fire unattended to go eat lunch. While he was gone, a piece of burning wood fell on the ground, igniting a grass fire that spread to the tire pile. There were approximately 1,000-1,500 truck tires on the site—some on the ground and some in a semi-trailer. MDEQ staff suggested that the fire fighters try to limit the runoff from fire suppression activities at the site. The fire was put out with water and foam. The largest tire pile had been aflame, but the burning tires were quickly separated from the pile. Ash from the fire and partially burnt tires remained on the site.

January 24, 2008 – Saginaw County

A fire consumed an abandoned house and hundreds of scrap tires. 50 to 60 firefighters from the Watertown Township, Mayville, Caro, North Branch, Deerfield Township and Millington-Arbela fire departments worked for more than five hours to extinguish the flames and the smoldering embers, which had erupted just after noon. The fire destroyed the house and an attached garage while the burning tires created a lot of thick smoke. Bitter temperatures also caused the water run-off to freeze quickly, presenting an additional hazard for firefighters.

July 23, 2008 – Ottawa County

A scrap yard fire, fueled by 1,000 tires, kept fire departments from Spring Lake Township, Coopersville, Fruitport, Ferrysburg, Ottawa County, Marne and Grand Haven Township busy for several hours and sent thick plumes of black smoke over the area. This fire in Nunica was first reported at around 3:45 pm and was caused by sparks from workers who were cutting off an automobile's catalytic converter. The blaze was confined to roughly a 50-by-50-foot area. Because the nearest hydrant was about 2,000 feet away, water had to be trucked in. In all, 70,000 gallons of water were poured onto the fire before it was brought under control after 90 minutes. No structures were damaged by the fire and no injuries occured. Because of possible oil contamination from melting tires, the Department of Environmental Quality was notified.

September 9, 2009 – Kalkaska County

Hundreds of scrap tires were on fire in a wooded area of Springfield Township of Kalkaska County. Natural causes were considered to be unlikely. Despite the size of the area that was burning, a large crew had the area under control in about an hour. Police say the quick response saved several homes and minimized any health risks from the black smoke being generated.

June 11-13, 2010 – Ingham County

The Onondaga Township Fire Department responded to a tire fire inside a barn in the 4000 block of Gale Road. There were several hundred tires there, and the fire department had to respond 4 or 5 times as the fire burned for 3 days before finally being excavated and extinguished. Some of the tires were so old that they had wooden rims. The equivalent of 800 tires were found throughout the rest of the property, and the landowner was allowed to apply for a grant to have remaining tires cleaned up on his property for free.

December 31, 2010 – Muskegon County

An early morning fire destroyed a Twin Lake tire business on December 31, 2010 with damage estimates over $325,000. The fire started on the west end of a100-by-60 foot pole barn construction building. The building had several tires inside it which provided extra fuel for the fire after it started. City water was not available on the scene so responding fire crews set up water reservoirs at three sites and used tanker trucks to shuttle water in from other areas. A tanker task force involving 10 area fire departments was used to battle the blaze. Assisting Dalton Township were fire departments from the townships of Muskegon, Blue Lake, Holton, Fruitport, and Egelston, along with the North Muskegon and Fremont city departments, the White Lake Fire Authority and Montague Fire District.

Programs and Initiatives

The Scrap Tire Regulatory Program

The Scrap Tire Regulatory Program is implemented by the Waste and Hazardous Materials Division of the Michigan Department of Environmental Quality, under the authority of Part 169 of the Natural Resources and Environmental Protection Act (1994 PA 451), as amended. Policies and regulations established under this law provide the basis for the Department of Environmental Quality to implement and administer an effective scrap tire management program.

Overall, the Program has been very successful. Throughout the state, stockpiles of scrap tires have decreased, compliance rates have increased, and markets for scrap tires have increased. Behind the Program's success to date are: (1) continuing an appropriately funded Scrap Tire Cleanup Grant Program to address abandoned scrap tires and those collected prior to 1991, when a predecessor to Part 169 was enacted, and (2) consistent enforcement of Part 169, which helps to ensure a level playing field for those voluntarily meeting Part 169 requirements. It should be noted that although markets for scrap tire material have continued to increase on their own with minimal governmental subsidies, the ongoing need for state funding for cleanup grants, compliance, and enforcement is clear.

Michigan's policy response to the scrap tire problem in the state is two-pronged: encourage market development and require proper management of scrap tires. The purpose of Part 169 is to help reduce illegal scrap tire accumulations and the public health and environmental concerns associated with these solid waste piles. Under this approach, the MDEQ's goals were to:

- Create regulatory incentives to recycle tires (such as a bonding exemption for sites that are in compliance for one year) and financial disincentives for improperly storing or dumping tires (such as higher bonding requirements and penalties for noncompliance);
- Assist in the development of viable end uses and markets for scrap tires;
- Improve management of scrap tires through registration and manifesting requirements (for transporters) and require proper storage through site registration, pile restrictions, mosquito control, and bonding requirements for storage (based on the number of tires);
- Conduct site, hauler, and retailer inspections to assess their management of scrap tires;
- Conduct appropriate enforcement, with criminal and civil culpability for violations, and prosecution of violations; and
- Allow private enterprise to establish market costs.

Part 169 was substantially amended in July 2002. Amendments were made to the definitions, scrap tire hauler registration exemptions, bonding provisions, manifest requirements, grant provisions, and penalty provisions. The MDEQ did not fully support all of the July 2002 amendments to Part 169 because some were contrary to the goals of the Program and would present great challenges from a regulatory perspective. As a result, Part 169 was again amended, effective December 29, 2006, based on the recommendations of the Scrap Tire Work Group. These amendments were developed in conjunction with, and with the support of the MDEQ. These amendments made substantial improvements to the statute in support of Program goals.

An amendment to reduce regulatory burdens and encourage the productive use of scrap tires by:

- Facilitating the processing of scrap tires into higher-value materials by creating a new category of scrap tires designated as a "commodity." Material that qualifies as a commodity is largely exempted from regulation as a scrap tire.
- Improving the definition of end-user, to clarify who meets the exemption from bonding and storage requirements. Also, clarifying the "scrap tire processor" definition and eliminating the definition of "scrap tire recycler," which has caused confusion for the industry.

- Simplifying the definition of scrap tire hauler, exempting retreaders from hauler registration requirements (as well as persons who haul only recognized commodities).
- Simplifying the manifest requirements by allowing the use of a consolidated load manifest by commercial businesses that service their own truck fleets, and for retail establishments and scrap tire haulers that pick up small numbers of scrap tires from multiple locations in the same load.
- Expanding funding eligibility to allow for research and development, capital expenditures, and other expanded areas under the Scrap Tire Market Development Grant Program.
- Specifying that tires can go to locations that have legally accumulated scrap tires below the regulatory threshold and clarifying whom a person can contract with for the removal of scrap tires.

An amendment to encourage the proper management of scrap tires by:

- Requiring that a collection site be in compliance with storage requirements to qualify for official site registration.
- Improving storage of tires at scrap tire collection sites by specifying that tires may only be stored in areas identified for that purpose on a map provided with the site registration application and approved by the MDEQ.
- Clarifying that shreds cannot be placed between piles. An exception is provided for commodities used to create a storage pad for, or access roads to, other commodities. The use of shredded tires between piles increases the fire danger present at collection sites and makes fighting a fire at a collection site more difficult. The open spaces between the tire piles are there to serve as fire lanes to segregate the tires into piles so that fire would not be as likely to spread between the piles.
- Providing local fire chiefs with the authority to determine whether collection site access roads meet the Part 169 requirement to be accessible at all times to emergency vehicles.
- Limiting the growth of unbonded collection sites. Previously, a scrap tire collection site could grow by 10 percent every year even though it was not bonded, provided that it met certain storage requirements. However, the number of tires should not increase on a properly managed collection site, since scrap tires that are brought in should (after processing, if necessary) leave the site for a market soon thereafter.
- Facilitating the proper use of portable shredding operations to clean up scrap tire piles, by ensuring that there is a tie to a properly registered collection site.

An amendment to support the public interest by:

- Providing the state with limited lien authority when state funds are used to clean up tire piles that were created illegally after the predecessor to Part 169 was enacted in 1991. This prevents the unjust enrichment of property owners from the public funds used to eliminate a problem that the landowner had created and profited from.
- Adding explicit inspection authority that allows the MDEQ to conduct inspections at reasonable times to enforce and administer Part 169.

An amendment to provide for the long-term success of the Program by:

- Extending the sunset on Program funding from 2007 to 2012. The Program is funded through a fee of $1.50 for each motor vehicle title transfer, established in the Motor Vehicle Code, 1949 PA 300, as amended (MVC). Continued Program funding was needed to allow the MDEQ to meet the 2009 statutory deadline for clean-up of pre-1991 scrap tires, and to continue efforts to clean up those post-1991 scrap tires that pose a danger to public health, safety, welfare, or the environment. Continued funding also supports ongoing grants to develop markets for scrap tires and helps to ensure proper disposal of the 10 million scrap tires generated annually in Michigan.
- Adding a requirement for the MDEQ to report every three years on the effectiveness of Part 169 in encouraging reuse and ensuring safe storage of scrap tires. (To read the full 2009 Report, please go to http://www.michigan.gov/documents/deq/DEQ-WHMD-STPTri_Scrap_Tire_Leg_Rpt_2009_309005_7.pdf .)

- Adding a requirement for the MDEQ Director to appoint the Scrap Tire Advisory Committee to advise the MDEQ on the required report, the relevance of national standards and specifications for commodities, and other issues.

Scrap Tire Management

To be effective, scrap tire management must be viewed from two perspectives. First, methods for dealing with the millions of scrap tires currently being generated must be devised to stop the problem from growing in scope and magnitude. Recycling and re-use appear to be the best options in that regard. Second, measures must be devised to address the issues pertaining to the millions of scrap tires already present in existing disposal sites.

Mitigation of Scrap Tire Fires

To combat these problems at current disposal sites, suggestions have been made about establishing a state policy and program for acquiring such sites and suitably disposing of the tires at these locations. Other proposals call for educating local jurisdictions on the hazards associated with scrap tire disposal sites so that enforcement of existing legislation is effective in minimizing future potential scrap tire fires.

The EPA developed the Resource Conservation Challenge (RCC), which is a national effort to find more flexible, yet effective ways to conserve natural resources and energy. In 2004, the RCC developed a program to clean up scrap tire piles in the Great Lakes Region. The project supports prioritization, funding and implementation of clean up efforts. The goal was to clean up 55% of tires in stockpiles (from the "2001 baseline") in the Great Lakes region, by 2008. The mitigation of these sites will provide for land revitalization and elimination of a potential source of benzo[a]pyrene (a PBT) in the Great Lakes, which are priorities of the Brownfields Program and Bi-National Toxics Strategy, respectively. A map showing the locations of regulated outdoor scrap tire piles in Michigan can be seen on the MDEQ web site at
http://www.michigan.gov/documents/deq/deq-whm-stsw-scraptiresites_230376_7.pdf.

The November 2006 RMA Scrap Tire Market Report ranked Michigan as tied with Ohio for being the third most improved state in the number of tires consumed by markets reduction of historical stockpiles, on absolute and per capita bases. According to the May 2009 RMA Scrap Tire Market Report, there were about 128 million scrap tires remaining in stockpiles throughout the United States at the end of 2007. This is a reduction of about 87% percent since 1990, when the number of tires in stockpiles was estimated at 1 billion. The reduction of tires below the 2001 baseline level (of 308.4 million) also marks a 58% reduction in stockpiles and therefore exceeds the EPA stakeholders' 2004 goal (of 55%), an accomplishment of which the industry should be proud.

Much of the reduction in illegal stockpiles in Michigan is due to Scrap Tire Cleanup Grants. Since the Legislature first appropriated funding in 1993, more than $27.2 million in public funds have cleaned up approximately 31.1 million Passenger Tire Equivalents (PTEs), restoring the environmental quality and economic value of more than 1,000 sites across the state. The average cost of removal of tires under the grant program has been 88 cents per PTE. Approximately $2.5 million is allocated for cleanup grants in fiscal year 2010. Based on the eligible applications received to date, it is estimated that at least another 1 million PTEs will be removed during the FY 2010 grant cycle.

Scrap Tire Fire Statewide Response Plan

To comply with the 2002 amendments to Section 169 of the Natural Resources and Environmental Protection Act, the State of Michigan has developed a statewide response plan for large scrap tire fires. This plan, which was written by the Michigan Department of Environmental Quality with input from the Michigan State Police and the Michigan Association of Fire Chiefs, establishes a framework for planning, preparedness and response measures for large scrap tire fires. While this plan will not entirely stop scrap tire fires from occurring, it is hoped that the plan will at least keep the problem in check until more permanent hazard mitigation measures can be instituted to reduce the threat of tire fires across Michigan.

Scrap Tire News

Scrap Tire News is a publication devoted to providing news and information about tire and rubber recycling. In addition to in-depth tire recycling company profiles that explore operational and market issues facing the industry, Scrap Tire News also provides a way to stay current with changes in the industry through regular reports on technology/design developments and breakthroughs; timely legislative and regulatory information; market trends; product briefs; product advances; global viewpoints; internet guides; and updates on equipment innovations and applications occurring throughout the industry.

The Recycling Research Institute, Suffield, CT (RRI) develops and disseminates information concerning the recovery, reuse, recycling and proper disposal of scrap tires and scrap rubber. In addition to publishing Scrap Tire News, the company produces and publishes the Scrap Tire & Rubber Users Directory—a nationally acclaimed business reference book for the scrap tire and rubber recycling industry. Another RRI publication, State Scrap Tire Management Programs, covers comprehensive profiles of state scrap tire legislation, regulation, and market development initiatives in all 50 states.

Scrap Tire Cleanup Guidebook

The Scrap Tire Cleanup Guidebook was created to help state and local and local governments reduce the economic burdens and environmental risks associated with scrap tire piles on their lands. The U.S. EPA Region 5 and Illinois EPA, along with the Michigan Department of Environmental Quality, have collaborated to create the Scrap Tire Cleanup Guidebook. The guidebook brings together the experience of dozens of professionals into one resource designed to provide state and local officials with the information needed to effectively clean up scrap tire piles. The guidebook discusses starting a cleanup program, working with contractors to clean up sites, and implementing prevention programs that will reduce scrap tire dumping.

The scrap tire clean up guidebook has a section on fire planning and prevention for site stabilization. Removal of trees, brush, and grass around stockpiles is an effective mitigation measure to avoid fire transmission to and from surrounding areas, especially if the site is inactive. Identification of available fire control resources, installation of supplemental fire control tools, the provision of at least two connected access points for emergency vehicles, and fire lanes (at least 50 feet wide) to divide a large stockpile into isolated segments, can all help to mitigate scrap tire fires. The pile sides should also be tapered to avoid collapse during fire turbulence. Piles generally should be removed early in the abatement process to prevent tire ignition by thrown objects as well as to show abatement progress.

Scrap Tire Advisory Committee (STAC)

The STAC was originally created by the Waste and Hazardous Materials Division in September 2005 to foster continued interaction between the MDEQ and other stakeholders. The STAC grew out of the Scrap Tire Work Group which was formed in April 2005 to assist the MDEQ with developing recommendations for statutory amendments and other regulatory and policy changes to improve the Scrap Tire Program administered under Part 169 of the Natural Resources and Environmental Protection Act. The Scrap Tire Work Group process highlighted the benefits of having a forum for the MDEQ and stakeholders to exchange information. The STAC will be available to advise the MDEQ on the implementation of Part 169 and to allow both the MDEQ and other stakeholders to identify and address challenges and opportunities in the Scrap Tire Program as they arise. In addition to any other issues the MDEQ wants the STAC to consider, the STAC shall advise the MDEQ on the report required every three years concerning the effectiveness of Part 169 and the relevance of national standards and specifications for commodity determinations.

Michigan Manufacturers' Guide to Environmental, Health, and Safety Regulations

The 2008 "Michigan Manufacturers' Guide to Environmental, Health, and Safety Regulations" is a joint publication of Michigan’s Department of Natural Resources, the Department of Environmental Quality and the Department of Licensing and Regulatory Affairs. Manufacturers, suppliers, consultants, and regulators can all benefit from this guide, which steers the reader through the maze of state and federal environmental, health, and

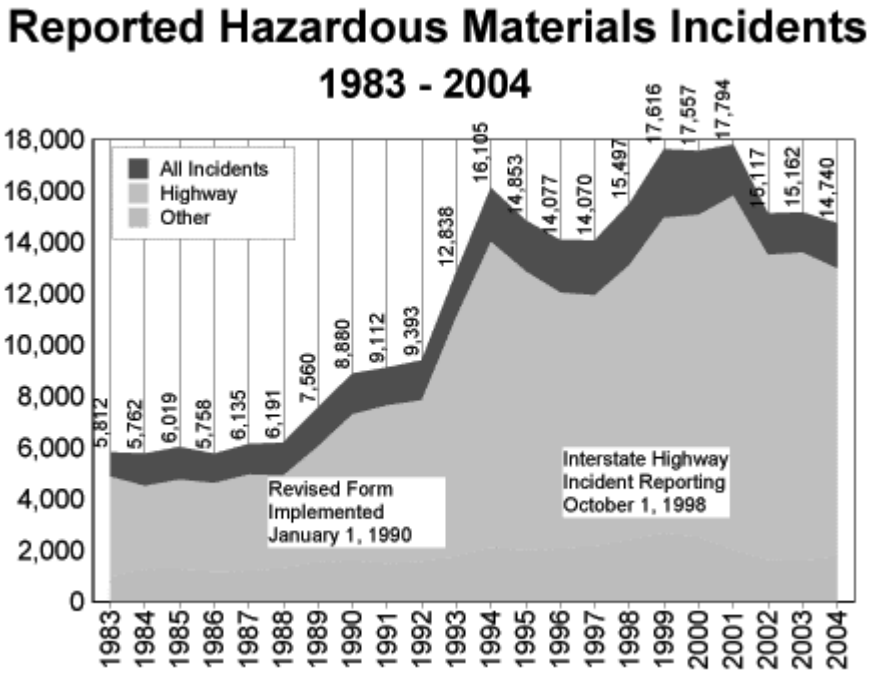
safety regulatory programs. Section 2.2.2 (2-7) of the environmental regulations is a section that deals specifically with scrap tires and includes basic requirements for scrap tire generators.

Michigan Department of Environmental Quality, Common Scrap Tire Violations Index

The Michigan Department of Environmental Quality website has an index that is organized into categories of registration application deficiencies and violations common to scrap tire collection sites and scrap tire haulers (http://www.michigan.gov/deq/0,1607,7-135-3312_4122-60866--,00.html). The violations or deficiencies have been identified either during scrap tire collection site or scrap tire hauler inspections, or upon review of registration applications, by MDEQ Waste and Hazardous Materials Division (WHMD) staff. It is not a comprehensive list of all requirements that staff look for while doing inspections or reviews, but should be helpful for those involved with tire storage/disposal sites.

HAZARDOUS MATERIAL INCIDENTS

A hazardous material is any solid, liquid, or gas that can cause harm to humans and other living organisms due to its being radioactive, flammable, explosive, toxic, corrosive, a biohazard, an oxidizer, an asphyxiant, or capable of causing severe allergic reactions. Mitigating the risks associated with hazardous materials often requires extensive safety precautions during their transport, use, disposal and storage. Hazardous materials are transported by highway, rail, pipeline, air, and water. Below is a chart showing the number of hazardous material transportation incidents in the United States reported to the federal Pipeline and Hazardous Materials Safety Administration. (Note: the chart only lists transportation incidents, not fixed site incidents.)



Source: Pipeline and Hazardous Materials Safety Administration

Impact on the Public

Both fixed site and transport-related hazardous material incidents involve the potential for evacuation (or sheltering in place), with significant problems possible for special populations in hospitals, schools, nursing homes, and other critical facilities. Certain types of extremely hazardous substances may result in a public health emergency, and a resulting need for triage, mass treatment, and congregate care. In addition to the direct impacts of the hazardous material event itself, transportation incidents may directly affect the transportation infrastructure in the area and cause extensive delays in travel and the conduct of business. This hazard is ranked as the second most frequent in occurrence (behind structural fires).

Impact on Public Confidence in State Governance

Discontent may arise from the NIMBY problem (as referred to in the Scrap Tire Fires section) or from difficulties in planning to avoid conflicting land uses. Mixed attitudes toward useful and needed employers/businesses may be fairly common, recognizing the economic benefits of companies that use hazardous materials, but unsettled by the perceived risks in the location of some of them (or their number, since there were 2,991 SARA Title III sites in Michigan in late 2009). Such perceptions of risk may be over-generalized toward other, undeserving businesses (e.g. those that pose minimal risks). Part of the public may not understand the balance between regulation and business needs concerning the use and handling of hazardous materials. Transportation delays due to transportation-related incidents may cause dissatisfaction with roadway provision, capacity, and maintenance.

Impact on Responders

Special procedures and additional information tend to be needed for incidents involving hazardous materials. Additional risks to responders may be present from exposure to extremely hazardous substances at or near these incident locations. Exposure can involve direct contact, the presence of toxic fumes, or the risk of fires and explosions from chemical reactions. Additional complexity therefore tends to be present in any response involving hazardous materials. A schedule of exercise activities needs to be maintained for staff preparedness, and larger budgets are needed to accommodate the staffing, training, exercising, and equipment needed. In addition to preparing for and handling this type of response, the creation, support, and participation in a Local Emergency Planning Committee is needed, along with work related to Section 302 site planning and mutual aid arrangements with nearby communities and relevant agencies. Extra work is also involved in creating and maintaining special contact lists for railroads, the MDEQ, drain and road commissions, airports, health departments, and private companies who may also be involved in incident response, as well as the State Emergency Operations Center (SEOC) and its notification/coordination procedures and protocols. Special expertise in substance types and risks, as well as software for plume modeling may also be needed for effective response, and such expertise has an expense associated with its development and maintenance.

Impact on the Environment

An incident involving hazardous material, whether at a fixed site or during transportation, may cause harm to the environment, as various types and quantities of chemicals are released. A hazardous spill involving an industrial or chemical plant can affect air quality, soil surrounding the area of the release, and an area's drinking water. A hazardous spill caused by a transportation accident can similarly impact the air, soil, and nearby lakes and rivers. A toxic release can also destroy the wildlife habitat in or around the areas where the release occurs.

HAZARDOUS MATERIAL INCIDENTS: FIXED SITE
(INCLUDING INDUSTRIAL ACCIDENTS)

Hazardous Material Incident – Fixed Site: An uncontrolled release of hazardous materials from a fixed site capable of posing a risk to life, health, safety, property or the environment.

Industrial Accident: A fire, explosion, or other severe accident (especially if it involves hazardous materials) at an industrial facility that results in serious property damage, injury, or loss of life.

Hazard Description

Hazardous Material Incidents

Over the past few decades, new technologies have developed at a stunning pace. As a result, hazardous materials are present in quantities of concern in business and industry, agriculture, universities, hospitals, utilities, and other facilities in our communities. Hazardous materials are materials or substances which, because of their chemical, physical, or biological nature, pose a potential risk to life, health, property, or the environment if they are released. Examples of hazardous materials include corrosives, explosives, flammable materials, radioactive materials, poisons, oxidizers, and dangerous gases.

Hazardous materials are highly regulated by federal and state agencies to reduce risk to the general public and the environment. Despite precautions taken to ensure careful handling during the manufacture, transport, storage, use, and disposal of these materials, accidental releases do occur. These releases can cause severe harm to people or the environment, and response actions often need to be immediately performed. Most releases are the result of human error. Occasionally, releases can be attributed to natural causes, such as a flood that washes away barrels of chemicals stored at a site. However, those situations are the exception rather than the rule.

Industrial Accidents

Industrial accidents differ from hazardous material incidents in the scope and magnitude of offsite impacts. Whereas hazardous material incidents typically involve an uncontrolled release of material into the surrounding community and environment that may require evacuations or in-place sheltering of the affected population, the impacts from industrial accidents are often confined to the site or facility itself, with minimal physical outside impacts. Nonetheless, industrial accidents, such as fires, explosions, and excessive exposure to hazardous materials, may cause injury or loss of life to workers at the facility, and significant property damage. In addition, industrial accidents can cause severe economic disruption to the facility and surrounding community, as well as significant long-term impacts on the families of the workers injured or killed.

Hazard Analysis

Hazardous Material Incidents

The map at the end of this section illustrates where the identified SARA Title III facilities are located in Michigan. An examination of the map indicates that the greatest concentration of facilities is located in southeastern Michigan and other urbanized areas. Fortunately, these are generally the areas with more resources to prepare for and respond to a hazardous material incident. However, the greater population concentrations also make these areas more vulnerable to a serious hazardous material incident.

Like all heavily industrialized states, Michigan will always be concerned with the risk of accidental hazardous material releases. However, the threat of accidental hazardous material releases that can affect life, health, property or the environment can be greatly reduced by: 1) developing and maintaining adequate community hazardous material response plans and procedures; 2) adequately training hazardous material workers and off-site emergency responders; 3) educating the public about hazardous materials safety; 4) enforcing basic hazardous material safety regulations; and 5) mitigating, wherever possible, the threat of accidental hazardous material releases. Fortunately, many Michigan communities are making great strides in these important areas.

NOTE: Nuclear research facilities can produce / use radioactive materials, as well as other hazardous substances, and therefore need to be dealt with by specially trained personnel. Caution should be exercised at these facilities, and proper radiological survey equipment should be used during a response.

Industrial Accidents

As a major manufacturing and industrial center, Michigan has had its share of industrial explosions and/or fires that resulted in deaths or injuries. Fortunately, industrial and fire safety regulations enacted over the years have kept these types of accidents to a minimum. Although industrial accidents occur with regularity in Michigan, major incidents with mass casualties, such as the four deadly explosions that occurred in 1998 and 1999, are relatively rare.

Significant Fixed-Site Hazardous Material Incidents and Industrial Accidents

December 3, 1984 – Bhopal, India

The world's worst hazardous material incident occurred on December 3, 1984 in Bhopal, India when a cloud of methyl isocyanate gas (an extremely irritating chemical that can cause severe acute respiratory problems) escaped from a Union Carbide chemical plant, killing about 2,500 persons and injuring tens of thousands more. Many of the injured later suffered permanent disabilities. Over 30 tons of the chemical was released. The exact cause of the release was not firmly established, but several safety systems designed to prevent a major release were either inoperative, under maintenance, or not activated by workers. Atmospheric conditions at the time of the release kept the toxic cloud close to the ground as it slowly drifted over the city, increasing the number of persons exposed. Unfortunately, warning systems for the community were not activated in a timely manner and many individuals died in their sleep.

The Bhopal incident helped to illustrate many important points about accidents that involve a release of hazardous materials. First, it was not caused by a single factor; rather, a number of contributing events had to occur for the methyl isocyanate to be released and have such a deadly public health impact. Second, human error and lack of adherence to safety rules and procedures played a substantial role in the incident. Third, the impact would not have been nearly so great had the population around the plant not been so large and densely housed, and had there been better preparation about how to respond to a hazardous materials release. Finally, the deadly release proved that worst-case scenarios do occur, and that emergency planning, training, and education must be geared toward that worst-case incident.

As tragic as the Bhopal incident was for India, it did have a positive side in that it triggered historic federal legislation intended to prevent such disasters from occurring in the United States. Shortly after the Bhopal incident, Congress enacted legislation (the Superfund Amendments and Reauthorization Act, signed into law October 17, 1986) that established new requirements for federal, state and local government, and private industry, for reporting on and planning for hazardous material incidents. (See the Programs and Initiatives section for more information on this law.)

NOTE: A reportable hazardous material incident is one in which all three of the following conditions apply: (1) a material is present that is suspected to be other than ordinary, combustible by-product material; (2) the material is in such a state, quantity or circumstance that, if left unattended, it is presumed to pose a threat to life, health, property or the environment; and (3) special hazardous material resources were dispatched or used, or should have been dispatched or used, for assessing, mitigating or managing the situation.

May 25, 1865 – Mobile, Alabama

On May 25, 1865, in Mobile, Alabama, an ordnance depot exploded, resulting in about 300 fatalities. This event occurred just after the end of the American Civil War. The depot was a warehouse where troops had stacked about 200 tons of shells and powder. The shells caught fire and exploded, with flames shooting up into the sky and bursting shells heard throughout the city. After the explosion, there were fires that burned until the entire northern part of Mobile was destroyed. The exact cause of the explosion was never determined.

December 6, 1917 – Halifax, Nova Scotia, Canada

One of the biggest and most deadly explosions occurred on December 6, 1917 in Halifax, Nova Scotia, Canada. It is known as the Halifax Explosion. The incident occurred when a French freighter carrying ammunition and wartime explosives collided with a Norwegian ship in Halifax Harbor. About 2,000 people were killed by debris, fires, or collapsed buildings, and it is estimated that over 9,000 people were injured. The French ship had caught on fire 10 minutes after the collision and exploded about 25 minutes later. The explosion was equivalent to about three kilotons of TNT and a fireball rose over a mile in the air to form a giant mushroom cloud. All of the buildings and structures covering nearly 2 square kilometers along the adjacent shore were destroyed, including those in the neighboring communities of Richmond and Dartmouth. The explosion also caused a tsunami in the harbor, with waves as high as 60 feet and a pressure wave of air that snapped trees, bent iron rails, demolished buildings, grounded vessels, and carried fragments of the ship for miles.

March 18, 1937 – New London, Texas

On March 18, 1937 the deadliest school disaster in United States history occurred in New London, Texas. An explosion was caused by a natural gas leak and resulted in the death of at least 295 students and teachers. Approximately 600 students and 40 teachers were in the building at the time, and only about 130 escaped without serious injury.

July 17, 1944 – Port Chicago, California

A major munitions explosion occurred at a naval base in Port Chicago, CA on July 17, 1944. The incident occurred during World War II, when munitions detonated while being loaded onto a cargo vessel, killing 320 sailors and civilians and injuring 390 others. The explosion resulted in an enormous fireball.

October 20, 1944 – Cleveland, Ohio

A significant gas explosion occurred on October 20, 1944 in Cleveland, Ohio. It resulted in 130 fatalities and destroyed one square mile around Cleveland's east side. The event occurred when an above-ground storage tank, holding liquefied natural gas in the East Ohio Gas Company's tank farm, began to emit

vapors. As the gas flowed and mixed with air and sewer gas, the mixture ignited. In the ensuing explosion, manhole covers launched skyward and massive fires erupted from the depths of the sewer lines. Then a second above-ground tank exploded, leveling the tank farm. The explosions and fires continued to occur, trapping many who had returned to what they thought was the safety of their own homes. Over 600 people were left homeless, and 70 homes, two factories, many cars and miles of underground infrastructure were destroyed. The explosion also had a long-range impact on the natural gas industry. Until the disaster, above-ground storage of natural gas, used as fuel for homes, office buildings and factories, was a common sight in cities across America. Following the disaster, utility companies and communities began to rethink their natural gas storage systems, and below-ground storage of natural gas grew in popularity.

April 16, 1947 – Texas City, Texas

One of the worst industrial accidents in United States history occurred on April 16, 1947 in Texas City, Texas. Approximately 2,300 tons of ammonium nitrate detonated and resulted in a chain reaction of fires and explosions. The incident started with a mid-morning fire on board the French-registered vessel SS Grandcamp in the port of Texas City. The fire led to a massive explosion that sent a 15 foot wave across the water—a wave that was detectable along about 100 miles of the Texas shoreline. The incident resulted in at least 581 fatalities, over 5,000 injuries, and the destruction of nearly 1,000 buildings, including a Monsanto Chemical Company plant. The Grandcamp explosion also caused the ignition of refineries and chemical tanks on the waterfront. Windows were shattered 40 miles away in Houston, and people reported feeling the shock about 250 miles away.

The Texas City disaster triggered the first ever class action lawsuit against the United States government, under the then-recently enacted Federal Tort Claims Act (FTCA), on behalf of 8,485 victims. The Texas City disaster led to widespread disaster response planning to help organize local and regional responses to emergencies. Offers of assistance came in from all over the country and several funds were established to handle donations, mainly the Texas City Relief Fund.

Hazardous Material Incidents

Michigan has not experienced such a large-scale hazardous material release involving mass casualties as that which occurred in Bhopal, India. This can be attributed, in large part, to the steps taken by government and private industry to carefully regulate those processes and practices that could cause an accidental hazardous material release. Michigan's population density is also lower, and its zoning and planning personnel tend to separate conflicting land uses from each other. Bhopal's 2001 population density was 12,655 persons per square mile, whereas Michigan's highest population density (according to the 2010 census) is the city of Hamtramck, at 10,751 persons per square mile. (Hamtramck, coincidentally, had a hazardous materials event of its own in 1984, as described later in this section.) Bhopal's population was reported as totaling 1.5 million in 2001—Michigan's smaller and more widely spaced urban developments tend to make it less vulnerable to the most severe types of impacts, as do the regulations it currently has in place to oversee the handling of extremely hazardous substances.

However, as the list on the following pages illustrates, Michigan has had numerous fixed-site hazardous material incidents in recent years that required a response by local fire departments and hazardous material response teams, and implementation of evacuation, in-place sheltering, and other protective actions. From 1994 through 1998, local fire chiefs in Michigan reported 730 hazardous material incidents on the Michigan Fire Incident Reporting System (MFIRS). Of those 730 reported incidents, approximately 15-20% (about 120 incidents) occurred at an industrial or service business site. That figure represents an average of one reportable fixed-site hazardous material incident statewide approximately every 15.2 days. (Note: 1998 is the last year for which statewide hazardous material incident response statistics were available.)

Industrial Accidents

Michigan has seen its share of tragic industrial accidents over the past few years, resulting in numerous deaths and injuries, serious property damage, and economic disruption to facilities and their surrounding communities. Following are brief synopses of the more significant accidents and their impacts:

Some Significant Industrial Accidents in Michigan

March 21, 1892 – East Jordan (Charlevoix Co.) – Explosion at Lumber Mill

On March 21, 1892 a boiler explosion occurred at a lumber mill in East Jordan. The accident resulted in six fatalities and three others left critically injured. The noise from the explosion could be heard from 14 miles away.

November 6, 1895 – Detroit (Wayne County) – Boiler Explosion at a Building

Another major fatal accident occurred on November 6, 1895 when a boiler explosion occurred in Detroit. The boiler exploded in the basement of the building occupied by the Detroit Journal and destroyed the building as well as another adjacent building. The incident resulted in at least 40 fatalities, and 20 more injuries. Several buildings on nearby blocks were shaken by the force of the explosion.

April 23, 1927 – Detroit (Wayne County) – Explosion/Fire at Automobile Plant

One of Michigan's worst industrial accidents occurred in Detroit on April 23, 1927 at the Briggs Manufacturing Plant (which built and painted auto bodies and parts for several automobile companies). In that accident, 21 workers died when sparks from machinery or mercury-vapor lamps in the paint booths ignited paint fumes, causing an explosion and tremendous fire that killed the workers and severely damaged the plant. Arson investigators later determined the explosion and fire to be accidental.

October 2, 1961– Detroit (Wayne County) – Explosion at Plastics Plant

On October 2, 1961 four people were killed and two others injured in an explosion in Detroit. The incident occurred at a plastics plant and the explosion occurred in a large gas-operated steam heating boiler.

December 11, 1971 – Port Huron (St. Clair County) – Explosion at Water Treatment Plant

A significant construction operation accident occurred on December 11, 1971 in Port Huron when 22 workers perished in a water project tunneling incident. The explosion occurred within a six-mile, 16-foot diameter tunnel that was being constructed 230 feet below the lake bed to draw up to 1.2 billion gallons of water per day when complete. Tragically, methane gas accumulated in an unventilated portion of the tunnel and was later inadvertently sparked, leading to the devastating underground explosion. Forty-three men were in the tunnel when it exploded. Twenty-one men were killed that day and another man got out of the tunnel but died 10 months later. The explosion ranks as one of the state's most deadly construction industrial accidents.

January 23, 1976 – Zilwaukee (Saginaw County) – Explosion at Grain Elevator

On January 23, 1976 five workers were killed and 12 others were injured in a grain elevator explosion in Zilwaukee, MI. The explosion occurred in a tower seven stories tall that housed grain hoists and other equipment. Eighteen men were working in the area at the time. The explosion was so powerful that it showered chunks of concrete over an acre of ground.

December 11, 1998 – Osseo (Hillsdale County) – Fireworks Plant Explosion

On December 11, 1998 an explosion at the Independence Professional Fireworks Company manufacturing plant near Osseo, in Hillsdale County, killed seven employees and leveled one building at the site. The blast, which occurred in a fireworks shell assembly room, sent debris flying in all directions for about 300 yards and could be heard for at least 20 miles. Fifteen other workers escaped serious injury in the explosion. Subsequent investigations by the Federal Bureau of Alcohol, Tobacco and Firearms, the Michigan State Police Fire Marshal Division, and the Michigan Occupational Safety and Health Administration (MIOSHA) were unable to determine a definitive cause of the explosion. This explosion was the worst industrial accident in Michigan in 20 years.

February 1, 1999 – Dearborn (Wayne County) – Automobile Plant Boiler Explosion

On February 1, 1999 an explosion in one of several large boilers at the Ford Motor Company Rouge Power Plant killed six workers, critically injured another 14, and caused extensive structural damage. State officials who investigated the accident concluded that human error played a major part in the explosion, when a work crew failed to shut off one of two gas mains leading to the boiler's furnace. That error caused a buildup of natural gas in the boiler that was somehow ignited and caused the explosion. The force of the explosion split open the 60-foot high furnace, blew off the roof of the power plant, ignited fires on five floors, and sprayed surrounding workers with super-heated water that caused severe burns. The blast, which forced the shutdown of the Rouge Complex and other Ford plants for several days, was the second worst industrial accident in Michigan in 20 years and the deadliest at an automobile plant in over 50 years. It also turned out to be the most expensive workplace disaster in U.S. history, with final costs of at least $1 billion. The seven-month probe by state officials was the largest and most complex in the history of state workplace safety investigations.

March 29, 1999 – Osseo (Hillsdale County) – Fireworks Plant Explosion

Another devastating explosion occurred at the same plant that had suffered a disastrous explosion the previous year, killing five more employees and destroying another building at the site. This second explosion, which included among its victims the company co-owner, was later determined by investigators to be accidental. The devastation brought by the two explosions, which resulted in a total of 12 deaths, forced the company to permanently shut down the business. Federal and state regulators have since issued numerous citations to the company for safety violations at the plant, with fines totaling several hundred thousand dollars.

November 10, 1999 – Flint (Genesee County) – Nursing Home Explosion

On November 10, 1999 an explosion at the Clara Barton Terrace Convalescent Home in Flint killed five persons, injured 32 others, and caused extensive to the basement and other parts of the facility. Although several theories surfaced as to the cause of the blast, subsequent investigations by the National Transportation Safety Board (NTSB) and the Michigan Department of Consumer and Industry Services (as it was then called) had stalled. The NTSB withdrew from the investigation in January 2000 after its investigators could find no pre-existing conditions linking the blast to natural gas lines leading to the nursing home. The Michigan Department of Consumer and Industry Services also pulled out of the investigation after determining that three boilers in the facility's basement were intact and not likely to be the cause of the blast. Officials had indicated that determining the cause of the explosion may be difficult unless new information comes to light.

April 12, 2000 – Muskegon (Muskegon County) – Chemical Plant Explosion

On April 12, 2000 two explosions occurred in rapid succession at a chemical plant in Muskegon, resulting in 10 workers sustained injuries. The contract workers were installing two tanks and upgrading the waste treatment system at the site of the explosions. The first, smaller blast occurred in a two-inch stainless steel pipe leading from a building to the wet well. The second, larger blast occurred below grade in the southwest quadrant of the wet well. The facilities sustained substantial damage from the second blast and the estimated magnitude of the second blast was equivalent to 250 pounds of TNT.

March 18, 2001 – Warren (Macomb County) – Plant Explosion

A plastics coating plant building was completely destroyed by a natural gas explosion around 8:20 am on a Sunday morning. Fortunately, no one was at the plant to be injured or killed by the explosion, but the 75 workers employed by the plant no longer had a place to come to work at, on Monday morning.

May 25, 2001 – Bagley Twp. (Otsego County) – Particle Board Plant Explosion

Two separate explosions on May 25 and 26, 2001, at a mill near Gaylord that produces particle board, injured a total of seven firefighters and nine plant workers (five critically), and caused extensive structural damage to the building. The first explosion occurred on May 25 in an area where glue is mixed with wood chips. The second explosion occurred on May 26 when the initial fire spread to an adjacent silo containing wood chips. As firefighters opened the silo to spray water on the flames, the sudden infusion of oxygen caused the blast.

July 21, 2002 – Battle Creek (Calhoun County) – Auto Supplier Factory Explosion

An explosion and a fire at a Johnson Controls Inc. plant sent seven employees and three firefighters to the hospital. The victims were not badly hurt and were quickly treated and released. They all suffered headaches and eye and skin irritation caused by the burning of an unknown toxic substance. The fire was extinguished in about 25 minutes and the plant suffered minor damages. Fire crews remained on the scene to clean up the hazardous materials.

September 17, 2003 – Dearborn (Wayne County) – Explosion at Industrial Plant

A leaking oxygen line exploded outside the Rouge Steel plant in Dearborn and destroyed 20 employee cars in the area. Five hundred employees were evacuated from the plant. The fire department later ordered a second round of evacuations, as a precautionary measure. No injuries were reported in the incident.

March 21, 2005 – Dearborn (Wayne County) – Explosion / Fire at Industrial Plant

Spilled molten steel caused a fire and two explosions on March 21, 2005 at a Dearborn steel plant, injuring 10 people. A vehicle carrying molten steel was backing into a building at the sprawling River Rouge industrial complex when some of its high-temperature cargo sloshed out, causing the fire and explosion.

August 9, 2005 – Romulus (Wayne County) – Chemical Plant Explosion

A series of explosions and fires occurred at a chemical plant in Romulus on August 9, 2005. Potentially toxic soot was strewn across neighborhoods surrounding the plant, and dangerous chemicals stewed in the hot rubble left by the explosions. The event caused evacuations within the cities of Romulus and Wayne and caused an environmental health scare. It was later determined that the debris strewn from the plant was not toxic, and the fire was put out after two days of burning.

February 20, 2006 – Hamtramck (Wayne County) – Explosion / Fire at Industrial Plant

Three people were injured after an explosion at an industrial plant in Hamtramck. The explosion occurred at a hydraulic pump station. The Hamtramck Fire Department and Detroit Fire Department responded to the explosion and were able to control the flames.

August 28, 2006 – Detroit (Wayne County) – Explosion / Fire at Chemical Plant

Several explosions and a fire spread through a chemical facility on Detroit's east side. The fire started in an aerosol decommissioning area. Three employees suffered injuries, and residents within a half-mile of the plant had to be evacuated for several hours.

April 4, 2007 – Chesterfield (Macomb Co) – Explosion / Fire at Plastics Plant

A fire at a plastics plant resulted in an explosion involving at least 30 propane tanks. The explosion knocked down phone lines, disabling the Chesterfield Township 9-1-1 system. Police shut down 21 Mile Road near Interstate 94, as firefighters struggled with high winds, terrain obstacles, and nearby power lines. There were no injuries.

August 4, 2009 – Clio (Genesee County) – Explosion / Fire at Chemical Plant

Explosions and a fire occurred at a chemical plant in Genesee County, resulting in more than 100 firefighters battling the blaze at the facility. An evacuation was ordered for a 2-mile wide radius around the fire, displacing roughly 1,000 residents. The Environmental Protection Agency advised those in the area to keep their windows closed.

August 27, 2009 – Hamtramck (Wayne County) – Explosion / Fire at Chemical Plant

A fire and an explosion at a chemical plant forced the temporary evacuation of hundreds of people and sent huge plumes of black smoke billowing into the sky above Detroit. The fire began when a rail tanker car ignited while being refueled. Drivers were told to evacuate the service drive in that area in both directions. About 300 homes in the Hamtramck Colonel housing development adjacent to the plant were also evacuated. Amtrak passenger rail service was suspended between Pontiac and Detroit. Amtrak passengers were shuttled about 20 miles between the cities by charter bus. There were no reports of injuries.

October 20, 2009 – River Rouge (Wayne County) – Explosion / Fire at Industrial Plant

Billows of thick, black smoke could be seen for miles on October 20, 2009 after a fire engulfed an asphalt spill nearly the size of a football field in an industrial area southwest of Detroit. The blaze at the plant was largely contained to its outdoor storage yard. A roughly 100-gallon oil tank also exploded during the fire. Hazardous materials crews, environmental cleanup workers, and other emergency personnel responded to the scene.

August 24, 2009 – Detroit (Wayne County) – Explosion / Fire at Industrial Plant

A fire at a Detroit chemical company was caused by chemicals inside a heating oven that caused several explosions and the factory to be evacuated. The fire created thick black smoke and could be seen in the air for miles. One firefighter was taken to a hospital with minor injuries.

November 2, 2009 – Marysville (St. Clair County) – Explosion / Fire at Chemical Plant

Fire crews extinguished a blaze with thick plumes of black smoke at a welding supply company in Marysville after a series of explosions rattled the nearby neighborhood, injured a worker, and sent pieces of metal flying through the air. About 15 to 20 nearby residents, Cleveland Elementary School and the Grant Education Center, along with some nearby businesses, were ordered to evacuate the area. Authorities told others to stay inside and close the windows because of the potential for airborne chemicals. Hazmat teams surveyed the area for several hours after the blast and determined that the air quality around the fire did not endanger the residents. Everyone was allowed to return to their homes.

Selected Fixed-Site Hazardous Material Incidents in Michigan Since 1976

January 22, 1976 – Saginaw (Saginaw County)

An explosion and fire at a farm supply shipping plant and grain tower killed five persons and injured 12 others. Grain storage areas often contain air that becomes loaded with flammable dust and has a high risk of an explosion being triggered from a spark or flame.

October 7, 1977 – Midland (Midland County)

A chlorine gas leak valve burst on a tank at chemical plant, producing a vapor cloud that incapacitated several schools. A total of 1,500 students and another 5,000 residents were evacuated.

May 3, 1979 – Adrian (Lenawee County)

Curene 442 (a chlorinated hydrocarbon) leaked from a plant into the nearby sewers in a five block area, affecting the Raisin River.

April 23, 1981 – Swartz Creek (Genesee County)

A court-ordered hazardous waste site cleanup forced the evacuation of 60 residents for one month. The possibility of cyanide and acid mixing had prompted the evacuation.

April 28, 1983 – Benton Harbor (Berrien County)

A chemical spill at a manufacturing plant (involving 6,500 gallons of toluene di-isocyanate) forced the closure of M-139.

June 17, 1983 – Shelby Twp. (Macomb County)

A fire at a hazardous waste site caused six injuries and forced the evacuation of 1,200 people.

March 5, 1984 – Adrian (Lenawee County)

A fire at a plastics plant (involving polystyrene) forced the evacuation of 1,000 people from nearby mobile home parks and a subdivision.

August 6, 1984 – Hamtramck (Wayne County)

A fire at a chemical plant involved exploding tanks of anhydrous ammonia, forcing the evacuation of 300 people from the scene. Several firefighters were injured.

May 12, 1988 – Detroit (Wayne County)
A chemical fire (involving sulfur chloride) at a manufacturing plant forced the evacuation of persons living around the plant.

October 24, 1988 – St. Clair Shores (Macomb County)
A chemical spill at a plant injured 40 persons and forced an evacuation of the site.

November 29, 1988 – Flint Twp. (Genesee County)
A fire at a plastics plant created a toxic plume that forced the evacuation of 75 homes. A total of 97 firefighters were injured while fighting the blaze, and 20 required hospitalization.

April 22, 1990 – Egelston Twp. (Muskegon County)
A release of phosphorus oxychloride from a plant created a toxic plume that covered a two-mile area, forcing the evacuation of 1,000 people from two mobile home parks.

March 27, 1998 – Brighton (Livingston County)
A fire at a plastics plant burned for 16 hours, injuring two persons, forcing the evacuation of 50 homes, and closing of US-23 for several hours. One-third of the plant was destroyed.

October 29, 1999 – Livonia (Wayne County)
An explosion and flash fire at a chemical plant released a plume of chromic acid over a nearby residential area and freeway, forcing 40 people to seek medical treatment at nearby hospitals. Persons within a quarter-mile radius of the plant were advised to stay indoors and keep doors and windows closed. A 1.5-mile stretch of Interstate 96 was closed for several hours, to allow for air monitoring and testing.

January 12, 2000 – Livonia (Wayne County)
An ammonia leak inside a food processing plant caused an explosion and fire that tore out the side of the building, injured three persons, forced the evacuation of 12 employees, and closed nearby roads for approximately 9 hours. The cleanup effort was complicated by the discovery that the leaked ammonia had mixed with water, creating a solution of ammonium hydroxide that can cause severe burns to skin and eyes, and in some cases, death. An environmental firm was brought in to clean up the solution.

April 12, 2000 – Egelston Twp. (Muskegon County)
An explosion and flash fire at a chemical plant injured 10 persons and flattened part of the plant's production area. The explosion is believed to have been caused by the chemical tetranitromethane, once used to make rocket fuel. Although the plant never produced the chemical, it may have been an unintended by-product of the company's herbicide production. The explosion shook buildings more than a mile from the plant and hurled sections of steel I-beams onto the roof of a nearby factory more than 200 yards away. The cleanup operation forced the evacuation of businesses within a one-half mile safety zone around the plant.

July 14, 2001 – Riverview (Wayne County)
An explosion at a chemical plant killed three plant workers, injured nine others, and forced the evacuation of 2,000 nearby residents. The explosion was caused when methyl mercaptan – a colorless flammable gas used in the manufacture of additives for chicken feed and pharmaceuticals and as an additive to natural gas – seeped from a 25,000-gallon rail car and exploded at the plant. (Methyl mercaptan is a foul smelling gas that can be toxic to humans if they are exposed to heavy concentrations for up to one hour. Exposure to small amounts of the chemical for several hours can cause headaches and burning sensations in the eyes and throat.) The toxic chemical cloud briefly threatened the city of Amherstburg in Ontario, Canada, but a wind shift reduced the threat and the need to evacuate. Fire officials at the scene indicate the situation could have been much worse had another nearby tanker containing methyl mercaptan, and three others containing chlorine, also ignited. Favorable wind conditions also helped push the fumes away from surrounding communities, reducing the need to evacuate more residents.

August 27, 2001 – Detroit (Wayne County)
A fire at a metal plating plant injured eight firefighters, forced the evacuation of residents within a five-block radius, and completely destroyed the plant. The fire, which continued to smolder for more than 24 hours, consumed large tanks of cyanide, sulfuric acid, and other chemicals. Toxic fumes from the fire forced a one-week closure of a local elementary school.

April 9, 2002 – Dearborn (Wayne County)
At least 15,000 gallons of oil was dumped into the Detroit and Rouge rivers, contaminating 27 miles of shoreline. The oil was apparently dumped into a Dearborn storm sewer, but the Environmental Protection Agency was unable to find conclusive evidence to point to one polluter. Federal authorities spent $3.7 million cleaning up the area.

July 7, 2003 – Linwood (Bay County)
A large industrial fire occurred at the American Recycling Company in Linwood. The fire involved butyl rubber (approximately 1,000 bags of 1,000 lbs. each) and 200 barrels of fuel additives. Residents of a mobile home park were evacuated to a safe location.

February 1, 2004 – Sarnia, Ontario (St. Clair River)
39,000 gallons of toxic chemicals leaked into the St. Clair River near Sarnia, Ontario. Methyl ethyl ketone and methyl isobutyl ketone, which are low toxicity solvents, leaked into the river from an Imperial Oil plant. Local residents were urged to refrain from using the tap water for cooking, bathing, or drinking, until the water could be tested.

October 16, 2007 – Melvindale (Wayne County)
Residents and three schools were evacuated after a leak was reported at a Melvindale chemical company, totaling nearly 3,000 evacuated residents. Hydrochloric acid was released into an overflow container, so it was not a direct spill. It was released into a container and was contained by Hazmat teams.

September 15, 2007 – Lowell (Kent County)
A fire and an explosion destroyed several connected buildings at a Lowell factory. The fire affected a quantity of 10% solution of sulfuric acid that was between 5 and 10 thousand gallons. There was a concern over the effect on groundwater, and on the Lowell municipal water supply. The blaze sent black and gray smoke billowing high into the evening sky, visible at least 10 miles away, and attracted hundreds of onlookers. A half-dozen area fire departments, from as far as East Grand Rapids and Belding, helped Lowell firefighters battle the blaze. There was at least one reported injury.

December 14, 2007 – Fraser (Macomb County)
A truck spilled 550 gallons of sulfuric and nitric acid in Fraser, closing a boulevard. Local businesses were evacuated and crews conducted a total cleanup of the area. The Clinton Township hazardous materials team arrived on the scene and determined that all of the truck's contents had emptied, some of which had run off the road and into a nearby sewer and drain. No one was injured in the incident.

July 18, 2008 – Grand Blanc (Genesee County)

Residents near a Grand Blanc plant were evacuated when several tanks filled with sulfuric acid caught fire. Police were called to the plant and most of the fires were quickly under control. However, firefighters were concerned about hazardous vapors in the air and began evacuating residences and businesses. One tank continued to burn from the inside, making it difficult for firefighters to put the flames out.

September 25, 2008 – Grand Haven (Ottawa County)

A small leak from a faulty plug in a one-ton sulfur dioxide tank, delivered to the Grand Haven wastewater treatment plant, forced authorities to evacuate about 75 homes for three hours. The plug had a faulty thread, allowing the liquid substance to escape and immediately turn to gas. There were no reported injuries or effects from the gas release.

March 9, 2009 – Detroit (Wayne County)

The Detroit Fire Department handled a chemical spill clean-up after an undetermined amount of sulfur dioxide had leaked from a railroad car in southwest Detroit. The leak happened at a city wastewater treatment plant just west of Zug Island. The car was carrying about 90 tons of sulfur dioxide, but it was unclear how much leaked out. A professional chemical handling company oversaw the transfer of the remaining sulfur dioxide to another railcar.

July 10, 2010 – Monroe County

Southbound I-75 was closed during the early morning hours because of a chemical spill at a Toledo industrial park. Although the spill was outside of the state, there was still an effect upon one of Michigan's major Interstate highways.

Programs and Initiatives

Note: Many of the programs and initiatives designed to mitigate, prepare for, respond to, and recover from hazardous material transportation incidents have the dual purpose of also protecting against fixed-site hazardous material incidents and some industrial accidents. As a result, there is some overlap in the narrative "Programs and Initiatives" sections for each respective hazard. This redundancy allows each hazard section to stand alone, eliminating the need to refer to other hazard sections for basic information.

Superfund Amendments and Reauthorization Act (SARA), Title III

As explained earlier, the Bhopal, India tragedy initiated a chain of events aimed at enhancing preparedness activities to minimize the potential for a similar event to occur in the United States. On October 17, 1986 the Superfund Amendments and Reauthorization Act (SARA) was signed into law. A major SARA provision is Title III (the Emergency Planning and Community Right-To-Know Act, also known as SARA Title III), which establishes hazardous material emergency planning, reporting, and training requirements for federal, state and local governments, and private industry. In Michigan, the SARA Title III program is jointly administered and implemented by two state departments—the Michigan State Police and the Michigan Department of Environmental Quality.

The emergency planning provisions of SARA Title III require each state to establish a state emergency response commission, emergency planning districts, and a local emergency planning committee for each district. The state commission and local committees are responsible for preparing and implementing emergency plans, as well as receiving and disseminating copies of material safety data sheets, chemical inventories, and other reports and forms necessary for compliance under the Act. The community right-to-know provisions of SARA Title III allow the public to access information on the hazardous materials stored in their community, and the quantities of toxic materials released into the environment.

State Emergency Response Commission

The Michigan Emergency Planning and Community Right-to-Know Commission (commonly known as the State Emergency Response Commission or SERC) was established in 1987 and then re-organized in 1994 and 1995. It consists of 17 members appointed by the Governor. The membership includes several state agencies, the general public, and a variety of other groups and professional disciplines (including agriculture, industry, labor, education, local government, and environmental protection and stewardship). The SERC is chaired and administered by the Emergency Management and Homeland Security Division, Department of State Police (EMHSD/MSP), in cooperation and conjunction with the Michigan Department of Environmental Quality (MDEQ). The primary purpose of the SERC is to monitor SARA Title III activities in the state and develop policy and overall direction for program administration. The EMHSD/MSP and MDEQ provide professional staff to assist the SERC in carrying out Title III planning, training, exercising and reporting activities.

Local Emergency Planning Committees

One of the major provisions of SARA Title III is the establishment of Local Emergency Planning Committees (LEPCs) for designated planning districts. The LEPCs are responsible for developing emergency response plans for communities that have facilities in their jurisdiction subject to SARA Title III emergency planning requirements. The LEPC is the primary mechanism through which local SARA Title III planning, training and exercising activities are implemented. Michigan has 88 designated LEPCs – one for each of the 83 counties and 5 in major cities. Nearly 2,800 facilities across the state have been identified as being subject to Title III emergency planning provisions. A facility is subject to SARA Title III provisions if extremely hazardous substances (as determined by the U.S. Environmental Protection Agency) are present at the facility in quantities at or above the minimum threshold quantities established in Section 302 of the Act. The map at the end of this section provides a breakdown of Title III (Section 302) sites by county.

Individual firms doubtlessly vary a great deal in their safety records, just as they vary in the types and quantities of hazardous materials that they handle. Use of GIS can be helpful since Section 302 sites can be located spatially and then ringed with a buffer representing the identified evacuation zone. A vulnerability assessment would primarily be based on the development that exists within that zone—especially if vulnerable populations are located within that area, such as schools, hospitals, other medical facilities such as blood banks or kidney dialysis centers, high-rise senior facilities, and day care centers. The probability of a local incident might be assessed from historical records of industrial accidents or chemical releases. Wide variation in estimates is likely, depending on whether the history of an entire industry or only of a particular site is used. Often, a local site may appear to have an incident-free history, but the risk cannot be assumed to be zero.

Hazardous Material Response Planning

Each Section 302 site must be covered by a community response plan that addresses the emergency planning requirements found under SARA Title III. Inclusion of Michigan Firefighter Right-to-Know provisions of the Michigan Occupational Health and Safety Act (1986 PA 80) is also encouraged in the planning guidance provided by the Emergency Management and Homeland Security Division, Department of State Police. The EMHSD/MSP provides technical planning assistance to the LEPCs to facilitate the development and maintenance of those required plans. That assistance typically includes provision of written planning guidance, interaction with the planning team, plan reviews, and limited financial assistance (via federal grant funds) to offset the costs of preparing the plans. Each facility plan must address the following critical areas: 1) hazard identification (to include chemical inventories, locations, release detection, and chemical-specific response information); 2) vulnerability map and analysis (to include a vulnerability zone, special populations affected, and other facilities and areas that may contribute to risk); 3) population protective actions (to include warning, access control, evacuation and in-place sheltering); 4) response procedures (to include both on-site and off-site expertise and equipment); and 5) a training and plan exercising program. The plans must be reviewed and commented upon by the Michigan SERC.

The Michigan Department of Environmental Quality and the Michigan Department of Agriculture and Rural Development provide technical information and planning assistance in the areas of community-right-to-know, material safety data sheets, chemical inventories, incident reporting, and (on a limited basis) incident cleanup.

Hazardous Material Response Training

The Emergency Management and Homeland Security Division, Department of State Police, provides a wide array of hazardous material response training programs through the Michigan Hazardous Material Training Center. The Center provides training courses for individuals and companies responsible for planning, inspection, response, mitigation, and cleanup activities involving hazardous materials. Specific subjects include: 1) computer-aided management; 2) hazardous materials chemistry; 3) hazardous materials emergency response; 4) hazardous waste worker compliance; 5) incident management; 6) hazardous materials monitoring/sampling; and 7) other specialized hazardous materials-related courses such as highway and rail cargo tanker handling, confined space

entry, emergency medical services, and technical rescue. Courses are conducted at the Center in Lansing and at various other locations throughout the state.

Federal/State Hazardous Material Response Resources

Even prior to the Bhopal, India incident in 1984, there were numerous groups at the federal, state, and local levels, and in private industry, trained to deal with hazardous material incidents. Those groups include the National Response Team (NRT), Regional Response Teams (RRTs), and state and local hazardous material response teams. The Chemical Manufacturers Association established the Chemical Transportation Emergency Center (CHEMTREC) to provide 24-hour technical advice to emergency responders. The National Response Center (NRC), which operates much like CHEMTREC, was established to provide technical advice and coordinate federal response to a hazardous material incident.

In Michigan, a 24-hour statewide notification system called the Pollution Emergency Alerting System (PEAS) was established for reporting chemical spills to the Department of Environmental Quality. As a companion to the PEAS, the Michigan Department of Agriculture and Rural Development (MDARD) has established a 24-hour Agriculture Pollution Emergency Hotline for use by agri-chemical users to report fertilizer and pesticide spills. Callers to the MDARD hotline gain immediate access to appropriate technical assistance, regulatory guidance for remediation, and common sense approaches for addressing the problem.

U.S. EPA Chemical Emergency Preparedness and Prevention Office

The USEPA's Chemical Emergency Preparedness Office (CEPPO) provides leadership, advocacy and assistance to states, local governments, and private industry to: 1) prevent and prepare for chemical emergencies; 2) respond to environmental crises; and 3) inform the public about chemical hazards that may be present in their community. The CEPPO works closely with several Michigan state agencies to implement and coordinate a number of regulatory and non-regulatory programs designed to protect human health and the environment in Michigan from chemical accidents—including the SARA Title III program.

Resource Conservation Recovery Act

Not all facilities with hazardous materials fall under the requirements of SARA Title III. The Michigan Department of Environmental Quality (MDEQ) regulates over 8,000 small and large hazardous waste generators under the federal Resource Conservation Recovery Act (RCRA). The RCRA provides MDEQ with the authority to control hazardous waste from "cradle to grave," which includes the generation, transportation, treatment, storage, and disposal of hazardous waste. The high number of RCRA facilities in Michigan is indicative of the widespread prevalence of hazardous materials throughout the state.

Michigan Chemical Council

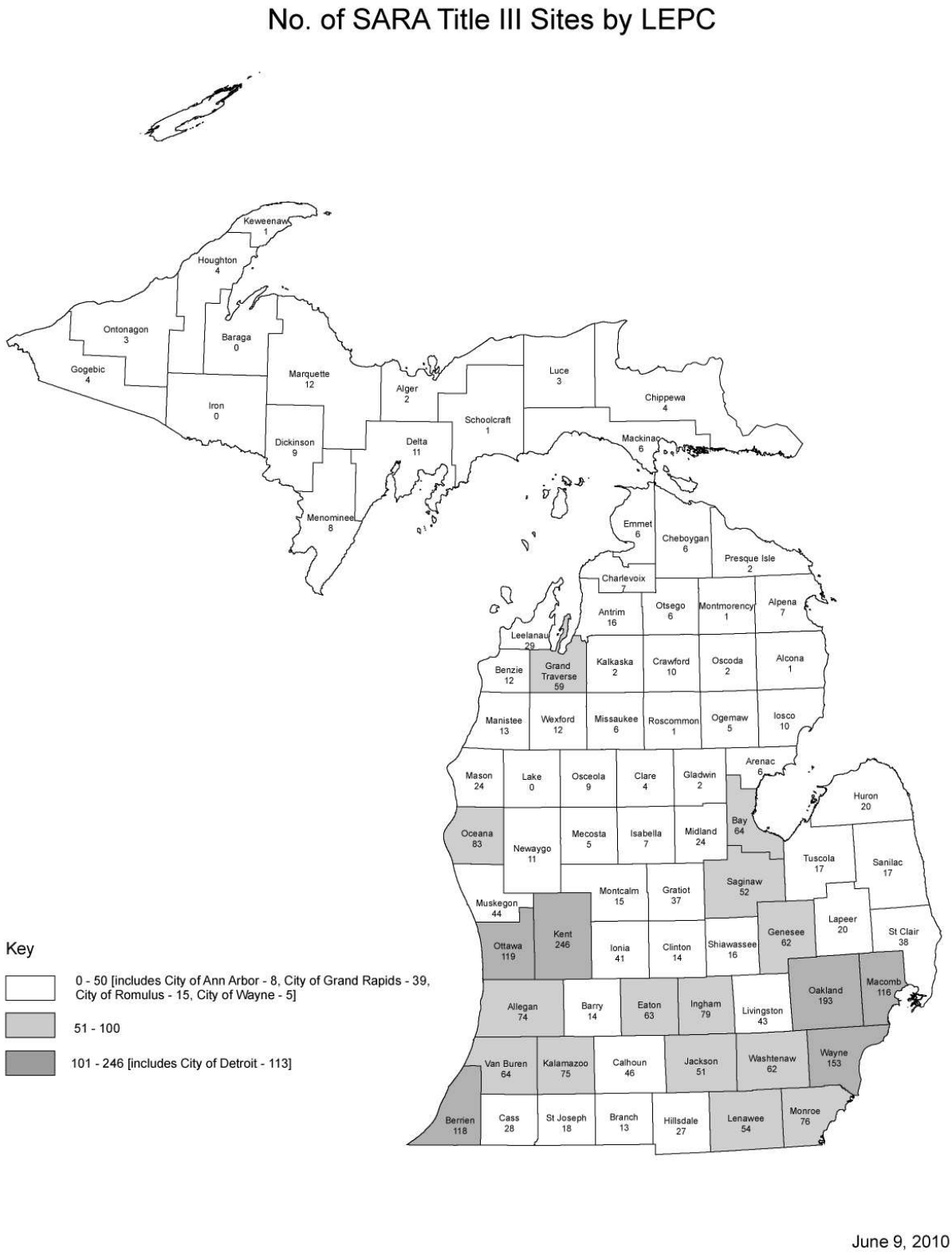
The Michigan Chemical Council is the primary trade association representing the chemical and allied industries in Michigan. As such, it works in partnership with the national Chemical Manufacturers Association, the Emergency Management and Homeland Security Division of the Department of State Police (MSP/EMHSD), and other agencies and local governments to provide educational and community outreach services in the area of chemical awareness and safety. The Council provides an important informational and coordination bridge between Michigan's chemical industries, federal, state and local regulatory agencies, and the public.

Chemical Awareness Week

Each spring, the MSP/EMHSD, in conjunction with several other state agencies, LEPCs, and the Michigan Chemical Council, sponsors Chemical Awareness Week. This annual public information campaign focuses on: 1) the hazards associated with the manufacture, transport, storage, use, and disposal of chemicals; 2) the programs and systems in place to protect the public from accidental chemical releases; and 3) community emergency response procedures for chemical accidents. Informational materials on chemical hazards and safety are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public.

SARA Title III Sites in Michigan

Source: Michigan Department of Environmental Quality



NUCLEAR POWER PLANT EMERGENCIES

An actual or potential release of radioactive material at a commercial nuclear power plant, in sufficient quantity to constitute a threat to the health and safety of the off-site population.

Hazard Description

Though the construction and operation of nuclear power plants is closely monitored and regulated by the Nuclear Regulatory Commission (NRC), accidents at these plants are considered a possibility, and appropriate on-site and off-site emergency planning is conducted. An accident could result in the release of potentially dangerous levels of radioactive materials into the environment and could affect the health and safety of the public living near the nuclear power plant. A nuclear power plant accident might involve both a release of airborne radioactive materials and radioactive contamination of the environment around the plant. The degree and area of environmental contamination could vary greatly, depending on the type and amount of release, and the weather conditions that are present. Response to a nuclear power plant accident requires specialized personnel who have been trained to handle radioactive materials safely, who have specialized equipment to detect and monitor radiation, and who are trained in personal radiation exposure control.

After a period of decline following the 1979 Three Mile Island accident and the 1986 incident at Chernobyl, there is a recent renewed interest in nuclear energy because it could partially address problems of dwindling oil reserves and global warming, with far fewer emissions of greenhouse gases than the use of fossil fuels. However, the use of nuclear power is controversial because of the problems of storing radioactive waste for indefinite periods, the potential for radioactive contamination by accident or sabotage, and the possibility that its use could in some countries lead to the proliferation of nuclear weapons. As the chart below shows, the United States produces the most nuclear energy of any country in the world, but many other countries actually use nuclear energy as a larger percentage of their overall energy production.

Nuclear Electricity Generation by Country: 2008

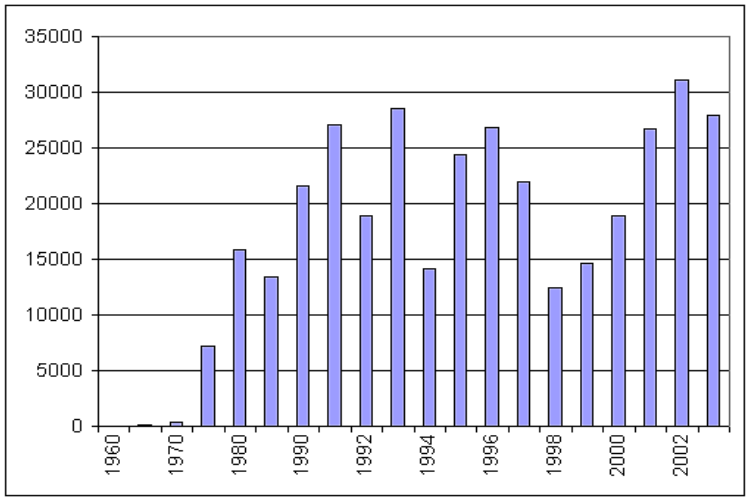
Country	Production (Billion Kilowatt Hours)	% of Country's Energy	Country	Production (Billion Kilowatt Hours)	% of Country's Energy
Argentina	6.9	6.2%	Korea RO (South)	144.3	35.6%
Armenia	2.3	39.4%	Lithuania	9.1	72.9%
Belgium	43.4	53.8%	Mexico	9.4	4.0%
Brazil	13.2	3.1%	Netherlands	3.9	3.8%
Bulgaria	14.7	32.9%	Pakistan	1.7	1.9%
Canada	88.3	14.8%	Romania	10.3	17.5%
China	65.3	2.2%	Russia	152.1	16.9%
China: Taiwan	39.3	17.1%	Slovakia	15.5	56.4%
Czech Rep.	25.0	32.5%	Slovenia	6.0	41.7%
Egypt	0	0%	South Africa	12.8	5.3%
Finland	22.1	29.7%	Spain	56.5	18.3%
France	419.8	76.2%	Sweden	61.3	42%
Germany	140.9	28.8%	Switzerland	26.3	39.2%
Hungary	13.9	37.2%	Turkey	0	0%
India	13.2	2.0%	Ukraine	84.5	47.4%
Indonesia	0	0%	United Kingdom	48.2	13.5%
Iran	0	0%	**USA**	**806.7**	**19.7%**
Israel	0	0%			
Japan	241.3	24.9%	**WORLD**	**2,597.8**	**14%**
Korea DPR (North)	0	0%			

Hazard Analysis

With three commercial nuclear power plants currently operating in the state, emergency preparedness is required in all potentially affected jurisdictions. Michigan's three commercial nuclear power plants are 1) the Enrico Fermi-2 plant near Monroe; 2) the Donald C. Cook plant near Bridgman; and 3) the Palisades plant near Covert.

A fourth plant, the Big Rock Point plant near Charlevoix, was closed in 1997 and then decommissioned, but spent fuel is still stored on-site in dry casks and will probably remain there quite a while. The Davis-Besse nuclear power station near Toledo, Ohio has several Michigan counties within its Secondary Emergency Planning Zone (EPZ), requiring coordinated planning between Michigan and Ohio. The commercial power plant facilities are located on the map at the end of this section. The chart below shows the amount of nuclear power that Michigan has generated since 1960.

Nuclear Generation in Michigan, 1960 through 2003
(Million Kilowatt Hours)



Source: Energy Information Administration, State Energy Data Report 1999, Electric Power Annual (Volume 1, 2001), and EIA Survey Form 906.

Federal, state and local governments and utility personnel take extensive precautions to ensure that, should a nuclear accident occur, its impact on the safety and well being of the general public and the environment will be minimal. These precautions include the development and continual testing of emergency plans, training of response personnel, coordination of response actions, and development and dissemination of emergency public information. A regular series of large, interagency drills and exercises takes place for each nuclear plant, and each plant has two designated emergency planning zones—primary (within a 10 mile radius) and secondary (within a 50 mile radius)—to handle all possible incidents and response activities that could be anticipated, both in the short-term and the long-term.

Impact on the Public

A nuclear power plant accident would tend to pose limited threats, directly involving the environment and public over a distance typically no greater than 10 miles away, even in the most severe U.S. events. Evacuation and contamination may occur within this limited distance from the plant, and any more far-reaching effects (e.g. food chain contamination) would vary with weather conditions and the extent and type of radioactive release. This hazard has been extensively studied and prepared for, allowing the likely impacts on the public to be efficiently assessed and addressed, should an event occur.

Impact on Public Confidence in State Governance

A nuclear power plant emergency may severely affect public confidence in state government if it results in significant environmental harm, displacement, or casualties. Although the odds of this happening are slim, nuclear power is poorly understood by many U.S. citizens, many of whom may be expected to misinterpret both the nature of the industry as well as the effects of an accident, and to perceive that any significant failures are likely the result of inadequate governmental oversight and regulation.

Impact on Responders

Due to pre-planning, training, and exercising, a nuclear power plant accident offers the opportunity to use planned staging areas, from which to handle equipment, protective clothing, medical treatment, decontamination, provision and sheltering needs. Responder exposure to radiation should not need to exceed amounts that have been mandated by law and by workplace regulations. (Extensive procedures and regulations are in place to minimize those types of risks.)

Impact on the Environment

A nuclear power plant accident could result in the release of potentially dangerous levels of radioactive materials both in the air and around the plant. Contamination may occur from radioactive gases, liquids or particles. Some possible accidents at nuclear power plants pose a risk for severe environmental contamination, and the degree and area of this contamination could vary greatly depending on the type and amount of radioactivity, and on the weather conditions.

An accidental release of large amounts of radioactive contamination could contaminate many areas of land for long periods of time, making it unusable for humans, wildlife species, and natural vegetation. The main reason is due to radioactive materials comprising unstable isotope elements that decay over a long period of time. Some isotopes can decay quickly, while others take a very long time to stabilize. Certain radioactive elements such as plutonium can remain hazardous for thousands of years, making re-use of an area difficult or hazardous. Nuclear reactors produce high level waste (an actual classification) in the reactor core that is highly reactive and thermally hot, presenting handling, transportation, and storage problems. Radioactive contamination may affect nearby water bodies, rivers, etc. and damage the environment and its aquatic life. Radioactive material has the potential to seep deep into the ground and water table.

Significant Nuclear Power Plant Accidents

Worldwide, three nuclear power plant accidents rank as most significant in the history of the nuclear power era:

March 28, 1979 – Three Mile Island, Harrisburg Pennsylvania

On March 28, 1979, the most serious nuclear reactor accident ever to occur at a commercial power plant in the United States took place at the Three Mile Island nuclear power plant near Harrisburg, Pennsylvania. This incident resulted from a plant malfunction, combined with operator overrides of automatic safety systems. These errors resulted in a partial meltdown of the reactor core. Utility, state, and local personnel implemented response plans to protect the public in the area around the plant, while on-site efforts were undertaken to cool the reactor and prevent any possible release of radioactive material. While this accident did not result in any off-site health consequences, it had a major impact on emergency planning regulations in the United States.

Following the accident, new federal regulations were written to mandate specific activities by both on-site and off-site emergency response organizations. These more stringent federal regulations aimed at improving emergency planning efforts at nuclear power plants and providing for additional plant safety systems. Among the new regulations was NUREG 0654/FEMA REP-1, which forms the basis for state and local government planning, training, and emergency exercises. The U.S. Environmental Protection Agency (EPA) also issued new guidance on environmental monitoring and protective actions.

April 26, 1986 – Chernobyl, Ukraine (then part of the Soviet Union)

On April 26, 1986 a Soviet nuclear reactor at Chernobyl, Ukraine suffered a steam explosion while conducting experimental testing. This explosion, and the ensuing fire in the graphite core of the reactor, released radioactive debris into the upper atmosphere, where wind currents dispersed it around the world. Other radioactive material was deposited in areas around the plant site, contaminating the land and food. The high levels of radiation on-site killed 32 plant workers and firefighters. The World Health Organization and other public health agencies are still studying the effects of the accident on public health in the Ukraine and nearby areas.

The long-term impacts of this accident are continuing today. The area within a 30 kilometer (20 mile) radius around the plant is heavily contaminated with radioactive material, and most of those who had previously resided there have not returned. Soil contamination does not allow the consumption of crops grown in these areas. Because residents had consumed contaminated crops and milk, studies have indicated significant increases in childhood thyroid cancer in the region around the plant. 4.5 million persons continued to live in less-severely contaminated areas in Ukraine, Russia, and Belarus. One of the major lessons learned from this accident is the need for early impoundment of suspected food and milk that may have been contaminated. The EPA has revised its guidelines for environmental monitoring in affected areas as a result of the Chernobyl experience.

While an event of this nature is not physically possible at a U.S. reactor due to differences in reactor design and safety systems (for example, the Chernobyl reactor did not have a containment building), the event did impact U.S. emergency planning regulations. Lessons learned from this accident have been incorporated into federal guidance (e.g., EPA 400 Ingestion Pathway Protective Action Guidance). Additional emphasis has been placed on the ingestion pathway aspects of nuclear power plant emergency exercises.

March 11, 2011 – Japan

On March 11, 2011 a 9.0 magnitude undersea mega-thrust earthquake occurred near Tohoku, Japan. The epicenter was approximately 43 miles east of the Oshika Peninsula of Tohoku and the hypocenter was at an underwater depth of approximately 20 miles. It was the most powerful known earthquake to have hit Japan, and one of the five most powerful earthquakes in the world since modern record-keeping began in 1900. There were multiple foreshocks, as well as hundreds of aftershocks of a 4.5 magnitude or greater. The earthquake triggered extremely destructive tsunami waves of up to 40.5 meters high, and in some cases traveling up to 6 miles inland in Tohoku. The Japanese National Police Agency has confirmed (as of 2012) 15,854 deaths, 26,992 injuries, and

3,155 people missing; as well as 129,225 buildings destroyed, and 945,970 damaged. The earthquake and tsunami caused extensive and severe structural damage in Japan, heavy damage to roads and railways, fires in many areas, and a dam collapse. Around 4.4 million households in northeastern Japan were left without electricity. The earthquake also moved Honshu 8 feet east and shifted the Earth on its axis an estimated 4 to 10 inches.

In addition to loss of life and destruction of infrastructure, the tsunami caused a number of nuclear accidents, primarily equipment failures, the release of radioactive materials, and level 7 meltdowns at three reactors in the Fukushima I Nuclear Power Plant complex. The Fukushima I, Fukushima II, Onagawa Nuclear Power Plant, and Tōkai nuclear power stations, consisting of a total of eleven reactors, were automatically shut down following the earthquake. Three nuclear reactors suffered explosions due to hydrogen gas that had built up within their outer containment buildings after cooling system failures. At Fukushima I and II, tsunami waves overtopped seawalls and flooded the entire plant, including low lying generators, electrical switch gears, and external pumps for supplying cooling seawater. The plant's connection to the electrical grid was broken because the tsunami destroyed the power lines. All power for cooling was lost and the reactors started to overheat from the natural decay of the fission products created before shutdown. The flood destroyed diesel backup power systems, leading to severe problems at Fukushima I, including three large explosions and radioactive leakage. Flooding with radioactive water also prevented access to basement areas where repairs where needed. Officials from the Japanese Nuclear and Industrial Safety Agency reported that radiation levels inside the plant were up to 1,000 times normal levels, and that radiation levels outside the plant were up to eight times normal levels. Residents within a 12 mile radius of the Fukushima I Nuclear Power Plant and a 6 mile radius of the Fukushima II Nuclear Power Plant were evacuated. There were associated evacuation zones that affected hundreds of thousands of residents.

An April 7, 2011 aftershock caused the loss of external power to Rokkasho Reprocessing Plant and Higashidori Nuclear Power Plant, but backup generators were functional. Onagawa Nuclear Power Plant lost 3 of 4 external power lines and lost its cooling function for as long as 80 minutes. It was also reported that radioactive iodine and cesium was detected in the tap water in several nearby areas. Radioactive strontium was detected in the soil in some places in Fukushima as well. It was estimated that the release of dangerous radioactive isotopes of iodine and cesium from Fukushima reached almost the same emission levels as those from Chernobyl in 1986. Food products were also found to be contaminated by radioactive matter in several places and food grown in the area was banned from sale. As the nuclear crisis entered a second month, experts recognized that Fukushima I was not the worst nuclear accident ever (compared to Chernobyl, which was worse) but it was the most complicated, due to the multiple reactors involved. Later analysis indicated that three reactors (Units 1, 2, and 3) had suffered meltdowns and continued to leak coolant water three months after the initial events.

Experts have said that a workforce in the hundreds or even thousands would take years or decades to clean up the area. It was announced that the plant would be decommissioned once the crisis was over. Early estimates placed insured losses from the earthquake alone at US$14.5 to $34.6 billion. The overall earthquake and tsunami event cost is estimated by the World Bank to be US$235 billion, making it the most expensive natural disaster on record. Even the United States suffered damage because, in California and Oregon, up to 8 foot high tsunami surges hit some areas, damaging docks and harbors and causing over $10 million in damages.

Michigan has also experienced a significant nuclear power plant incident, although nothing along the lines of the Chernobyl, Three Mile Island, and Japan accidents in terms of scope, magnitude, or severity:

October 5, 1966 – Enrico Fermi-1, Monroe County, Michigan

Although Michigan has never experienced a significant nuclear power plant accident that involved an off-site release of radioactive material, on October 5, 1966, a serious incident did occur at Detroit Edison's then-new Enrico Fermi Atomic Power Plant near Monroe (commonly called Fermi-1). Fermi-1 was an experimental breeder reactor designed to demonstrate the feasibility of liquid fast-metal breeder reactor technology. On October 5, a metal flow guide inside the reactor broke off and blocked the flow of sodium coolant in the space below the reactor core. As a result, approximately 1% of the fuel melted. The fuel damage caused the release of some radiation into the reactor containment building; however, no off-site release occurred. The plant was eventually repaired, and it operated for a short period until it was permanently shut down in 1972. The fuel and related materials were removed and sent to a federal government facility in the mid-1970s. The Enrico Fermi-2 nuclear power plant opened next door in 1988.

March 5, 2002 – Davis-Besse, Oak Harbor, Ohio

An incident occurred on March 5, 2002 at the Davis-Besse Nuclear Power Station in Oak Harbor, Ohio when maintenance workers discovered that corrosion had eaten a football-sized hole into the plant's reactor vessel head. Although the corrosion did not lead to an accident, the Nuclear Regulatory Commission kept the plant shut down until March 2004. The U.S. Justice Department investigated and penalized the owner of the plant $28 million in fines for safety and reporting violations related to the incident. The NRC also imposed its largest fine ever, more than $5 million, against First Energy for the actions that led to the corrosion.

Programs and Initiatives

Since the Three Mile Island accident in 1979, federal, state and local governments have developed detailed radiological emergency response plans for each nuclear power plant based on NUREG 0654/FEMA REP-1 and subsequent federal regulations and guidance. These plans are exercised on a biennial basis and are reviewed by the Federal Emergency Management Agency (FEMA) and the Nuclear Regulatory Commission (NRC).

Ownership and use of radioactive materials is strictly regulated by the federal government. Nuclear power plants must follow strict building and safety codes. Material storage, use, and waste management practices are strictly monitored. In 1977, President Carter placed a moratorium on the shipping of spent fuel from commercial nuclear power plants to burial sites or spent-fuel reprocessing centers. Spent fuel is now stored at the plant site in spent fuel pools or dry cask storage facilities until the issue of permanent nuclear waste disposal is resolved.

Response to a nuclear power plant accident in Michigan is the joint responsibility of the plant owner/operator and the federal, state, and local government. State and local governments implement protective actions and other preparedness and response activities, based on the Nuclear Accident Emergency Action Level Classification

System. In most cases, the Primary Emergency Planning Zone (EPZ) around a nuclear power plant is 10 miles. Within this zone, plans are developed to protect the public through in-place sheltering and evacuation, in the event of an accident. The area within the Primary EPZ for which protective actions are implemented will depend on the type and amount of radioactive material released, and on weather conditions. The Secondary Emergency Planning Zone, consisting of a 50-mile radius around most plants, exists for planning considerations which aim to prevent radioactive contamination of the food chain.

International Nuclear Event Scale (INES)

The International Nuclear Event Scale is a seven scale level system that is designed to describe event severity in terms of a logarithmic scale in which each level is ten times more severe than the preceding one. After the zero level classification (denoting no significant threat), there are then three levels of "incident" and four levels of "accident," with the most serious being classified as a 7 (major accident). The selection of a level for a given event is based on three parameters: effect on people or the environment, loss of protective radiation barriers, and loss of any of the layers of safety systems. There have only been two Level 7 accidents (Chernobyl in 1986 and Japan in 2011) and only one Level 6 accident (Mayak, in 1957, also in the former Soviet Union). Three Level 5 accidents have also been classified—the Windscale Pile (United Kingdom, in 1957), the Three Mile Island accident in 1979, and the Goiânia accident (Brazil, in 1987, which is described in the Terrorism section of this document, within the subsection that assesses radiological attacks).

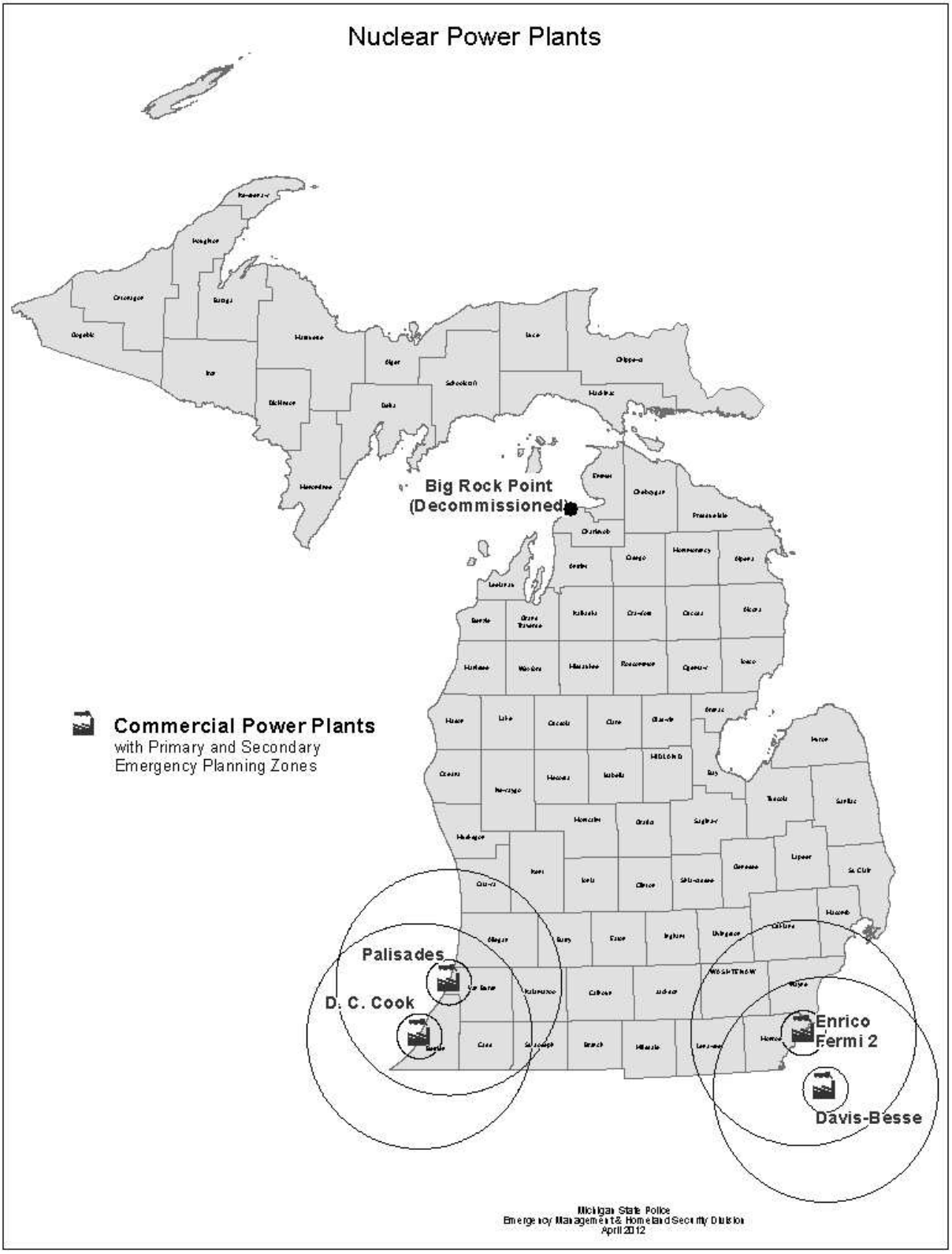
Radiological Emergency Preparedness (REP) Program

The Radiological Emergency Preparedness Program is responsible for the development and implementation of Michigan's Nuclear Facilities Emergency Management Plan, and for the nuclear accident aspects of the Michigan Emergency Management Plan, including the Department of Environmental Quality's radiological responsibilities to respond to accidents or emergencies at any of Michigan's commercial nuclear power plants. These efforts are conducted in cooperation with other state agencies and under the overall emergency response coordination responsibilities of the Michigan Department of State Police. Program staff also interacts with nuclear plant utility staff, and personnel from the U.S. Nuclear Regulatory Commission, concerning the day-to-day operations of nuclear power reactors to ensure radiological protection for the public and the environment.

Potassium Iodide (KI) Distribution

The possibility that radiation could be released into the environment during a radiation emergency, such as a nuclear reactor accident, has been a concern for years. The major concern with exposure to whole-body radiation or to heat and debris from a radioactive explosion is massive tissue damage and death from the explosion. Radiation-related thyroid cancer is another possible effect of exposure if radioactive iodine (radioiodine) is released by the accident. It can take 10 years or more after exposure for the thyroid cancer to develop, but it may then require surgery or chemotherapy. Taking potassium iodide (KI) pills in the immediate aftermath of radioiodine exposure can reduce the risk of subsequent thyroid cancer. The pills protect the thyroid from radiation poisoning for 24 hours, which is usually enough time to evacuate to safety. Though the pills won't protect against the other harmful effects of radiation exposure, they are so effective at preventing thyroid cancer caused by this type of radiation that many people and organizations have begun purchasing and stockpiling supplies of this over-the-counter tablet as a precautionary step. The federal government has asked states to consider the distribution of potassium iodide pills to people who live within 10 miles of nuclear plants, as a precaution against a severe nuclear accident. About 220,000 people in Michigan live within 10 miles of the state's three nuclear power plants. People living or working within 10 miles of any of the three nuclear power plants are able to receive a voucher for a 20-pill pack of potassium iodide (KI pills) at nearby pharmacies, free of charge.

Nuclear Power Plants in Michigan



HAZARDOUS MATERIAL INCIDENTS: TRANSPORTATION

An uncontrolled release of hazardous materials during transport, capable of posing a risk to life, health, safety, property, or the environment.

Hazard Description

As a result of the extensive use of chemicals in our society, all modes of transportation – highway, rail, air, marine, and pipeline – are carrying thousands of hazardous materials shipments on a daily basis through local communities. A transportation accident involving any one of those hazardous material shipments could cause a local emergency affecting many people.

Hazard Analysis

Michigan has had numerous hazardous material transportation incidents that affected the immediate vicinity of an accident site or a small portion of the surrounding community. Those types of incidents, while problematic for the affected community, are fairly commonplace. They are effectively dealt with by local and state emergency responders and hazardous material response teams. Larger incidents, however, pose a whole new set of problems and concerns for the affected community. Large-scale or serious hazardous material transportation incidents that involve a widespread release of harmful material (or have the potential for such a release) can adversely impact the life safety and/or health and well-being of those in the area surrounding the accident site, as well as those who come in contact with the spill or airborne plume. In addition, damage to property and the environment can be severe as well. Statistics show that almost all hazardous material transportation incidents are the result of an accident or other human error. Rarely are they caused simply by mechanical failure of the carrying vessel.

Being surrounded by the Great Lakes, one of the most dangerous hazardous material transportation accident scenarios that could occur in Michigan would be a spill or release of oil, petroleum or other harmful materials into one of the lakes from a marine cargo vessel. Such an incident, if it involved a large quantity of material, could cause environmental contamination of unprecedented proportions. Fortunately, the Great Lakes states, working in partnership with oil and petroleum companies and other private industry, have taken significant steps to ensure that a spill of significant magnitude is not likely to occur on the Great Lakes. (See the Programs and Initiatives section for more information.)

(Note: Pipeline transportation accident issues are addressed in the Petroleum and Natural Gas Pipeline Accidents section of this document. Refer to that section for specific information on that hazard. For an assessment of the various types of potential impacts from this hazard, please refer to the introductory section on hazardous materials, preceding the section on fixed site hazardous materials, earlier in this document.)

The maps at the end of this section illustrate the major railroads, highways, and Great Lakes ports in the State of Michigan. These transportation links and nodes have the greatest probability of experiencing a hazardous material transportation incident. Although the greatest risk involving hazardous materials comes from highway and rail shipments, a petroleum or chemical spill on the Great Lakes could have disastrous consequences for shoreline communities, recreational areas, tourism, and the environment. Fortunately, only about 3% of all shipments on the Great Lakes involve petroleum or chemicals, and most of those are through the Port of Detroit.

Significant Hazardous Material Transportation Incidents

Michigan has been fortunate not to have a large-scale, serious hazardous material transportation incident. However, Michigan has had numerous smaller-scale hazardous material transportation incidents that required a response by local fire departments and hazardous material teams, and many events also required evacuations and other protective actions. As a major manufacturer, user, and transporter of hazardous materials, Michigan will always be vulnerable to the threat of a serious hazardous material transportation incident.

From 1994 through 1998, local fire chiefs in Michigan reported a total of 730 hazardous material incidents on the Michigan Fire Incident Reporting System (MFIRS). Of those 730 reported incidents, approximately 25-30% (about 200 incidents) involved some form of motorized vehicle transportation. That figure represents an average of one reportable hazardous material transportation incident statewide approximately every 9.1 days. (Note: 1998 is the last year for which statewide hazardous material incident response statistics are available.)

A reportable hazardous material incident is one in which all three of the following conditions apply: 1) a material is present that is suspected to be something other than ordinary combustible by-product material; 2) the material is in such a state, quantity or circumstance that, if left unattended, it is presumed to pose a threat to life, health, property or the environment; and 3) special hazardous material resources were dispatched or used, or should have been dispatched or used, for assessing, mitigating or managing the situation.

Significant Hazardous Material Transportation Incidents in Michigan: Selected Incidents since 1978

February 4, 1978 Woodland Park (Newaygo County)
A freight train derailment caused a chemical spill of ethylene oxide, carbolic acid, methylene chloride, and phropheline oxide. A total of 50 persons were evacuated from the vicinity of the accident scene.

July 31, 1978 Milan (Monroe County)
A fuel tanker accidentally pumped 1,000 gallons of gasoline into Milan's sewer system, resulting in an explosion. A total of 1,500 persons were evacuated from a 50 square block area until the system could be adequately flushed out to prevent the threat of additional explosions.

August 27, 1978 Farmington Hills (Oakland County)
A commercial van containing radioactive material (iridium 192) was involved in an accident. The van caught on fire, prompting fears of a serious radiological incident. Traffic was re-routed around the accident site until it was determined that no leakage of radioactive material had occurred.

January 11, 1979 Frankenmuth Twp. (Tuscola County)
A freight train derailment involving liquid petroleum gas forced the evacuation of 75 persons in the vicinity of the accident site.

June 22, 1979 Newaygo (Newaygo County)
A freight train derailment caused a chlorine leak that eventually sealed itself. A total of 300 persons were evacuated as a precautionary measure.

November 12, 1979 Holland Twp. (Ottawa County)
A freight train derailed, causing a spill of hydrogen fluoride. The accident prompted the evacuation of 1,500 persons.

February 18, 1981 River Rouge (Wayne County)
A freight train derailed, carrying 56,000 gallons of liquid propane gas, and resulted in a precautionary evacuation of over 6,000 persons. Fortunately, a serious spill was averted.

February 27, 1981 Dayton Twp. (Tuscola County)
A freight train derailed, spilling hydrochloric acid, liquid petroleum gas, isobutane, and butylene. The derailment prompted the evacuation of 60 persons living in the vicinity of the accident site.

August 7, 1981 Bridgman (Berrien County)
A freight train derailment resulted in a spill of fluourosulfonic acid, which formed a vapor cloud that forced the evacuation of 1,000 persons. A State Police trooper died as a result of breathing the toxic fumes.

March 15, 1982 Fruitport Twp. (Muskegon County)
A freight train derailment caused a spill of chlorine and caustic acid, forcing 600 persons to evacuate the accident vicinity.

April 11, 1982 St. Joseph (Berrien County)
A freight train derailed near St. Joseph, causing a spill of ethylene benzoil and benzine. The accident prompted the evacuation of 500 nearby residents until the spill could be contained and cleaned up.

December 28, 1982 Chesterfield Twp. (Macomb County)
A tanker truck began leaking nitric acid, which resulted in 12 injuries from product exposure and forced the evacuation of 1,200 persons in the surrounding area, due to the toxic fumes.

February 1, 1983 Coopersville (Ottawa County)
A gasoline tanker truck rolled over on I-96 near Coopersville, resulting in a spill of 9,000 gallons of gasoline. The gasoline then caught on fire, forcing the closure of I-96 for several hours until the fire could be suppressed and the site cleaned up and restored.

October 12, 1983 Fraser (Macomb County)
A tanker truck overturned, spilling 5,000 gallons of methyl amyl ketone. The spill forced the evacuation of 600 persons, and M-97 and 14 Mile Road were closed until the spill could be cleaned up and the site restored.

October 12, 1984 Thompson Twp. (Schoolcraft County)
A gasoline tanker truck swerved to avoid hitting a school bus and rolled over, spilling approximately 7,000 gallons of gasoline and 1,000 gallons of diesel fuel. The accident prompted the evacuation of 30 persons until the spill could be cleaned up and the site restored.

April 25, 1989 Highland Twp. (Oakland County)
A freight train thought to be carrying hazardous materials derailed, prompting the evacuation of residents within one half mile of the accident site (including a high school). It was later determined that the tank cars were not filled and only material substance residue was present in the cars. However, emergency workers at the scene felt the remaining residue posed a danger to the community. The accident site was cleaned up and the evacuees were allowed to return later that day.

July 22, 1989 Tittabawassee Twp. (Saginaw County)

A freight train carrying a variety of hazardous materials derailed near Freeland, causing two rail cars to catch on fire and forcing a weeklong evacuation of over 1,000 residents. One home near the accident site was destroyed by the fire. After the fire was extinguished one week later, the site was cleared and the contaminated soil surrounding the site was excavated and transported to a hazardous waste landfill. After all hazardous conditions and health concerns were alleviated, the evacuation was lifted and evacuees were allowed to return to their homes.

July 29, 1989 Otsego/Bailey Twps. (Otsego County)

A semi-trailer carrying acetic acid, potassium hydroxide and ammonium thiocyanate rolled over on I-75, just south of Gaylord. The accident caused the evacuation of approximately 150 people from nearby homes and businesses. Traffic on I-75 had to be rerouted for the duration of the 12-hour event. No injuries were reported.

January 12, 1990 Buena Vista Twp. (Saginaw County)

A semi-tanker carrying 5,000 gallons of gasoline and 5,000 gallons of diesel fuel overturned due to icy roads and high winds. Approximately 2,500 gallons of diesel fuel spilled into the drain system and traveled an estimated ¾ mile before it could be diked and removed by an environmental cleanup contractor. The spill prompted the evacuation of approximately 520 persons in a half-mile radius. The evacuated area was re-opened 12 hours later, after the cleanup was completed.

March 12, 1990 Dearborn and Detroit (Wayne County)

A leak of the chemical copper chloride from a delivery truck prompted the evacuation of several homes and businesses on the Dearborn-Detroit border. No injuries were sustained in the incident, but the roadway was closed for several hours while cleanup operations were completed. Copper chloride is a corrosive that is hazardous to touch, and the fumes can cause respiratory problems.

September 16, 1990 Bay City (Bay County)

The tanker vessel Jupiter exploded and caught fire while moored in Bay City's harbor. The vessel was carrying approximately two million gallons of unleaded gasoline. The fire burned for several days. After the fire was extinguished, the remaining petroleum product had to be pumped out of the cargo hold–a difficult and risky task–and sent to a treatment facility. This incident created a concern for the safety of the residents in the vicinity of the fire, for response personnel who had to extinguish a shipboard fire, and for the river environment. In addition, river commerce was disrupted for an extended period of time because of the incident. A Governor's Emergency Declaration was granted to provide supplemental state assistance in the containment and suppression of the fire, and the required environmental monitoring during the transfer of the remaining gasoline to another tanker vessel.

March 24, 1993 Sylvan Twp. (Washtenaw County)

A semi truck carrying DCT acid drove off of I-94, one mile west of M-52, and struck a tree. The collision caused approximately 220 gallons of the material to leak from the vehicle onto an area on and near the roadway. Two police officers and two motorists were injured due to exposure to the product, and all were hospitalized for a brief time. Interstate 94 was closed for several hours to avoid any further exposure to the chemical.

November 16, 1994 Morrice & Perry (Shiawassee County)

A fire aboard a freight train carrying sodium isopropyl xanthate prompted an evacuation of residents in the immediate vicinity of the railroad tracks, on the outskirts of Morrice. The fire burned for approximately 10 hours before it was completely extinguished and area residents were allowed to return to their homes.

April 5, 1995 Detroit (Wayne County)

A tractor trailer transporting 8,500 gallons of gasoline overturned on a ramp at I-94 and I-75. The driver was killed in the crash and ensuing fire. A one-half mile area around the crash scene was evacuated, due to the risk of explosion from seeping gas that washed down into the sewer.

June 4, 1999 Whitehall (Muskegon County)

At a tannery, a tanker truck driver unloaded (unknowingly) a shipment of sodium hydrosulfide solution into a storage tank normally used exclusively for ferrous sulfate solution, creating a chemical reaction that produced hydrogen sulfide – a poisonous gas. The truck driver was pronounced dead at the scene after having been overcome by the hydrogen sulfide gas. An employee of the tannery was rendered unconscious by the gas, but regained consciousness in time to avoid lasting, serious injury. Eleven employees at the tannery were evacuated. Total property damage was in excess of $411,000.

August 29, 1999 Birmingham and Bloomfield Twp. (Oakland County)

More than 40 cars of a 98-car freight train carrying automobiles and some hazardous materials (yellow phosphorous) derailed in Birmingham and Bloomfield Township, causing two rail cars to catch on fire and forcing police and fire officials to warn nearby residents and motorists to stay indoors and keep their windows closed, due to possible toxic fumes. None of the cars containing hazardous materials derailed. Some local roads were closed for several hours. The derailment caused an estimated $6 million in damage.

September 7, 1999 Ecorse (Wayne County)

A four-car freight train derailment that included a tanker car carrying 23,000 gallons of ethylene oxide forced an evacuation of 600 persons from nearby homes, businesses, and schools on the Ecorse-River Rouge border. The tanker car was inspected and determined not to be leaking. After several hours, the train cars were uprighted and the evacuated residents were allowed to return to the area.

January 21, 2000 Flint (Genesee County)

A rail car with 33,000 gallons of liquid propane gas caught fire in the CSX rail yard in Flint, forcing the evacuation of 2,600 homes within a one-mile radius of the incident site. The danger of a potential explosion also shut down a section of I-475 and closed two elementary schools near the scene. An estimated 3,500 evacuees were housed in three shelters and local motels until the incident was stabilized the next day. CSX railroad and local fire officials determined that the best course of action was to separate the burning tanker from the 54 other liquid propane tanker cars, vent the tanker, and allow the remaining product to burn off.

May 27, 2000 Detroit (Wayne County)

A semi-tanker carrying 13,000 gallons of gasoline overturned, ignited, and exploded on I-75 in downtown Detroit, killing the driver and forcing the cancellation of the city's Memorial Day parade that was to be held nearby. The parade was cancelled because officials feared that fuel entering the sewer system could ignite and launch manhole covers into the crowd. Firefighters pumped foam and water into storm drains to prevent further explosions. The stretch of I-75 involved in the accident was closed for several hours to allow for cleanup activities.

July 14, 2001 Riverview

A pipeline attached to a fitting on the unloading line of a railroad tank car fractured and separated, causing the release of methyl mercaptan, a poisonous and flammable gas. Shortly after, the tank car ignited and sent a fireball 200 feet into the sky. Fire damage to cargo transfer hoses on an adjacent tank car

resulted in the release of chlorine, a poisonous gas that is also an oxidizer. Three plant employees were killed in the accident. About 2,000 residents were evacuated from their homes for about 10 hours.

November 15, 2001 Springfield Twp. (Oakland County)

Two freight trains – one carrying a tanker of chloride gas – collided head on and derailed in rural Springfield Township, killing two train crewmen and critically injuring two others. The crash ignited the swampland around the accident site as three of the four locomotives derailed and caught on fire. The accident forced the evacuation of 100 homes within a half-mile radius (for several hours) and closed two nearby schools for the day. Fortunately, the tanker of chloride gas did not leak.

May 27, 2002 Potterville

A horizontal break in a railroad track running through Potterville caused the derailment of 35 cars from a 58-car Canadian National Railroad freight train. Nine cars contained liquid propane, two of which leaked the gas. About 2,200 citizens were evacuated for up to four days. Canadian National Railroad reimbursed residents who could document losses such as missed work, spoiled food, and hotel stays.

January 29, 2003 Flint

A truck hauling propane gas plunged from a freeway overpass and exploded on top of a set of railroad tracks, killing the driver and cutting off power to 1,100 people. Interstate 69 was closed in both directions for several hours because of this incident.

February 24, 2003 Holland Twp. (Ottawa County)

Four tanker trucks exploded and burned at an oil company in Holland Township. The blaze injured four people who were rushed to the hospital to be treated for burns and smoke inhalation. A warehouse nearby also reportedly caught fire, but firefighters were able to extinguish the blaze within an hour.

August 8, 2003 Pittsfield Twp (Washtenaw County)

A stretch of Interstate 94 was closed in both directions due to a chemical leak from a tractor-trailer. Formaldehyde was leaking from a tractor-trailer onto the freeway and hazardous materials officials determined that a cap on the truck was loose and fell off, or had never been placed, causing the spill. Two people were exposed to the vapor when driving through the spill, were treated at the scene, and released.

August 27, 2003 Barry County

A tanker transporting 13,500 gallons of gasoline overturned and spilled approximately 5,900 gallons. One person was hospitalized, seven homes were evacuated, M-37 was shut down and gasoline threatened to, but did not, seep into a county drain leading to a lake.

September 16, 2003 Detroit (Wayne County)

A collision between a car and a tanker resulted in an explosion at an I-75 overpass on Detroit's southwest side. The tanker was carrying 22,000 gallons of gasoline, and burned for several hours. The truck's driver had been pulled to safety before the explosion.

October 6, 2003 Detroit (Wayne County)

A tanker explosion and fire killed the tanker's driver and closed nearby expressway ramps for about six months. The fire was extremely intense (estimated at 2400 degrees Fahrenheit), and gasoline leaked and burned over a stretch of about one mile, causing I-94 to be closed down in that area.

October 21, 2003 Detroit (Wayne County)

A rollover accident involving a tractor-trailer closed a major freeway interchange. Hazardous materials crews worked to clear the westbound ramp from Interstate 94 to Interstate 75, following the crash. About 40 gallons of fuel spilled and about 40,000 pounds of coiled steel also spilled onto the freeway ramp.

December 17, 2003 Marysville (St. Clair County)

A stretch of Interstate 94 in St. Clair County was closed after a tractor trailer carrying hazardous materials rolled over. Hazardous materials crews were called because the tractor trailer involved was hauling plastic chemicals.

January 28, 2004 Van Buren County

A tanker truck collided with a pickup truck, spilling ethyl alcohol onto I-94. About 150 people were evacuated within a half-mile radius of the scene. One person was killed during the incident.

March 15, 2004 Taylor (Wayne County)

A collision between a pickup and a tanker truck caused an explosion at Telegraph Road and I-75 in Taylor. Flames reached 400 feet in the air, and the driver of the pickup truck was killed. Telegraph Road was closed for several hours as the scene was investigated and cleared.

August 13, 2004 Coloma (Berrien County)

Hazardous materials crews closed an eight-mile stretch of both lanes of Interstate 94 after two tractor-trailers collided and resulted in several loud explosions. One of the trucks was transporting Drano, which spilled onto the freeway. One of the drivers was injured in the crash and taken to a hospital.

January 7, 2005 Detroit (Wayne County)

A collision between a jeep and tanker truck resulted in the tanker overturning on northbound I-75. The tanker spilled an estimated 5,000 gallons of flammable xylene and toluene liquid, requiring the freeway to be closed for several hours. The driver of the jeep was injured, but no evacuations were required.

September 13, 2005 Detroit (Wayne County)

A collision between a car and tanker on I-275 caused the tanker to roll over into the median. Hazardous materials crews responded, due to leaking chemicals that are used in asphalt manufacture. The driver of the car was killed, and the driver of the tanker suffered minor injuries. Lane closures on the freeway continued through the afternoon rush hour.

July 7, 2006 Tustin (Osceola County)

A semi truck overturned on US-131 in an accident involving ethanol fuel near Tustin in Osceola County. Both lanes of the highway were shut down. Over 2,000 gallons of fuel contaminated the soil, resulting in about 10,000 gallons of sludge being removed by the hazardous materials teams.

December 14, 2007 Fraser (Macomb County)

A sulfuric acid spill of 550 gallons from a vacuum truck shut down an intersection during rush-hour traffic in Fraser. Some of the chemical leaked into a nearby field and may have gotten into a sewer drain. Several businesses in the area were evacuated.

August 28, 2007 Wixom (Oakland County)

Approximately 5,000 to 10,000 gallons of nitric acid leaked when the driver was forced to stop quickly, due to a traffic jam. Two buildings were evacuated during the clean-up process.

January 10, 2008 Detroit (Wayne County)

A liquid propane tanker hauling approximately 7,200 gallons of butane plunged through an overpass guardrail. The resulting explosion damaged a section of northbound Interstate 75, set nearby homes on fire, melted a school playground, and killed the driver. One home was completely destroyed, and many others were damaged. Two northbound lanes of I-75 were closed for several weeks, due to severe structural damage to the concrete overpass pillars.

January 31, 2009 Dearborn (Wayne County)

A hazardous materials situation occurred when a tanker truck slid on ice (created by a broken water main) and overturned in Dearborn. Fuel was spilled on the roadway and ran off into storm drains. Crews sprayed the fuel on the road with foam and took several hours to pump fuel out of the drains. About 100 homes were evacuated.

July 15, 2009 Hazel Park (Wayne County)

A collision between a car and a gasoline tanker on I-75 caused an explosion. The gasoline tanker contained 13,000 gallons of fuel, and the explosion caused the Nine Mile Road overpass to collapse, crushing a passing tractor-trailer. The drivers of the three involved vehicles each suffered minor injuries. Thick smoke and flames shot up 150 to 200 feet in the air, melting the overpass structure. Investigators said that the temperatures reached 2300 degrees. MDOT spent 5 months clearing debris, replacing the bridge, and replacing stretches of concrete that had been compromised as a result of extreme heat. The total cost for the repairs was about $12 million.

May 19, 2010 Brighton (Livingston County)

A semi trailer truck carrying a load of hazardous material overturned on Interstate 96, near Brighton, and closed all lanes of traffic around the accident site, leading to significant traffic delays for hours. The 18-wheeler was traveling eastbound and carrying 70 barrels of Monolube 3400, a potentially hazardous lubricant used in tire manufacturing. Monolube 3400, if shaken in unventilated containers, could produce hydrogen gas that could explode. The truck driver had a collision with a passenger car, and the impact of the rollover truck accident spilled several of the barrels of the Monolube 3400 out onto the roadway. The truck driver was sent to the hospital with injuries, and a hazardous materials team was called to handle the clean up at the scene.

July 3, 2010 Flint (Genesee County)

A semi-tanker and a motorcycle collided on southbound I-475 and the tanker exploded shortly afterwards. The heat from the explosion was so intense that it melted construction barrels and damaged the concrete. The tanker explosion sent a huge fireball into the sky and flames could be seen for miles. The man riding the motorcycle was killed, but the truck driver survived the explosion. Both sides of the expressway were shut down as hazardous materials teams were called to deal with the toxic spill.

July 14, 2010 Romulus (Wayne County)

A vehicle exiting I-275 North at westbound Interstate 94 clipped a semi truck, causing the semi to lose control and roll on its side. The truck was hauling several different chemicals that are used to make detergent, but one of the chemicals leaking was hydrogen peroxide. Many frustrated motorists experienced long waits in traffic, because of delays in transferring the remaining materials to another vehicle. High heat and humidity were also a challenge for the two hazardous materials teams, but there were only minor injuries.

Programs and Initiatives

Note: Many of the programs and initiatives designed to mitigate, prepare for, respond to, and recover from fixed-site hazardous material incidents have the dual purpose of also protecting against hazardous material transportation incidents. As a result, there is some overlap in the narrative programs and initiatives descriptions for each respective hazard. This redundancy allows each hazard section to stand alone, eliminating the need to refer to other hazard sections for basic information.

Federal Hazardous Material Transportation Regulations

The transportation, manufacturing, storage, and disposal processes for hazardous materials are highly regulated by federal and state agencies in order to reduce risk to the general public. At the federal level, the U.S. Department of Transportation, Office of Hazardous Materials Safety (USDOT/OHMS), is the regulating agency for all modes of hazardous material transportation. In addition to enforcing federal hazardous material transportation regulations, the USDOT/OHMS is also involved in a number of other areas aimed at improving the safety of hazardous material shipping. Those areas include: 1) the research and development of improved containment/packaging and other technological aspects of hazardous material shipping; 2) interagency coordination efforts in hazardous material transportation planning and standards setting; 3) management of data information systems pertaining to hazardous material transportation; and 4) development of hazardous material safety training policies and programs.

The USDOT regulations specify the type and size of container that can be utilized for shipping each hazardous material, the label that must be on the container, the placards that must be shown on the carrying vessel, how much of the material can be shipped in one vessel, and in some cases how the contents should be organized or loaded. Many hazardous materials are assigned a unique four-digit identification number that is located on the placard or container. In addition, the regulations also require a company involved with hazardous material

transport to maintain a manifest that details what material is being transported, its quantity, a list of emergency contact numbers in case of an uncontrolled release, where the material is from, and its intended destination.

In Michigan, the Motor Carrier Division of the Department of State Police oversees, coordinates, and implements the commercial truck safety aspects of the USDOT regulations. The Michigan Department of Transportation oversees programs aimed at enhancing railroad safety and improving the rail infrastructure (which helps reduce the likelihood of a hazardous material rail transportation accident).

Hazardous Materials Transportation Uniform Safety Act

The federal Hazardous Materials Transportation Uniform Safety Act (HMTUSA), enacted in 1990, provides funding for the training of emergency responders and the development of emergency response plans for both fixed site facilities and transportation-related incidents. (This funding mechanism under the HMTUSA is referred to as Hazardous Material Emergency Preparedness [HMEP] grants.) In Michigan, the HMTUSA/HMEP program is coordinated and implemented by the Emergency Management and Homeland Security Division, Department of State Police. Since the program's inception, over $3 million in grants have been allocated to 80 Michigan communities for hazardous material planning and training activities.

Transportation Community Awareness and Emergency Response

Many industry groups are involved in an outreach program, coordinated by the Chemical Manufacturers Association, called Transportation Community Awareness and Emergency Response (TRANSCAER). This program is a nationwide community outreach program that addresses community concerns about the transportation of hazardous materials, through planning and cooperation. The program provides assistance to communities to develop and evaluate their emergency response plan for hazardous material transportation incidents. In Michigan, TRANSCAER activities and initiatives are coordinated by the Michigan Chemical Council.

Hazardous Material Response Training

The Emergency Management and Homeland Security Division, Department of State Police, provides a wide array of hazardous material response training programs through the Michigan Hazardous Material Training Center. The Center provides training courses for individuals and companies responsible for planning, inspection, response, mitigation, and cleanup activities involving hazardous materials. Specific subjects include: 1) computer-aided management; 2) hazardous material chemistry; 3) hazardous materials emergency response; 4) hazardous waste worker compliance; 5) incident management; 6) hazardous materials monitoring/sampling; and 7) other specialized hazardous materials-related courses such as highway and rail cargo tanker handling, confined space entry, emergency medical services, and technical rescue. Courses are conducted at the Center in Lansing and at various other locations throughout the state.

Federal/State Hazardous Material Response Resources

There are numerous groups at the federal, state, and local levels, and in private industry, that are trained to deal with hazardous material fixed-site and transportation incidents. These groups include the National Response Team (NRT), Regional Response Teams (RRTs), and state and local hazardous material response teams. The Chemical Manufacturers Association established the Chemical Transportation Emergency Center (CHEMTREC) to provide 24-hour technical advice to emergency responders. The National Response Center (NRC), which operates much like CHEMTREC, was established to provide technical advice and coordinate the federal response to a hazardous material incident.

In Michigan, a 24-hour statewide notification system called the Pollution Emergency Alerting System (PEAS) was established for reporting chemical spills to the Department of Environmental Quality. As a companion to the PEAS, the Michigan Department of Agriculture and Rural Development (MDARD) has established a 24-hour Agriculture Pollution Emergency Hotline for use by agri-chemical users to report fertilizer and pesticide spills.

Callers to the MDARD hotline gain immediate access to appropriate technical assistance, regulatory guidance for remediation, and common sense approaches for addressing the problem.

U.S. EPA Chemical Emergency Preparedness and Prevention Office

The U.S. Environmental Protection Agency's Chemical Emergency Preparedness and Prevention Office (CEPPO) provides leadership, advocacy and assistance to states, local governments, and private industry to: 1) prevent and prepare for chemical emergencies; 2) respond to environmental crises; and 3) inform the public about chemical hazards that may be present in their community. The CEPPO works closely with several Michigan state agencies to implement and coordinate a number of regulatory and non-regulatory programs designed to protect human health and the environment in Michigan from chemical accidents—including the SARA Title III program.

National Transportation Safety Board

The National Transportation Safety Board (NTSB) investigates all significant transportation accidents that occur nationwide and issues safety recommendations (to the transporter and to government regulators) aimed at preventing future accidents. To date, five hazardous material transportation accidents in Michigan—the November 15, 2001 freight train accident in Springfield Township, the June 4, 1999 cargo transfer accident in Whitehall, the September 16, 1990 Jupiter tanker fire in Bay City, the July 22, 1989 train derailment in Freeland, and the August 2, 1975 propane pipeline accident in Romulus—have resulted in an NTSB investigation. The NTSB also publishes a list of "most wanted" safety improvements for all modes of transportation, for nationwide implementation by appropriate entities. Although these safety improvement recommendations are not mandatory, and the NTSB has no regulatory or enforcement powers, it nonetheless has been successful in getting more than 80% of its recommendations adopted. Many safety features currently incorporated into the various hazardous material transportation vessels had their genesis in NTSB recommendations. The NTSB works directly with the USDOT on most hazardous material transportation accident issues.

Michigan Chemical Council

The Michigan Chemical Council is the primary trade association representing the chemical and allied industries in Michigan. As such, it works in partnership with the national Chemical Manufacturers Association, the Emergency Management and Homeland Security Division, Department of State Police, and other agencies and local governments to provide educational and community outreach services in the area of chemical awareness and safety. The Council provides an important informational and coordination bridge between Michigan's chemical industry, federal, state and local regulatory agencies, and the public.

Chemical Safety Board (CSB)

The CSB (www.csb.gov) is an independent federal agency charged with investigating industrial chemical accidents. Headquartered in Washington, DC, the agency's board members are appointed by the President and confirmed by the Senate.

The CSB conducts root cause investigations of chemical accidents at fixed industrial facilities. Root causes are usually deficiencies in safety management systems, but could be any factor connected with causing or preventing the accident. Accident causes often involve equipment failures, human errors, unforeseen chemical reactions, or other problems. The agency does not issue fines or citations, but does make recommendations to plants, regulatory agencies such as the Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA), industry organizations, and labor groups. Congress designed the CSB to be non-regulatory and independent of other agencies so that its investigations might, where appropriate, review the effectiveness of regulations and regulatory enforcement.

Chemical Awareness Week

Each spring, the Emergency Management and Homeland Security Division, Department of State Police, in conjunction with several other state agencies, Local Emergency Planning Committees (LEPCs), and the Michigan Chemical Council, sponsors Chemical Awareness Week. This annual public information campaign focuses on: 1)

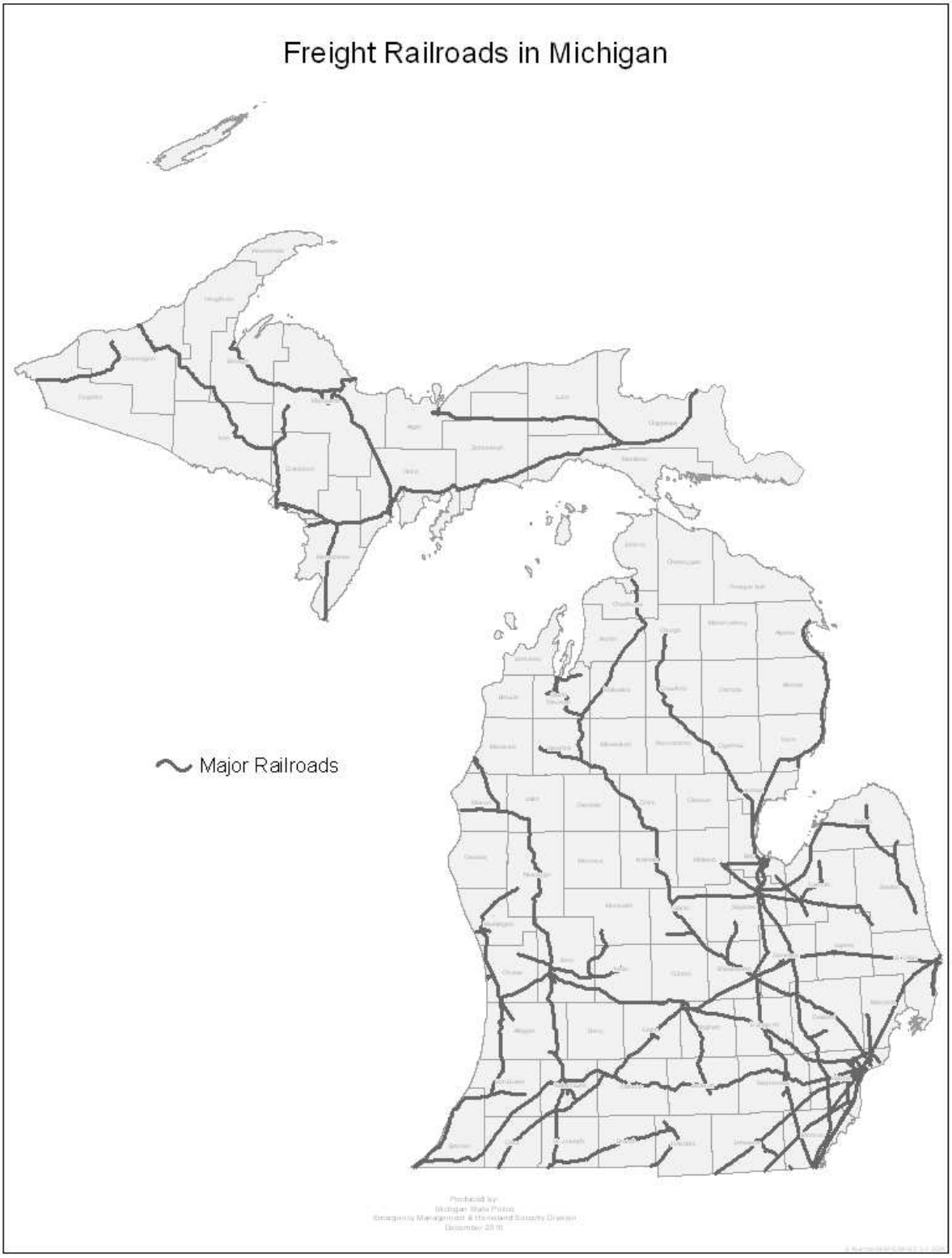
the hazards associated with the manufacture, transport, storage, use and disposal of chemicals; 2) the programs and systems in place to protect the public from accidental chemical releases; and 3) community emergency response procedures for chemical accidents. Informational materials on chemical hazards and safety are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public.

Final Rule on Reflectorization of Rail Freight Rolling Stock

The Final Rule requires railroads and other companies owning rail cars to install yellow or white reflective materials on locomotives over a five-year timeframe and on freight trail cars over a 10-year period. The reflective materials will be installed on all newly constructed locomotives and freight rail cars, and on existing ones, during periodic maintenance repair, unless alternate implementation plans have been developed that meet the deadlines. Nearly one quarter of all highway-rail at-grade crossing collisions involve motor vehicles running into trains occupying crossings. This new rule is the most recent effort by the Federal Railroad Administration (FRA) to increase the visibility of trains at highway-rail at-grade crossings.

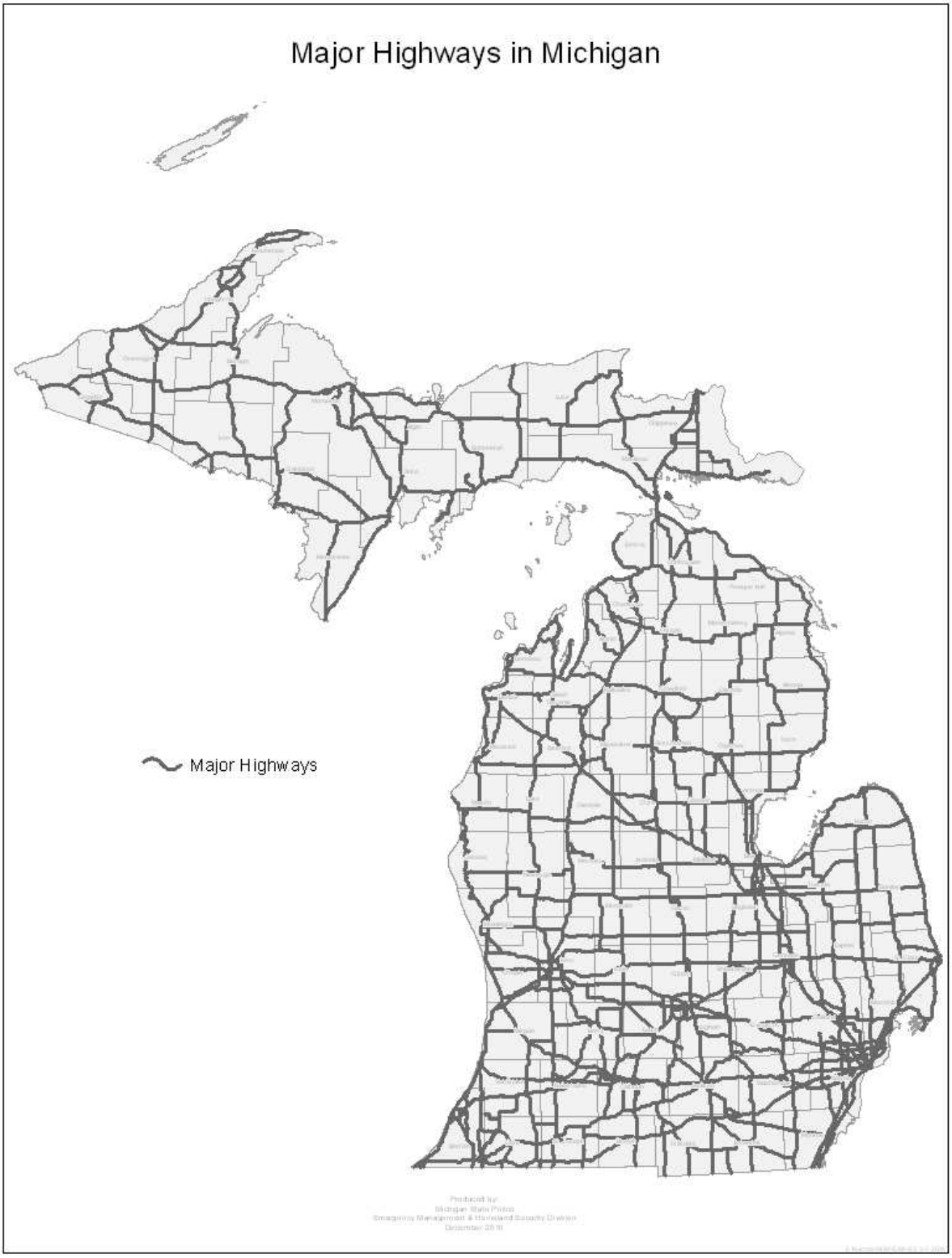
Freight Railroads in Michigan

Source: Michigan Department of Transportation



Major Highways in Michigan

Source: Michigan Department of Transportation



Great Lakes Commercial Ports in Michigan

Source: Michigan Department of Transportation

PETROLEUM AND NATURAL GAS PIPELINE ACCIDENTS

An uncontrolled release of petroleum or natural gas, or the poisonous by-product hydrogen sulfide, from a pipeline

Hazard Description

Though often overlooked, petroleum and natural gas pipelines pose a real threat in many Michigan communities. Petroleum and natural gas pipelines can leak or fracture and cause property damage, environmental contamination, injuries, and even loss of life. The vast majority of pipeline accidents that occur in Michigan are caused by third party damage to the pipeline, often due to construction or some other activity that involves trenching or digging operations. Many structures are located right next to pipelines and thus may be at risk. Pipelines can also cross through rivers, streams, and wetlands, thus posing the possibility of extensive environmental damage in the event of a major failure.

Michigan is both a major consumer and producer of natural gas and petroleum products. According to the federal Energy Information Administration, Michigan's consumption of petroleum products, particularly liquefied petroleum gases (LPG) is high; Michigan is the largest residential LPG market in the nation, due mostly to high residential and commercial propane consumption. The state has a single petroleum refinery but a large network of product pipelines. More than 78% of the overall home heating market uses natural gas as its primary fuel. With over one-tenth of U.S. capacity, Michigan has the greatest underground natural gas storage capacity in the nation and supplies natural gas to neighboring states during high-demand winter months. Driven largely by the residential sector, Michigan's natural gas consumption is high. Nearly four-fifths of Michigan households use natural gas as their primary energy source for home heating.

The State Energy Data System (SEDS) released data in August 2009 that describes energy consumption by source and total consumption per capita. Michigan ranks 13th in the nation in production of natural gas, with 264.9 billion cubic feet, and 7th in consumption, at 847.8 billion cubic feet. These figures underscore the fact that vast quantities of petroleum and natural gas are extracted from, transported through, and stored in the state, making many areas vulnerable to petroleum and natural gas emergencies. Michigan's gas and petroleum networks are highly developed and extensive, representing every sector of the two industries—from wells and production facilities, to cross-country transmission pipelines that bring the products to market, to storage facilities, and finally to local distribution systems.

While it is true that the petroleum and natural gas industries have historically had a fine safety record, and that pipelines are by far the safest form of transportation for these products, the threat of fires, explosions, ruptures, and spills nevertheless exists. In addition to these hazards, there is the danger of hydrogen sulfide (H_2S) release. These dangers (fully explained in the Oil and Natural Gas Well Accidents section) can be found around oil and gas wells, pipeline terminals, storage facilities, and transportation facilities where the gas or oil has a high sulfur content. Hydrogen sulfide is not only an extremely poisonous gas, but is also explosive when mixed with air at temperatures of 500 degrees Fahrenheit or above.

In 2010, Michigan suffered what may be the largest inland oil release in the country, when a pipeline in Calhoun County failed and released large quantities of crude which ended up in the Kalamazoo River and flowed downstream for many miles. Although a description of this event appears later in this section, it must be noted here that because the recovery activities for this disaster are still ongoing, an after-action report was not yet available for use in this analysis, to efficiently relay "lessons learned" and the final results of the extensive cleanup activities.

Hazard Analysis

The map at the end of this section shows the location of major petroleum and natural gas pipelines within Michigan. It is apparent from the map that petroleum and natural gas pipelines crisscross the entire state, from well heads to storage sites, through distribution to consumers. Major compressor stations that receive and redistribute natural gas are located at key points along the pipelines (but are not shown on the map). These stations monitor and maintain pressure levels within the pipelines. In the event of a pipeline rupture, the compressor stations shut down to stop the flow of product. Many smaller compressor stations are located across the state to complete the distribution process to consumers.

The state's major natural gas storage facilities are located in the central part of the Lower Peninsula. Natural gas is piped into those storage facilities from Michigan wells, and from large transmission pipelines that originate in Canada, the southwestern United States, and the Gulf of Mexico area.

Petroleum pipelines carrying crude oil, fuel oil, propane, butane, gasoline, and other petroleum products have their heaviest concentrations in central Lower Michigan and between Detroit and Toledo. Many of the refineries, terminals, and storage areas are located in urban areas where the potential for extensive damage, and threat to lives and property, is greatest. The largest concentration of these facilities is found in the Detroit metropolitan area.

Petroleum and natural gas pipeline accidents are on the rise, due to the aging of the underground infrastructure (much of which was laid over 50 years ago) and an increase in construction excavation. According to studies conducted by the General Accounting Office (GAO), an average of 22 people died annually from 1988 to 1998, when the number of accidents was increasing by four percent per year. The GAO also found that the USDOT/OPS has not adequately enforced many safety regulations passed by Congress since 1988 and is instead relying more on industry self-regulation as an enforcement tool.

Increased pipeline safety regulations again came to the forefront in 2000, after deadly pipeline explosions occurred in Bellingham, Washington in June 1999 (three deaths) and Carlsbad, New Mexico in August 2000 (11 deaths). In 2004, the Pipeline and Hazardous Materials Safety Administration (PHMSA) was signed into law. The purpose of the Act was to provide a more focused research organization and establish a separate operating administration for pipeline safety and hazardous materials transportation safety operations.

The Pipeline Safety Improvement Act of 2002 mandated significant changes and new requirements in the way that the natural gas industry ensures the safety and integrity of its pipelines. The law applies to natural gas transmission pipeline companies. The law places requirements on each pipeline operator to prepare and implement an “integrity management program” that, among other things, requires operators to identify so-called “high consequence areas” (HCA) on their systems, conduct a risk analysis of these areas, perform baseline integrity assessments of each pipeline segment, and inspect the entire pipeline system. Companies were required to identify all HCAs and submit specific integrity management programs to the Office of Pipeline Safety (OPS), the Research and Special Projects Administration, and the U.S. Department of Transportation. All pipeline segments within HCAs were to be inspected and remediation plans completed by December 17, 2008, while non-HCA segments must be inspected by 2012. All segments must be re-inspected on a 7-year cycle, with certain exceptions.

Because petroleum and natural gas pipeline accidents will occur eventually, affected local communities must be prepared to respond to the accident, institute necessary protective actions, and coordinate with federal and state officials and the pipeline company emergency crews to effectively manage and recover from the accident. That can best be accomplished through the collaborative planning, training, and exercising of emergency procedures with all potentially involved parties.

Impact on the Public
Severe events may cause shortages of, and higher prices for, petroleum and other fuels. Some residents with low incomes or fixed budgets may find higher prices to be unaffordable, and may face problems involving heating and other energy needs being used to maintain their homes and health. Transportation and fuel costs may become too expensive to allow business profits to be maintained, when such businesses rely on fuel-driven transportation or functions. Those in the vicinity of the pipeline break itself may suffer from health problems, unpleasant odors, evacuations, and damage/contamination of their property. Some pipeline accidents result in explosions that cause extensive damage, injury and even loss of life. Gas leaks in particular can cause surprising amounts of damage from sudden explosions, without any advance warning to those nearby.

Impact on Public Confidence in State Governance
As with the oil and gas well hazard, there may be a sense that inadequate regulation, authorization, or oversight was maintained by the state, if there is an event of significant size or impact. The nature of the transported materials also causes concern about environmental and health impacts.

Impact on Responders
Special expertise is often needed, and the cooperation of the utility provider is often critical to an efficient and successful response. Enclosed areas may be involved in these incidents (e.g. those occurring in a densely populated urban area), and thus may require special equipment, personnel, and training in search and rescue.

Impact on the Environment
Petroleum and natural gas pipelines pose a real threat in many Michigan communities because they can lead to leaks, fractures, fires, explosions, ruptures, and spills that cause environmental contamination. The danger of hydrogen sulfide (H_2S) release can occur where the gas or oil has a high sulfur content. Hydrogen sulfide is not only an extremely poisonous gas, but is also explosive when mixed with air at temperatures of 500 degrees Fahrenheit or above. Atmospheric concentrations of greenhouse gases, especially carbon dioxide, methane, and nitrous oxide, can contribute to climate change, both regionally and globally. Adverse local consequences to ecological and socio-economic systems can result from a major petroleum or natural gas pipeline accident. Particulate pollutants may consist of metals, soot, or similar small substances. Soft sloping ground near waterway crossings can be susceptible to erosion or lateral spreading, which may cause significant pipe displacement or rupture.

Significant Petroleum and Natural Gas Pipeline Accidents

Petroleum and natural gas pipeline accidents occur with regularity, but they usually have a limited impact and are quickly and adequately handled by pipeline company emergency crews and by local and state responders. According to figures released by the U.S. Department of Transportation's Office of Pipeline Safety (USDOT/OPS), in 1998 (the latest year for which complete data are available) Michigan gas companies had to repair 9,300 leaking underground gas lines. That figure is double the 4,400 reported breaks in 1991. It is estimated that three-quarters of gas line breaks are caused by excavation damage. Many more gas line breaks go unreported, according to regulators from the Michigan Public Service Commission (MPSC). National estimates rank Michigan second only to Texas in the number of repairs to damaged or leaking natural gas pipelines.

Michigan has had numerous petroleum or natural gas pipeline accidents in recent years that resulted in injury, loss of life, or significant property damage. Since 1996, the MPSC has investigated over 100 incidents involving pipelines, and at least half of those incidents involved injury, loss of life, or significant property damage. The pipeline accidents described in this section include the worst in recent Michigan history, which required a combined emergency response effort by pipeline companies and state and local officials.

In 2003 the U.S. Department of Transportation, Research and Special Programs Administration, Office of Pipeline Safety conducted a survey of Natural gas distribution pipeline accidents per state. The state of Michigan

was third overall with 11 recent accidents, trailing only Pennsylvania and California for the highest in the nation. The weighted average for all states was only 2.8 accidents during that time period.

A ten year survey was conducted by the PHMSA of its Pipeline Safety Program Filtered Incident Files, and several other pipeline mileage data sources, to compile a report of significant and serious Michigan incidents involving pipeline accidents from 1999-2008. The results are provided in the table below:

Michigan Pipeline Incidents (all pipeline systems, 1999-2008)

Year	Number	Fatalities	Injuries
1999	16	6	4
2000	5	2	4
2001	5	0	3
2002	5	0	4
2003	13	0	4
2004	5	0	0
2005	7	0	2
2006	9	1	0
2007	1	0	0
2008	7	2	5
Totals	73	11	26
3 Year Average (2006-2008)	6	1	2
5 Year Average (2004-2008)	6	1	1
10 Year Average (1999-2008)	7	1	3
20 Year Average (1989-2008)	7	1	3

Recent Significant Petroleum and Natural Gas Pipeline Accidents in Michigan

NOTE: Natural gas leaks are also a common cause of structural fires, but only some of those incidents (residential house explosions) have been listed here, since most do not rise to the level of community-wide emergency events.

September 7, 1950 Big Rapids (Mecosta County)

A newly installed natural gas pipeline exploded near Big Rapids because of a flaw in the line. Two barns were destroyed and many windows were shaken. The ensuing fire was seen from 50 miles away.

September 26, 1952 Mt Pleasant (Isabella)

Four men were injured in a gas pipeline fire. They had been raising the eight-inch pipeline for reconditioning, when it broke.

May 16, 1967 Dearborn (Wayne County)

A pile driver ruptured a gas line near an underground storage cavern, trapping seven men in a pit with fire at Ford Motor Company's River Rouge Plant. Two of the men were killed and four more were injured. Fire fighters took two hours to bring the blaze under control, and police routed traffic away from the area.

August 2, 1975 Romulus (Wayne County)

On August 2, 1975, an 8-inch pipeline owned by the Sun Pipeline Company ruptured in Romulus. Propane escaped from the rupture, sprayed into the air, vaporized, and then ignited. Flames 500 feet high engulfed an area 600 feet in diameter. The blast created a 12-foot diameter, 7-foot deep hole in the ground. The fire injured nine persons, destroyed four houses and damaged three others, burned 12 vehicles, and consumed 2,389 barrels (100,338 gallons) of propane. The National Transportation Safety Board (NTSB) investigated this accident and determined that the probable cause was the propagation of surface cracks on the pipe, caused by abnormally high pressure within the pipeline at the leak site. The NTSB further found that inadequate inspection during construction had contributed to the accident.

February 22, 1986 Muskegon (Muskegon County)

A Muskegon County pipeline break occurred when an 8-inch high-pressure Marathon Oil pipeline ruptured, spilling thousands of gallons of gas into streams feeding Ruddiman Creek. Gas vapors also caused some minor house explosions that forced dozens of Lakeside-Glenside residents to flee. No one was injured in the incident, although the environment suffered damage.

February 23, 1989 Gratiot County

On February 23, 1989, a Michigan Consolidated Gas Company (MICHCON) underground natural gas pipeline in rural Gratiot County exploded and caught on fire, releasing a vast quantity of gas into the atmosphere. The huge fire necessitated the evacuation of several families from the immediate area. No deaths or injuries occurred. Company officials shut off valves on either side of the break and allowed the remaining gas to burn off.

July 17, 1991 Freeland (Saginaw County)

Workers were removing a corroded segment of a Consumers Power Company's 10-inch-diameter transmission line pipeline. As a segment of the pipeline was being removed, natural gas at 360-psig pressure exerted about 12 tons of force on an adjacent closed valve (H-143), causing it and a short segment of connected pipe to move and separate from an unanchored compression coupling. The force of the escaping gas killed one worker, injured five other workers, and collapsed a steel pit that housed valve H-143. Fortunately, there was no explosion from the natural gas leak.

May 20, 1992 Rochester (Oakland County)

On May 20, 1992, a natural gas explosion occurred in a two-story commercial building in Rochester, killing one person and injuring 17 others. Estimated property damage was nearly $1 million. The explosion occurred when the gas service line to the building was damaged during excavation of a sidewalk. The service line separated under the sidewalk and gas migrated into the building, where it was ignited by an unknown source, causing the explosion.

February, 1996 Napoleon (Jackson County)

In February 1996, a house exploded in Napoleon, resulting in two fatalities. The cause of the explosion was a natural gas build-up.

December 15, 1998 Galesburg (Kalamazoo County)

A natural gas leak caused an explosion in downtown Galesburg in the early morning hours of December 15, 1998, destroying two businesses and damaging a third. One person in an automobile sitting at a nearby red light was slightly injured when a Christmas tree and other debris flew through his windshield. Fortunately, the downtown area was not crowded when the explosion occurred. An eight square block area was evacuated as a precaution, in case of further explosions, but utility workers were able to shut off the gas supply to avert further damage.

January 15, 1999 Whitmore Lake (Livingston County)

A natural gas explosion at a home on January 15, 1999 in Green Oak Township, Livingston County, killed one person, injured four others, and forced the evacuation of 17 residents. The explosion and resulting fire destroyed two homes and damaged several other homes and a business. Subsequent investigation of the incident indicated that a steel gas main in the area was dented, bent, and cracked by a third-party excavation a number of years before it failed.

January 18, 1999 Leslie (Ingham County)

On January 18, 1999, a leaking gas main in Leslie forced the evacuation of two schools (over 1,000 students) and approximately 75 other nearby residents for several hours, until utility workers were able to cap the leak.

March 7, 1999 Plainwell (Allegan County)

On March 7, 1999, a ruptured natural gas transmission line near Plainwell caused an explosion and fire that could be seen for 20 miles away. The explosion and fire occurred in a primarily rural area two miles southeast of Plainwell and about 10 miles north of Kalamazoo. Fortunately, there were no structures nearby, and the explosion and fire did not cause any injuries. The fire, which spread to over 400 feet wide and 100 feet high, burned for nearly two hours before utility workers were able to shut down the gas supply to the line.

June 15, 1999 Battle Creek (Calhoun County)

A natural gas pressure surge caused fires in 24 homes in a 20 block area in Battle Creek on June 15, 1999, resulting in major damage to eight structures and injuries to two persons. The fires forced gas service to be shut off to approximately 1,500 homes for two to three days. Construction work by the natural gas utility caused the gas surge.

June 23, 1999 Lake County

A broken gas main near the intersection of US-10 and M-37 in Pleasant Plains Township, Lake County, forced the evacuation of nearby residences (including senior and low-income housing complexes) until the main could be repaired.

June 25, 1999 Howell (Livingston County)

On June 25, 1999, a ruptured gas main set off an explosion and fires in Howell, destroying one business, severely damaging three homes, and forcing the evacuation of more than 60 homes. Three firefighters were injured while responding to the fires. The explosion was caused by a contractor who accidentally bored through the gas main and the sewer line.

July 24, 1999 Lake Orion (Oakland County)

On July 24, 1999, a natural gas explosion heavily damaged a house in Lake Orion, but caused no injuries or fatalities. The explosion was believed to be caused by contractors who had accidentally broken a nearby gas main.

January 13, 2000 Madison Heights (Oakland County)

A natural gas explosion destroyed a Madison Heights home on the morning of January 13, 2000, shortly after a utility service person had visited the home to check on a report of a possible natural gas leak. The service person corrected what was believed to be the problem and then left the home. Less than three hours later, the home was completely destroyed by the blast. No one was home at the time of the explosion and no injuries were reported.

February 11, 2000 Detroit (Wayne County)

A natural gas explosion at a Detroit home on February 11, 2000 blew out one wall and scattered bricks onto a neighboring home. No one was home at the time of the explosion and no injuries were reported.

June 7, 2000 Jackson County

On the morning of June 7, 2000, a Wolverine Pipeline Company gasoline pipeline ruptured in Jackson County's Blackman Township, releasing 75,000 gallons of gasoline into the environment and forcing the evacuation of more than 500 homes in a one square mile area around the spill. The leak was detected when a drop in pressure was recorded at a metering station along the 80-mile pipeline that runs through Blackman Township from Joliet, Illinois to Detroit. The spill caused significant environmental and public safety problems and shut down 30% of the state's gasoline supplies for nine days. (The pipeline carries approximately seven million gallons of gasoline per day.) Most of the evacuees were allowed to return to their homes within five days of the accident. Wolverine Pipeline Company worked with affected federal, state, and local regulatory agencies to develop and implement a plan to complete the pipeline repair, cleanup and restore contaminated sites, and provide for long term environmental monitoring. Wolverine Pipeline Company expended in excess of $10 million in response to this pipeline accident.

August 7, 2000 Canton Township (Wayne County)

A Canton Township home was destroyed in an August 7, 2000 natural gas explosion caused by a broken pipe that fed natural gas to the furnace. Two homeowners were hospitalized for injuries sustained in the blast, which also caused significant fire damage to two neighboring homes.

August 8, 2000 Redford Township (Wayne County)

On August 8, 2000, a Redford Township couple was killed and their home destroyed by a natural gas explosion, caused by a broken connection leading to the kitchen range.

September 7, 2000 St. Clair (St. Clair County)

On September 7, 2000, a propane explosion destroyed a house in downtown St. Clair and killed an elderly occupant and a repairman who was working on the house. A second repairman was thrown across the street by the explosion, and sustained injuries. The explosion damaged neighboring homes, but no other injuries were reported.

October 21, 2000 Woodland Park (Newaygo County)

A propane explosion on October 21, 2000, demolished a summer home in Woodland Park and killed 4 members of a family, just minutes after they had arrived at the home for a weekend visit. Two other family members survived the blast, which may have originated in the basement of the home.

March 18, 2001 Warren (Macomb County)

An apparent natural gas explosion destroyed a portion of a plastics factory in Warren on March 18, 2001. Fortunately, the building was empty at the time of the explosion, which collapsed the roof and blew out parts of the wall at the loading dock, causing significant damage.

December 18, 2001 Waterford (Oakland County)

An apparent natural gas explosion destroyed a Waterford home on December 18, 2001, and injured two family members. The blast hurled one of the injured persons more than 60 feet across the street.

December 20, 2001 Southfield (Oakland County)

A 12-inch, high-pressure natural gas main ruptured near a commercial strip in Southfield on the evening of December 20, 2001, injuring one person and forcing the evacuation of several businesses in the area. The explosion was apparently caused by a leak in the pipeline.

March 15, 2002 Crystal Falls (Iron County)

On March 15, 2002, a pipeline break occurred in Crystal Falls, resulting in a half hour of rerouted traffic and two months of pipeline shut-down. The cost of repair was around 4 million dollars.

August 31, 2002 Dansville (Ingham County)

An apparent natural gas explosion destroyed an apartment complex on August 31, 2002, killing a woman who was moving into the building and injuring four others. The explosion forced a nearby road to be closed for several days while debris was removed.

September 15, 2002 Bangor Township (Van Buren County)

An apparent natural gas explosion destroyed a farm house and killed five family members. The one-story home was flattened by the blast. Small pieces of debris were scattered up to a quarter-mile away.

November 20, 2002 Rose Township (Oakland County)

An apparent propane leak caused a house in Wayne County to explode. Houses up to 1,000 feet away were shaken as well. Amazingly, the man in the destroyed house made it out alive, with only a few cuts on his forehead.

September 20, 2003 Detroit (Wayne County)

A natural gas explosion destroyed three houses and caused minor damage to nearly 10 others. The explosion at a vacant house resulted in fires that destroyed occupied homes on both sides of it. Residents escaped with only minor injuries. Cars parked on the street nearby were also destroyed.

April 14, 2004 Taylor (Wayne County)

A natural gas leak caused a house in Taylor to explode, shooting debris 100 feet in all directions. Remains from the house were discovered in yards five lots away, and houses up to a mile away were shaken by the explosion.

September 3, 2005 Caledonia Township (Shiawassee County)

Over Labor Day weekend in 2005, a Shiawassee County home exploded while relatives were gathered for a family reunion. A total of six children were killed, and three more were seriously injured from the blast. Witnesses claimed that they felt the blast up to 10 miles away. Analysis showed that there was something wrong with the copper tubing that had carried propane gas to the Copas Road home. It was reported that the copper tubing was too thin and that proper tests had not made certain that the tubing wouldn't leak. Large amounts of liquid propane seeped into the ground, gas filled the basement, and the smallest spark could therefore trigger the blast.

December 12, 2006 Mason Township (Cass County)

On December 12, 2006 a natural gas pipeline explosion occurred at US-12 and Tharp Lake Road in Mason Twp. Homes within a half mile of the incident were evacuated, and traffic was also diverted. The explosion had occurred when a Midwest Energy employee was operating a trencher and struck the pipeline, resulting in one fatality.

July 17, 2007 Mayville (Tuscola County)

A man was trying to light his home's propane-fueled water heater when an apparent gas leak caused an explosion. The man was sent to the hospital in critical condition. Firefighters didn't have much of a fire to battle because the explosion was one big flash. The house collapsed in on itself and required demolition.

August 28, 2007 Muskegon (Muskegon County)

A house exploded after a contractor accidentally struck a natural gas line. Fortunately, no one was inside the home when the incident occurred. The explosion also caused damage to a neighbor's house.

November 20, 2007 Canton Township (Wayne County)

Natural gas leaks at 8am on November 20, 2007 led to a house exploding in Canton Township. One woman was injured and was pulled from the rubble by neighbors.

February 26, 2008 Grand Rapids (Kent County)

A natural gas explosion occurring at 3:30pm on February 26, 2008 resulted in the collapse of a two story building. Seven persons were injured, and five neighboring businesses suffered damage. A fire burned well into the night, due to an inability to shut off the natural gas until 9:30pm because the fire wouldn't allow access. Three quarters of the city's firefighters were involved in the effort, with neighboring departments covering calls in the city. A gas leak was also detected under the road.

February 28, 2008 Flint (Shiawassee County)

Around noon on February 28, 2008, a man was injured in a house explosion that was an apparent suicide attempt. The man disconnected a gas line in his house and then intentionally sparked the blast, resulting in the explosion of his Linden Place manufactured home. The park's maintenance manager kicked in the door to the home and pulled the man to safety just before a major fire broke out, and fire fighters later rescued a pet cat safely.

March 29, 2008 Lake Ann (Benzie County)

A man was injured as a result of a propane explosion that destroyed a house. Debris was sent flying more than 1,600 feet, and the explosion and fire had been triggered by a relief valve blocked by snow falling off the house's roof.

June 25, 2008 Yankee Springs (Barry County)

One person died during an overnight fire in a lake house at Gun Lake, followed by an explosion caused by a gas line rupture which then took place.

July 14, 2008 Allegan (Allegan County)

On July 14, 2008 a two story house exploded during the night in Lee Township. Nobody was injured because no one was home at the time of the incident.

August 6, 2008 Hastings (Barry County)

A house explosion near Hastings blew out the home's windows and caused severe structural damage. Two teenage boys were inside the home but managed to leave without injury. An investigation found that the explosion was a result of a build-up of leaking propane gas that ignited in the home's basement. The explosion did not cause a fire but the explosion blew the house about 6 inches off of its foundation.

December 5, 2008 Colon (St Joseph County)

A man was killed in a one-car crash that ruptured a gasoline pipeline valve and caused a massive explosion and fire in St Joseph County. The pipeline, which spilled 14,322 gallons of oil, was shut down for more than a week, and authorities routed traffic around the area as the fire continued to burn out.

December 13, 2008 Maple Grove (Saginaw County)

A natural gas leak caused an explosion and fire that burned down a Saginaw County home. Two residents escaped without injury. Freezing winds, icy conditions, poor accessibility, and a lack of water made it difficult for neighborhood fire fighters to stop the blaze. The gas was shut off at the meter and a 3,000 gallon tanker was sent in to help eliminate the hazard.

August 4, 2009 Clio (Genesee County)

In the afternoon of August 4, 2009, an employee reported a small fire at an electrical meter outside one of the buildings at the White Oil Co. Storage Facility plant in Clio when a massive fire broke out and shot heavy plumes of black smoke into the air. Several 50 gallon oil barrels created explosions over 50 feet in the air. Twenty-five fire departments responded, sending over 100 fire fighters to battle the blaze. There were no reported major injuries, and only two minor injuries, but emergency officials contacted about 4,000 residential and business telephone numbers to notify them of the evacuation within a 2 mile radius. Around 150 people were sent to a shelter, and motorists were asked to avoid the area as well.

September 17, 2009 St. Clair Shores (Macomb County)

A gas leak was the reason for a home to explode in St. Clair Shores that resulted in the death (the following day) of the home's 83-year-old owner.

October 2, 2009 Tallmadge Township (Ottawa County)

A natural gas buildup in the afternoon of October 2, 2009 was the cause of a rental house explosion in Ottawa County. Nobody was injured at the time because the previous tenant had moved out the day before, but the debris also destroyed the neighboring houses' windows.

May 16, 2010 Kentwood (Kent County)

A natural gas leak caused a four-unit apartment to explode on May 16, 2010, resulting in 4 injuries. The gas leak occurred in a vacant apartment in the complex. The scene resembled that of a tornado, with debris scattered nearby, shards of broken window glass littered on the ground, lumber lodged into a neighbor's garage, and siding propelled through a neighbor's window.

May 29, 2010 Constantine (St Joseph County)

On May 29, 2010 a gasoline pipeline rupture spilled 89,000 gallons of fuel on farmland west of Constantine. The underground leak sprayed a two- to three-foot-high plume of gasoline into the air and saturated the ground of a newly planted corn field. BP Oil, the owner of the 12-inch gasoline distribution pipeline, drilled 70 temporary monitoring wells and set up 40 water extraction points, in an effort to keep the spilled fuel from contaminating groundwater in the areas in southern St. Joseph County. Thousands of gallons of contaminated water were "vacuumed" daily from underground aquifers. No injuries were reported, but 12 people from four nearby homes were evacuated from the area for nearly 48 hours.

June 21, 2010 Oshtemo Township (Kalamazoo County)

A natural gas leak caused an explosion that destroyed a house near Kalamazoo. Fortunately, there were no injuries because the owner of the home was at work and his wife and kids were out of town.

July 2, 2010 Wixom (Oakland County)

A natural gas line leak caused an explosion that destroyed 22 units in an apartment complex. Only one person was injured.

July 21, 2010 Ravenna (Muskegon County)

A man was killed in a propane leak explosion that destroyed his mobile home. The man had attempted to convert a kitchen stove from natural gas to propane, but a leak later occurred, resulting in the explosion while he was sleeping.

July 26, 2010 Calhoun & Kalamazoo Counties Enbridge Pipeline Disaster

On July 26, 2010, an oil spill was discovered by the owners of an oil pipeline, Enbridge Energy Partners L.P., during a maintenance activity at a pumping station located on the south edge of the City of Marshall. The 30-inch pipeline normally transported 190,000 barrels per day from Griffith, Indiana, to Sarnia, Ontario, and passes through Calhoun County and several other Michigan counties. Oil from the pipeline leaked into the Talmadge Creek and then into the Kalamazoo River and began to flow downstream toward Lake Michigan. Enbridge Energy officials shut down the pipeline pumps and closed valves located upstream and downstream from the leak site to stem the flow of additional oil and try to contain the spill. Based on company estimates, up to 19,500 barrels of crude oil had leaked from the pipeline (approximately 800,000 gallons).

Calhoun County declared a local state of emergency and several downstream communities, including Kalamazoo County, took emergency response actions in coordination with Calhoun County. The State Emergency Operations Center in Lansing was activated and a number of state departments and support organizations convened there to monitor the incident and coordinate state response activities with involved governmental agencies and company officials. Representatives of the U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, National Transportation Safety Board, U.S. Department of Transportation and other federal agencies quickly convened at the incident site and began working with company, local and state officials (under a Unified Command structure) to develop and implement a spill containment, recovery, and clean-up plan and protection strategy for the environment and affected local residents.

A coordination facility was established in the City of Marshall and contractors where brought in for environmental restoration and product recovery. Aggressive product recovery efforts were instituted to expedite oil containment and environmental clean-up. Wildlife rescue and rehabilitation operations were also implemented to aid in protecting animals and aquatic life from harm, and saving wildlife that had been adversely impacted by the spill. Health

advisories were issued to protect the public from harm, and some of the nearby residents were evacuated for a time until the air quality improved within the area. A number of contracted cleanup crews were brought in to perform clean-up and product recovery work.
On September 27, the repaired oil pipeline was restarted by company officials, with the approval of the U.S. Department of Transportation. New oil again flowed through the pipeline, initially at a reduced pressure level but then at full capacity again. Clean-up and product recovery efforts are still ongoing. The unified command center remained operational for an extended period of time, due to the long-term nature of product recovery and environmental clean-up operations.

December 29, 2010 Wayne (Wayne County)

An aging natural gas pipeline exploded under a furniture store, destroying the building and resulting in two fatalities and one injury. Rescue workers spent all day and into the night combing through the pile of crumpled drywall, twisted metal, and broken bits of furniture. The explosion also shattered windows at nearby businesses and hospitalized one person who had been driving by when the building exploded. Police evacuated homes and businesses near the store, and a local state of emergency was declared. Residents in the area had reported the smell of gas to the utility company three hours before the explosion. A second leak was discovered in the same area after the explosion, but was successfully capped before exploding.

January 10, 2011 Grand Rapids (Kent County)

A house exploded as a result of a natural gas leak, causing one fatality and leaving another person critically injured.

January 12, 2011 Columbus (St. Clair County)

One person was hurt during a natural gas explosion at a facility in Columbus. Residents within a five-mile radius of the gas storage company said they first heard a loud boom and then saw a fireball. The company sells natural gas, and stores it in a two-mile-long cavern underground. The explosion occurred during a separation of gas and oil, and then the facility's safety valve kicked in, preventing the fire from spreading until it burned out.

April 13, 2011 White Oak Township (Ingham County)

A gas leak occurred on April 13, 2011 when between 294,000 and 462,000 gallons of gasoline leaked from a faulty Marathon Pipe Line LLC pipeline in mid-Michigan. Marathon originally estimated that 126,000 gallons had leaked into the soil before it was detected by a man in Ingham County's White Oak Township whose 16-acre farm backs up to four fuel storage tanks. Environmental experts said the Ingham County gasoline leak didn't harm residents' drinking water. They also said it was unlikely that contamination from the leak had affected the Red Cedar River watershed and neighboring communities.

May 4, 2011 Warren (Macomb County)

A natural gas explosion in a commercial Laundromat in Detroit's northern suburbs leveled the building and injured two passers-by. The blast was felt several miles away and nearby residents reported seeing a large cloud of smoke.

The relatively small number of deaths and injuries associated with these petroleum and natural gas pipeline accidents is a testament to the emergency preparedness efforts of the pipeline companies and local communities, as well as the regulatory oversight of the Michigan Public Service Commission and the U.S. Department of Transportation's Office of Pipeline Safety. The possibility is always there for a significant accident to occur, since Michigan is crisscrossed by several major petroleum and natural gas pipelines. Pipelines could rupture at any time, resulting in severe explosion, fire, property damage, environmental contamination, and casualties.

Programs and Initiatives

Pipeline jurisdiction and oversight in Michigan is complex, determined primarily by the type and function of a pipeline and its location. Agencies involved include (1) the MPSC Gas Safety Office, (2) the USDOT/OPS in Kansas City, Missouri, and (3) the Michigan Department of Environmental Quality, Office of Geological Survey (MDEQ/OGS). The table below is a breakdown of jurisdictional and inspection responsibilities for the various types of pipelines present in Michigan:

Pipeline Safety Regulation in Michigan

Pipeline Type	Jurisdiction	Applicable Code	Inspected By
Inter-state Natural Gas	USDOT/OPS	49 CFR Part 192	MPSC Gas Safety
Intra-state Natural Gas	State of Michigan/MPSC	Michigan Gas Safety Standards	MPSC Gas Safety
Liquid Petroleum	USDOT/OPS	49 CFR Parts 193/195	USDOT/OPS
Gathering Lines*	MDEQ/OGS	Oil/Gas Administrative Rules under Part 615, 1994 PA 451	MDEQ/OGS

*Note: Gathering lines run from a production facility (i.e., a well) to a pre-processing plant (i.e., dehydration facility, or separator, compression station).
Source: Michigan Public Service Commission, Gas Safety Office.

The issue of gathering line jurisdiction is even more complex. Gathering lines in non-rural areas fall under the jurisdiction of the Michigan Gas Safety Standards. Gathering lines that serve as common carriers fall under the jurisdiction of the MPSC, but may not necessarily fall under the Michigan Gas Safety Standards. All other gathering lines fall under the jurisdiction of the MDEQ/GSD. (Note: Even though gathering lines in rural areas do not fall under the direct jurisdiction of the Michigan Gas Safety Standards, the MPSC requires all common carrier pipelines to be designed, constructed and operated under the requirements of the Standard.)

The following are major programs and initiatives in place to help ensure petroleum and natural gas pipeline safety in Michigan.

Michigan Gas Safety Standards

Pipeline operators are regulated under the Michigan Gas Safety Code, 1969 PA 165 and its implementing Administrative Rules - the Michigan Gas Safety Standards, to ensure that public safety is protected to the extent that is possible in the industry. Under the Code (which is administered by the MPSC), gas pipeline companies (operators) must develop and maintain written procedures to minimize the hazards resulting from a gas pipeline emergency. The procedures must provide for the following: 1) identification and classification of events; 2) notification of and communication with local response agencies and public officials; 3) response to all types of gas emergencies, including emergency shutdown and pressure reduction procedures; 4) coordination of response actions with the local jurisdiction(s); and 5) restoration of service. Operators must also ensure that personnel are properly trained and knowledgeable about emergency procedures. If an incident occurs, the operator must review response actions to determine whether procedures were followed, and if necessary, take samples of the failed facility or equipment for laboratory examination to determine the cause of the failure. Mitigation actions are taken as necessary to minimize the possibility of a recurrence. The latest edition of the Michigan Gas Safety Standards was filed with the Secretary of State and became effective on April 17, 2009.

U.S. Department of Transportation, Office of Pipeline Safety

Additional pipeline safety requirements are contained in the Federal Safety Standards (Parts 191, 192, 193 and 195), as administered by the USDOT/OPS. Interstate gas and liquid petroleum pipeline operators must develop and maintain written emergency procedures similar to those required under the Michigan Gas Safety Standards. In addition, they are required to coordinate both planned and actual response actions with local officials and response agencies. There is also a Federal Grant Program authorized to reimburse a state agency up to 80 percent of the actual cost for carrying out its pipeline safety program. The actual amount of Federal reimbursement depends upon the availability of appropriated funds and state program performance (and the formula used to allocate funds includes performance factors). The Natural Gas Grant Allocation and Hazardous Liquid Grant Allocation participate in the program. The OPS provides grant funding to Michigan to improve communication among excavators and owners of underground facilities. The PIPES Act of 2006 also authorizes grants to Michigan state authorities, designated by the Governor, to create or maintain effective State damage prevention programs.

Part 195 also has a continuing education requirement to keep local officials and the general public informed about the risks associated with the transportation of hazardous liquids via pipeline. OPS and Michigan partners regularly participate in joint government-industry-public committees and task forces to discuss and address concerns related to risk management, compliance, emerging technology, damage prevention, and environmental protection. Current initiatives include the Risk Management Demonstration Program, the Local Distribution Company Feasibility Study, Technical Pipeline Safety Standards Committees, Best Practices for One-Call Centers, and the National Pipeline Mapping System (GIS-based).

MPSC Pipeline Safety Inspections

MPSC safety engineers are certified by the USDOT/OPS to conduct inspections on natural gas pipelines to ensure the structural and operational integrity of the systems. If violations are found, the pipeline company can be ordered to take corrective actions, and the pipeline operator may be fined. The MPSC safety engineers also respond to accidents involving natural gas or petroleum pipelines (to ensure compliance with federal and state law, and to offer technical assistance to emergency responders).

The Protection of Underground Facilities Act / MISS DIG Program

Michigan's first line of defense against pipeline (and other utility line) breaks from construction excavations is the "MISS DIG" Program established with the passage of 1974 PA 53 – The Protection of Underground Facilities.

MISS DIG System, Inc., is a 24-hour utility communications system that helps contractors comply with the state law (Act 53) that requires the notification of utilities at least three working (but not more than 21 calendar) days before starting the excavation, tunneling, demolishing, drilling or boring procedures, or explosive discharges for a project. When properly administered and followed, the MISS DIG safety system does an excellent job of minimizing pipeline and utility line accidents.

National Transportation Safety Board

The National Transportation Safety Board (NTSB) investigates all significant pipeline accidents in the U.S., and provides pipeline company and government regulators with safety recommendations aimed at preventing future accidents. The NTSB also publishes a list of “most wanted” safety improvements, for pipelines and other modes of transportation, for nationwide implementation by appropriate entities. Although these safety improvement recommendations are not mandatory, and the NTSB has no regulatory or enforcement powers, it nonetheless has been successful in getting more than 80% of its recommendations adopted. Many safety features currently incorporated into pipelines and other transportation modes had their genesis in NTSB recommendations.

Local Emergency Capability

Communities that may be affected by petroleum or natural gas emergencies should have adequate procedures in their Emergency Operations Plans to address the special types of problems associated with this hazard, including specific functions such as rescue and evacuation. Affected communities must work closely with company officials and surrounding jurisdictions to ensure a fast, coordinated response. Mitigation possibilities include the use of community zoning regulations to provide suitable open, unoccupied "buffer" areas around pipelines, storage fields, refineries, and compressor stations.

American Petroleum Institute (API) Recommended Practice (RP) 1162

The American Petroleum Institute (API) Recommended Practice (RP) 1162, "Public Awareness Programs for Pipeline Operators" has regulations for pipeline operators to provide the affected public with information about how to recognize, respond to, and report pipeline emergencies. The importance of using the one-call notification system prior to excavation is to be emphasized for all stakeholders. Emergency officials and local public officials must be provided with information about the location of transmission pipelines, to enhance emergency response and community growth planning. Affected municipalities, school districts, businesses, and residents must be advised of pipeline locations. Of particular significance is the requirement that operators must periodically review their programs for effectiveness, and enhance the programs as necessary.

This industry consensus standard provides guidance and recommendations to pipeline operators for the development and implementation of enhanced public awareness programs. It addresses multiple elements of such programs, including the intended audiences, the kinds of information to be communicated, frequencies and methods of communicating the information, and evaluation of the programs’ effectiveness.

Michigan Propane Gas Association (MPGA)

The Michigan Propane Gas Association was created to promote the proper handling and use of propane, to work for a favorable environment for propane distribution and marketing, and to increase its use by demonstrating propane's value as a clean energy source. The MPGA is a trade and membership service organization that represents propane marketers throughout the state. The MPGA's primary purpose is to maintain high standards of practice within the industry and, in so doing, protect and expand the ability of its members to compete in the marketplace.

Interstate Natural Gas Association of America (INGAA)

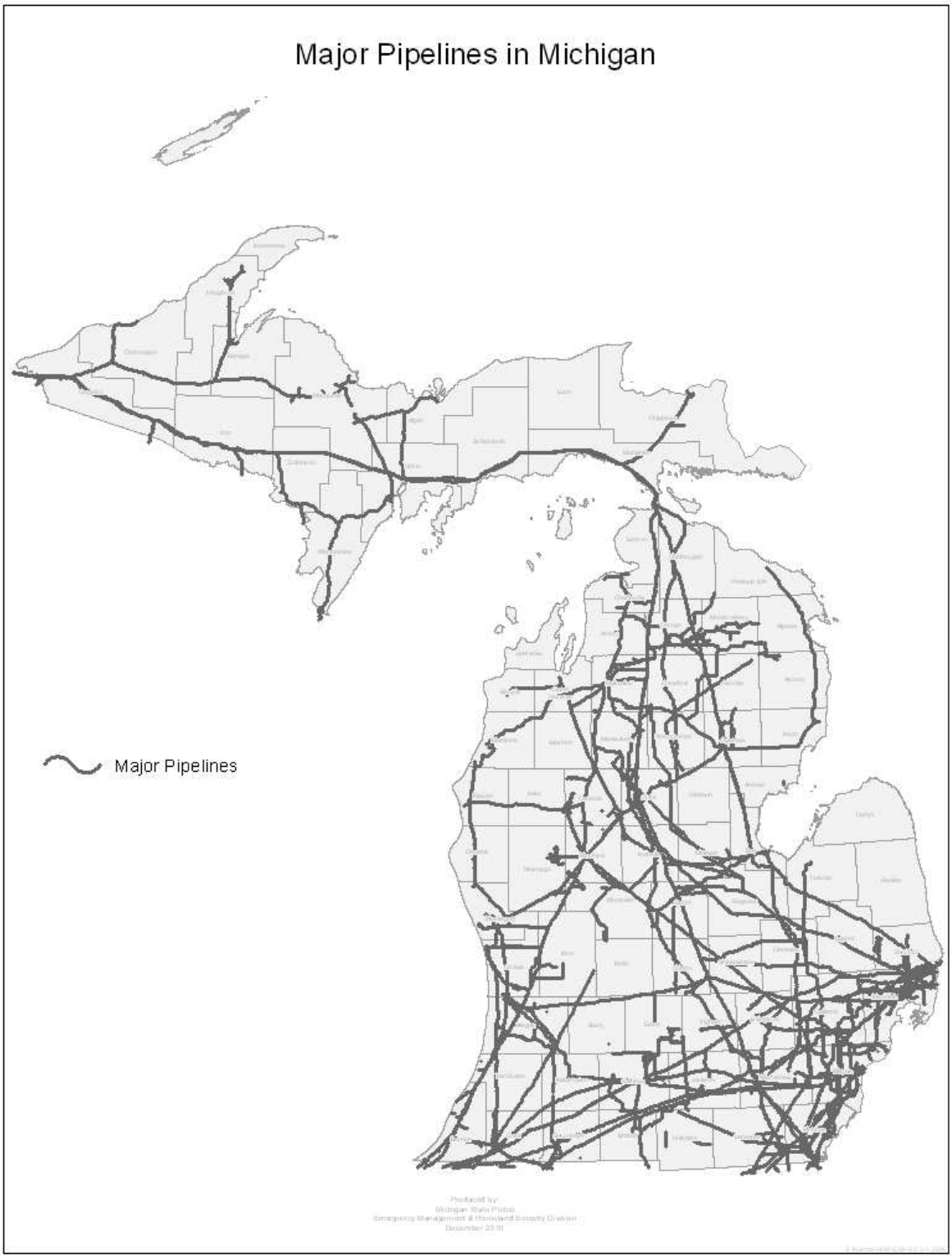
The Interstate Natural Gas Association of America (INGAA) is a trade organization that advocates regulatory and legislative positions of importance to the natural gas pipeline industry in North America. Its members transport over 95 percent of the nation's natural gas through a network of 200,000 miles of pipelines. The interstate natural gas pipeline industry has two principal federal regulators: the Federal Energy Regulatory Commission (FERC) is responsible for the economic regulation of pipelines, while the U.S. Department of Transportation (DOT) Office

of Pipeline Safety oversees the industry's safety efforts. INGAA's primary mission is to create a regulatory and legislative climate that allows interstate natural gas pipeline companies to optimize efficient and profitable operations.

Nonprofit Pipeline Safety Organizations

There are several nonprofit organizations and agencies that provide information encouraging pipeline safety in Michigan. These organizations can work to educate the public by organizing meetings, seminars, and workshops to improve pipeline reliability, operational efficiency, and the regulatory environment. These organizations can support the safe delivery of pipeline products; research pipeline operational problems; act as a common ground forum where members can discuss and seek solutions to industry problems; promote underground facilities, damage prevention, and implementation of damage prevention best-practices to all stakeholders; and represent industry interests before Congress, federal agencies, and other energy-related stakeholders by developing regulatory and legislative policies. These particular organizations include the National Association of Pipeline Safety Representatives (NAPSR), Association of Oil Pipe Lines (AOPL), American Public Gas Association (APGA), Pipeline Research Council International, Inc. (PRCI), the Common Ground Alliance (CGA), etc.

Major Petroleum and Natural Gas Pipelines in Michigan
Source: Michigan Public Service Commission; pipeline company maps



OIL AND NATURAL GAS WELL ACCIDENTS

An uncontrolled release of oil or natural gas, or the poisonous by-product hydrogen sulfide, from production wells.

Hazard Description

Oil and natural gas are produced from fields scattered across 63 counties in the Lower Peninsula. From 1927 to January 2009, there have been 56,525 oil and natural gas wells drilled in Michigan, of which roughly half have produced oil and gas. To date, Michigan wells have produced over 1.4 billion barrels of crude oil and 6 trillion cubic feet of gas.

The petroleum and natural gas industry is highly regulated and has a fine safety record, but the threat of accidental releases, fires and explosions still exists. In addition to these hazards, many of Michigan's oil and gas wells contain extremely poisonous hydrogen sulfide (H_2S) gas. Hydrogen sulfide is a naturally occurring gas mixed with natural gas or dissolved in the oil or brine and released upon exposure to atmospheric conditions. Over 1,300 wells in Michigan have been identified as having H_2S levels exceeding 300 parts per million (ppm).

As the table below indicates, at concentrations of 700 ppm, as little as one breath of hydrogen sulfide can kill. Although hydrogen sulfide can be detected by a "rotten egg" odor in concentrations from .03 ppm to 150 ppm, larger concentrations paralyze a person's olfactory nerves so that odor is no longer an indicator of the hazard. Within humans, small concentrations can cause coughing, nausea, severe headaches, irritation of mucous membranes, vertigo, and loss of consciousness. Hydrogen sulfide forms explosive mixtures with air at temperatures of 500 degrees Fahrenheit or above, and is dangerously reactive with powerful oxidizing materials. Hydrogen sulfide can also cause the failure of high-strength steels and other metals. This requires that all company and government responders be familiar not only with emergency procedures for the well site, but also with the kinds of materials that are safe for use in sour gas well response.

Physiological Response to H_2S

10 ppm	Beginning eye irritation
50-100 ppm	Slight conjunctivitis and respiratory tract irritation after 1 hour exposure
100 ppm	Coughing, eye irritation, loss of sense of smell after 2-15 minutes. Altered respiration, pain in the eyes and drowsiness after 15-30 minutes, followed by throat irritation after 1 hour. Several hours of exposure results in gradual increase in severity of these symptoms and death may occur within the next 48 hours.
200-300 ppm	Marked conjunctivitis and respiratory tract irritation after 1 hour of exposure.
500-700 ppm	**Loss of consciousness and possibly death in 30 minutes to 1 hour.**
700-1000 ppm	**Rapid unconsciousness, cessation of respiration, and death.**
1000-2000 ppm	**Immediate unconsciousness, with early cessation of respiration and death following within a few minutes. Death may occur even if the individual is removed to fresh air at once.**

Source: American National Standards Institute, Standard: 237.2-1972

An unplugged abandoned well, also known as an orphan well, can be a hazard to the health and safety of the surrounding people and environment. There are many situations where an unplugged well can become dangerous. For example, a rusted-out casing in a gas well can let natural gas flow underground and accumulate in the basement of a nearby building, possibly causing an explosion. Occasionally, gas leaking from an old well can contaminate a nearby water well. An old well might also be a conduit for salt brine from deeper formations to pollute fresh groundwater, or to discharge at the surface. In some cases, oil leaks from abandoned wells, polluting soil and water. In the vicinity of a coal mine, an old well can be a conduit for explosive gas to enter the mine, a

serious mine safety problem. Also, where coal mining has occurred, an old well can allow acidic mine water to discharge at the surface.

Hazard Analysis

Over the years, Michigan has experienced periodic upward and downward trends in oil and natural gas production as new reservoirs were discovered and older ones became depleted. However, oil production has been declining at 5-8% per year since 1990. Natural gas production peaked in 1998 and has also begun to indicate a decline in production. As the table and map indicate at the end of this section, a large number of Michigan's oil and natural gas wells are located in the western counties bordering on Lake Michigan, and in the central part of the Lower Peninsula. A thin band of fields also runs from Calhoun County to St. Clair County in the southern Lower Peninsula, and across the northern Lower Peninsula from Manistee County to Presque Isle County. Oil and natural gas wells are scattered around other Lower Peninsula counties, but the Upper Peninsula contains few productive oil and gas wells.

Michigan reaps tremendous economic and social benefits from oil and natural gas production. As with all industrial and commercial activities, along with those benefits come some risks as well. Despite the best efforts of the MDEQ Office of Geological Survey and the drilling companies to minimize oil and natural gas well accidents, it is inevitable that such accidents will occur from time to time. When they do, the affected local communities must be prepared to respond to the accident, institute necessary protective actions, and coordinate with state officials and drilling company emergency crews to effectively manage and recover from the accident. That can best be accomplished through collaborative planning, training, and the exercising of emergency procedures with all potentially involved parties.

Using revenues from oil and gas production taxes, the Michigan Department of Environmental Quality has plugged and restored at least 200 wells. Out of the 62,376 oil and gas wells drilled in Michigan since the 1920s, 26 orphan wells remain to be plugged as of 2012.

It can be difficult to accurately assess incident probabilities for oil and gas wells, but some indications might be gained from existing OSHA data. As related in the section on hazard identification, information about the location of wells is available since permits needed to be issued before they are dug or drilled. If permit sites are near developed or potentially sensitive areas, specific inquiries can then be made with MDEQ to see if the permit actually resulted in a well being created, whether the well is still open or has been capped, and whether open wells have been known to contain hydrogen sulfide. Wells that are open and potentially hazardous should be reconsidered if they are located very near to vulnerable populations or densely developed areas.

Impact on the Public

Those who are in or near a well site during a hazardous event (workers, inspectors, trespassers) may face severe injury or death. Those living in the close vicinity of such a well may potentially be affected by gases and thus require temporary evacuation, but these cases would be extremely rare.

Impact on Public Confidence in State Governance

An event of significant size or impact may provoke a perception that inadequate regulation, authorization, or oversight was maintained by the state.

Impact on Responders

Wells may contain poisonous hydrogen sulfide gas, and thus require responders to use special equipment when nearby. Special search and rescue skills may be needed for victim extraction. In this regard, the oil and gas well hazard may be considered to be similar to a fixed site hazardous materials incident (q.v).

Impact on the Environment

The process of getting oil and natural gas from underground to the end user has the potential to be environmentally destructive. The environmental impacts of oil and natural gas well accidents include the emission of air pollutants, leaks and spills, groundwater contamination, and the effects of well "blowouts." Many of Michigan's oil and gas wells contain extremely poisonous hydrogen sulfide (H_2S) gas. Productive natural gas wells and their associated utilities and access roads also "eat up" natural land, and many areas where gas is found are natural areas where drilling puts industrial facilities into rustic settings.

An unplugged abandoned well (orphan well) can be a hazard to the environment. For example, a rusted-out casing in a gas well can let chemical substances flow underground, and gas leaking from an old well could contaminate a nearby water well. An old well might also be a conduit that allows salt brine from deeper formations to pollute fresh groundwater, or to discharge at the surface. In some cases, oil leaks from abandoned wells may cause the pollution of soil and water.

Significant Oil and Natural Gas Well Accidents

To date, Michigan has been fortunate not to have an oil or natural gas well accident that resulted in loss of life (other than to company employees) or caused significant property damage. However, significant oil and natural gas well accidents have occurred that required an emergency response by the drilling company and by state and local officials:

April 1973 Williamsburg (Grand Traverse County)

The drilling of oil and natural gas wells may result in another type of hazard, as demonstrated by an incident near Williamsburg in Grand Traverse County during April 1973. Gas pressure in a well forced gas through porous rock formations to the surface. This eruption of natural gas caused craters of bubbling muddy water that flowed into nearby streams and into the Grand Traverse Bay. Due to the threat of an explosion, the townspeople of Williamsburg were evacuated, but an explosion did not occur. Damage was confined to building foundations (which settled) and environmental damage to trees and streams. Fortunately, the Williamsburg incident was resolved without death or injury. The Michigan Department of Natural Resources subsequently imposed improved well casing and sealing requirements to prevent this type of occurrence.

April 16, 1984 Bay County

On April 16, 1984 a sour gas well in Hampton Township (Bay County) developed a leak at its surface casing, emitting sour gas for several hours. Residents within a half-mile radius were evacuated for approximately 24 hours until the well could be completely repaired. There were no injuries or property damage.

February 24, 1988 Buckley (Wexford County)

On February 24, 1988 a gas leak occurred in a well located near the village of Buckley in Wexford County. Several children in a nearby school complained of nausea from the strong odor, so the school was evacuated as a precaution. After a short investigation, the well site was located and it was determined that the site had suffered a deck blow-off and was emitting gas directly into the atmosphere. The well was subsequently shut down until permanent repairs could be made.

January 9, 1989 Arenac County

On January 9, 1989 a natural gas well blew out in Au Gres Township, Arenac County. Although there was no fire, methane, butane, and hydrogen sulfide leaked from the wellhead. The surrounding area was evacuated while attempts were made to seal the leak with mud and concrete and to replace the wellhead. On January 11, a new valve was successfully installed and the community resumed its normal activities.

February 17, 1989 Grand Traverse County

On February 17, 1989 a Shell Western oil well in Mayfield Township (Grand Traverse County) blew out, resulting in an evacuation of nearby residents and the cancellation of local school classes. The well was eventually capped, later that night.

June 15, 1993 St. Clair County

On June 15, 1993 a natural gas explosion occurred at a Michigan Consolidated Gas Company (MICHCON) underground storage facility in Columbus Township, St. Clair County. One worker was injured in the explosion, two vehicles were burned, and several homes in the immediate vicinity of the facility were evacuated.

February 3, 1994 Ogemaw County

On February 3, 1994 an explosion and fire occurred when a pipe released gas under pressure at an American Oil Company (AMOCO) production facility in Ogemaw County. One service company employee was killed and another employee was injured. The situation was immediately brought under control with no additional injuries, damage, or threat to public safety.

May 13, 1994, and August 1996 Manistee and Mason Counties

An accident occurred when a blown gasket released hydrogen sulfide emissions after a seal in a compressing station in Mason County's Victory Township failed. The incident resulted in 11 people requiring emergency hospital treatment (four of them children) and the death of 10 cattle. Another similar incident occurred two years later when a release of 5,500 cubic feet of natural gas containing 900 ppm of poisonous H_2S occurred in Manistee Township. The release, which occurred while workers were attempting to plug a well, caused several citizens in the neighborhood to lose consciousness and collapse. Eleven victims were treated at the hospital; at least one of them sustained serious lung damage. Others were being treated for symptoms of asthma, skin irritations and neuropsychological problems. From 1980 to 1998, other injuries and evacuations have occurred in Manistee and Mason Counties as a result of H_2S releases. At least 10 separate accidental releases of H_2S from pipelines and processing plants caused at least 262 people in Manistee and Mason Counties to evacuate their homes (five since 1995), caused at least 22 people to have been injured and seek medical treatment since 1994, and caused 35 cattle to be killed in

Mason County since 1994. Many more have suffered respiratory and skin complications, and all are bearing the psychological burden of repeated evacuations.

December 2006 Mecosta County

In December, 2006 a gas well burst into an explosion in Mecosta County, resulting in the evacuation of several nearby residents. The issue was later resolved, with no additional threat to public safety.

Programs and Initiatives

Oil and Natural Gas Well Regulatory Authority

Part 615 of the Natural Resources and Environmental Protection Act, 1994 PA 241, as amended, regulates oil and natural gas well drilling in Michigan. Revisions to this "Supervisor of Wells" statute, in 1999, clarified the Supervisor's authority to address public health and safety issues. The Administrative Rules for Part 615 were most recently updated in September, 1996. These Rules require the classification of wells using the concept of radius of exposure (RoE). A simple formula is used to calculate the distance, in feet, from the point of release at which the H_2S concentration in air reaches 100 ppm. This is the 100 ppm RoE. Wells with more than 300ppm H_2S in the gas stream are classified according to the 100 ppm RoE. Part 616 deals with an Orphan Well Fund created within the State Treasury for the purpose of plugging the abandoned or improperly closed oil or gas wells, or for response activity, and/or for site restoration at oil or gas wells. The fund can be used when no owner or operator is known, when all owners or operators are insolvent, or when the supervisor determines there is an imminent threat to public health and safety.

Michigan Oil and Gas Association (MOGA)

The Michigan Oil and Gas Association (MOGA) represents the exploration, drilling, production, transportation, processing and storage of crude oil and natural gas in the State of Michigan. The organization has over 1,000 members, which include major oil companies, independent oil companies, and the exploration arms of various utility companies. The MOGA monitors the pulse of the Michigan oil and gas industry as well as the political, regulatory, and legislative interest in the state and the nation's capital as well. The organization has been described as the collective voice of the petroleum industry in Michigan, speaking to the problems and issues facing the various companies involved in the state's crude oil and natural gas business. One of the ongoing issues of concern to the MOGA is oil and natural gas well safety.

Interstate Oil and Gas Compact Commission (IOGCC)

Michigan is a member of Interstate Oil and Gas Compact Commission (IOGCC) that represents the governors of oil and natural gas producing states. In 1935, six states endorsed and Congress ratified the Interstate Compact to Conserve Oil and Gas, resulting in the formation of the unique governmental entity now known as the Interstate Oil and Gas Compact Commission. The IOGCC has helped states (including Michigan) to establish effective regulation of the oil and natural gas industry through the gathering and sharing of information, technologies, and regulatory methods. The IOGCC advocates for environmentally sound ways to increase the supply of American energy. This can be accomplished by providing governors of member states with a clear and unified voice to Congress, while also serving as the authority on issues surrounding these vital resources. The unique structure offers a highly effective forum for states, industry, Congress, and the environmental community to share information and viewpoints to advance our nation's energy future. The organization is dedicated to securing resources needed to ensure our nation's energy, economic, and national security.

Michigan Oil & Gas Producers Education Foundation (MOGPEF)

MOGPEF was created in 2003 to assist in supporting educational projects and programs about the industry. It is a tax-exempt organization under Section 501(c) (6) of the United States Internal Revenue Service code. Its mission is to provide financial support for programs that will inform the people of Michigan about the importance of the local oil and natural gas industry and about the environmental safeguards that are employed. Materials and programs developed by MOGPEF are available for use by members of petroleum, energy, and allied industries and by the general public.

Contingency Planning

Contingency plans for public protection are required for wells at which the 100 ppm RoE is greater than 100 feet. The plans are divided into two parts. Part I contains general procedures that must be implemented by company personnel in an emergency when H_2S is released. This includes emergency contacts and their assigned duties and responsibilities, notification and evacuation procedures for the general public, and procedures for igniting the well. Part II contains site-specific information and must be filed with an application for a drilling permit. Well owners have the option of working with the local Emergency Management Coordinator instead of preparing a required site map and list of residences. This option can be used in highly populated areas. Other H_2S Administrative Rules address special equipment requirements for the drilling, testing, and production of H_2S-bearing wells. The Rules are intended to provide for public protection and nuisance odor mitigation.

Local Emergency Capability

Communities that may be affected by oil or natural gas well accidents should have adequate procedures in their Emergency Operations Plans to address the types of problems especially associated with this hazard, including rescue and evacuation. Affected communities must work closely with company officials and surrounding jurisdictions to ensure the compatibility of procedures for a fast and coordinated response. Mitigation possibilities include the use of community zoning regulations to provide suitable open, unoccupied "buffer" areas around refineries and compressor stations. Michigan Department of Environmental Quality regulations provide for buffer zones around wells and around treatment and storage facilities.

Oil and Gas Advisory Committee

The Oil and Gas Advisory Committee advises the MDEQ on matters of regional or state-wide significance relating to oil and gas exploration and production. The Committee provides input on policy, rules, orders, instructions, technical reviews, and hearings. The Committee is composed of members from the oil and gas industry and the public, with background or expertise in oil and natural gas, and related environmental and resource issues.

Michigan Department of Environmental Quality - GeoWebFace online

The Michigan Department of Environmental Quality now provides many GIS layers, along with an online interface called GeoWebFace, which allows users to view oil and gas well information in an interactive map. Its web address is http://ww2.deq.state.mi.us/GeoWebFace/.

Michigan's Oil and Gas Wells, by County
(As of 2012)

County	Wells	County	Wells	County	Wells
Alcona	**478**	Gratiot	**1**	Missaukee	**164**
Alger	**0**	Hillsdale	**29**	Monroe	**2**
Allegan	**196**	Houghton	**0**	Montcalm	**32**
Alpena	**894**	Huron	**2**	Montmorency	**2,539**
Antrim	**1,706**	Ingham	**31**	Muskegon	**15**
Arenac	**241**	Ionia	**0**	Newaygo	**33**
Baraga	**0**	Iosco	**7**	Oakland	**19**
Barry	**20**	Iron	**0**	Oceana	**48**
Bay	**393**	Isabella	**170**	Ogemaw	**326**
Benzie	**48**	Jackson	**40**	Ontonagon	**0**
Berrien	**0**	Kalamazoo	**0**	Osceola	**56**
Branch	**0**	Kalkaska	**268**	Oscoda	**450**
Calhoun	**79**	Kent	**145**	Otsego	**3,652**
Cass	**4**	Keweenaw	**0**	Ottawa	**155**
Charlevoix	**218**	Lake	**8**	Presque Isle	**39**
Cheboygan	**28**	Lapeer	**18**	Roscommon	**81**
Chippewa	**0**	Leelanau	**0**	Saginaw	**54**
Clare	**123**	Lenawee	**19**	St. Clair	**86**
Clinton	**0**	Livingston	**32**	St. Joseph	**0**
Crawford	**346**	Luce	**0**	Sanilac	**0**
Delta	**0**	Mackinac	**0**	Schoolcraft	**0**
Dickinson	**0**	Macomb	**9**	Shiawassee	**5**
Eaton	**9**	Manistee	**565**	Tuscola	**106**
Emmet	**0**	Marquette	**0**	Van Buren	**7**
Genesee	**18**	Mason	**21**	Washtenaw	**5**
Gladwin	**184**	Mecosta	**21**	Wayne	**7**
Gogebic	**0**	Menominee	**0**	Wexford	**13**
Gd. Traverse	**164**	Midland	**110**	**STATEWIDE**	**14,539**

Source: Michigan Department of Environmental Quality Office of Geological Survey

Michigan's Oil and Gas Fields

Source: Michigan Department of Environmental Quality, Geological Survey Division

II. Technological Hazards
B. Infrastructure Problems

The following list summarizes the broad types of infrastructure problems covered in this section:

1. Infrastructure Failures
2. Energy Emergencies
3. Transportation Accidents (air, rail, highway, marine)

A specific chapter is dedicated to infrastructure failures. Although various industrial hazards involve certain types of infrastructure (e.g. pipelines), and their breakdown, and this entire section of the hazard analysis relates to other types of infrastructure, the chapter specifically called infrastructure failures focuses upon interruptions in the provision of critical life-sustaining infrastructure, such as electricity and water supplies. As reported in a 2009 study by the National Academy of Sciences, an electrical blackout "has the potential to affect virtually all sectors of society: communications, transportation, banking and finance, commerce, manufacturing, energy, government, education, health care, public safety, emergency services, the food and water supply, and sanitation." Moreover, modern technological systems tend to be vulnerable to two trends that have been called "dependency creep" and "risk migration." These can be summarized as follows: "As systems become more complex, and as they grow in size, understanding and oversight become more difficult. Subsystems and dependencies may evolve that escape the close scrutiny of organization operators. Dependencies allow risk present in one part [of the] overall system to 'migrate' to others, with potentially damaging results. GPS and electric power systems have clearly accelerated dependency creep, and consequent risk migration. New technologies, such as nanoscale components, may not be adequately understood in the context of" existing risks to electric power systems.

One of the overarching patterns to be found within technical systems is the tradeoff between efficiency and vulnerability. Reserve capacity within a system can serve as a means for dealing with uncertainties and contingencies. In a competitive market environment, systems operate close to their full capacity and maximum efficiency during times when everything is functioning smoothly and predictably. Under such ideal conditions, "buffers shrink, costs fall, and profits rise," but when something in the operating environment breaks down, as in the case of a disaster or system failure, "unexpected developments perturb the system, finely tuned technical systems become brittle and have trouble operating outside relatively narrow parameters. Vulnerability can be the consequence of increased efficiency." Within this framework, solutions may involve the use of systems designed to include "excess capacity: costs are passed on to users and the society" as part of this operational design, rather than in the form of disaster response efforts after a failure has already occurred. Extra security may come at the expense of decreased efficiency, but the costs can be more fairly spread across the users of the technology, rather than concentrated in disastrous events. This problem of system management operates in an environment of "interdependencies, lack of knowledge, lack of slack, lack of trust, and lack of ways to overcome coordination problems." However, they key to the mitigation of problems in such complex systems can probably be found through addressing each of those conditions, point for point, and together as a whole.

> "Systems can quickly become dependent upon new technologies in ways that are unknown and unexpected by both developers and users… vulnerabilities in one part of the broader system have a tendency to spread to other parts of the system."

(The information and quotations in the preceding two paragraphs and text box were primarily obtained from "Severe Space Weather Events—Understanding Societal and Economic Impacts: A Workshop Report – Extended Summary," the National Academies Press, Washington DC, 2009.)

For the 2012 update of the MHA, new consideration has been given to aspects involving the safety and integrity of the built environment—bridges and structures—in addition to the traditional problems that had been covered in previous editions: broken water mains, sewage system breakdowns, and widespread and extended power failures. Energy emergencies are then discussed in a separate section, describing potential vulnerabilities involving

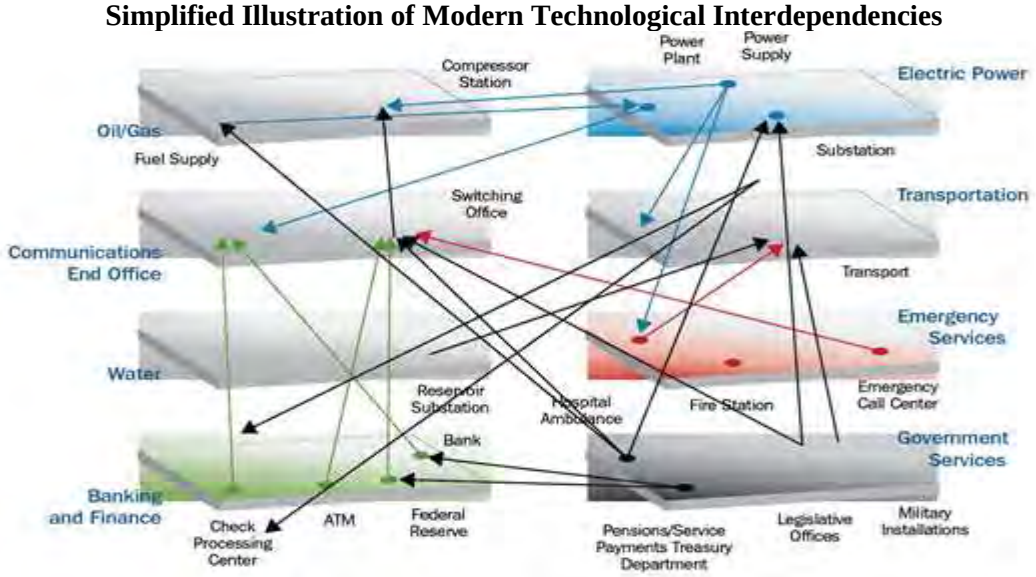
breakdowns in the availability of key energy sources that power most of our modern activities—especially gasoline, electricity, natural gas. Finally, the last section deals with major transportation accidents that might involve any of the major modes of our transportation system.

Overlap Between Infrastructure Problems and Other Sections of the Hazard Analysis

Some specialized forms of infrastructure are addressed in other sections of this document—dam failures appear in the Hydrological Hazards section because they can be a direct cause of flooding. Urban flooding is closely related to failures in the drainage infrastructure, and is included in the Hydrological Hazards section, as part of the Riverine Flooding chapter. Many of the ordinary means that enable weather hazards to be regularly endured (winds, storms, and extreme temperatures) involve the provision of adequate means of safely sheltering and transporting people, goods, and services in spite of such weather events. Storm events are a major cause of infrastructure failures, which then expose people more directly to the severe weather extremes that occur in Michigan's climate. Hail, ice, lightning, and strong winds have all caused breakdowns in electrical supply, for example, which in turn may expose persons to extreme cold or heat. Floods are often prevented through the use of drains and pumps and structures, and a breakdown in the functions of such infrastructure can lead to extensive flood damages.

There are cases in which various industrial accidents and technological hazards might arise from failures in the electrical or water supply system, which may be needed for the maintenance and cooling of complicated processes, and without which some disastrous fire, explosion, or release of hazardous materials might occur. Infrastructure failures may lead to energy shortages, a breakdown in vital health care, transportation, and communication services, thus having not only a costly economic impact but also putting lives at stake. Public health emergencies, in particular, may arise from the effects of a breakdown in sanitation infrastructure, or power failures that cause breakdowns in food supply and preservation chains (refrigeration, processing, and storage conditions). In addition to being able to hinder emergency response capabilities, infrastructure failures can also make it more difficult to maintain the effectiveness of law enforcement services, and thus enable criminal activities (e.g. looting) to increase. Certain types of civil disturbance or terrorism might be more likely to arise in circumstances involving lengthy power failures. Many types of catastrophic incidents would be expected to disrupt energy supplies or infrastructure in some way. Some types of hazards (e.g. earthquakes, space weather) are most likely to cause damage through their effects on Michigan's infrastructure, rather than in direct harm to humans. The space weather hazard in particular (addressed in the chapter on Celestial Impacts) needs to gain new recognition, because satellites have now become a type of critical infrastructure.

Simplified Illustration of Modern Technological Interdependencies



Source: Department of Homeland Security, through the National Academies Press

INFRASTRUCTURE FAILURES

The failure of critical public or private utility infrastructure that results in a temporary loss of essential functions and/or services.

Hazard Description

Michigan's citizens are dependent on public and private utility infrastructure to provide essential life-supporting services such as electric power, heating and air conditioning, water, sewage disposal and treatment, storm drainage, communications, and transportation. When one or more of these independent, yet interrelated systems fail due to disaster or other cause – even for a short period of time – it can have devastating consequences. For example, when power is lost during periods of extreme heat or cold, people can literally die in their homes if immediate mitigation actions are not taken. When the water or wastewater treatment systems in a community are inoperable, serious public health problems can arise that must be addressed immediately to prevent outbreaks of disease. When storm drainage systems fail, due to damage or an overload of capacity, serious flooding can occur.

These are just some examples of the types of infrastructure failures that can occur, and all of these situations can lead to disastrous public health and safety consequences if immediate actions are not taken. Typically, it is the most vulnerable members of society (i.e., the elderly, children, impoverished individuals, and people in poor health) who are the most heavily impacted by an infrastructure failure. If the failure involves more than one system, or is large enough in scope and magnitude, whole communities and possibly even regions can be severely impacted. (Note: Refer to the Dam Failures and Petroleum and Natural Gas Pipeline Accidents sections for more information on those particular types of infrastructure failures.)

Hazard Analysis

Infrastructure failures can affect hundreds of thousands of Michiganders when the conditions are "right" for a loss of critical systems. Melted transformers, ruptured pipes, crumbled bridges, and exploded transformers can cause inconvenience or havoc around the nation and the state, depending on the severity of the problem. The risk of infrastructure failure grows each year, as physical and technological infrastructure gets steadily more complex, and the interdependency between various facets of infrastructure (like pipelines, telecommunications lines, and roads) becomes more intertwined. Additionally, more vulnerable and aging infrastructure (rail lines, electrical components, bridges, roads, sewers, etc.) is in need of repair. Because of these reasons, large-scale disruptions in various components of infrastructure are likely. Major disruptions could lead to widespread economic losses, limit security, and altered ways of life.

Infrastructure failures can occur at any time and in any place in the state of Michigan. The metropolitan areas may be the most susceptible to interruptions in infrastructure, due to the additional volume of critical components of transportation, power, water, and telecommunication networks. Residents of these areas are also less likely to have adequate measures to "get through" infrastructure failures with generators, wood, and fireplaces. Economic losses from incapacitated business and industry are great in these areas. In northern regions of the state, there are fewer networks of infrastructure, but greater geographic areas are affected during infrastructure failures. Downed lines or blocked roads affect many more square miles than a similar occurrence around Detroit, but there are far fewer individuals and businesses at risk.

Although Michigan has in place many codes and standards that govern the design, construction and operation of public and private utility infrastructure, these codes and standards are often inadequate to protect the infrastructure from disaster-related damage. In many cases, the codes and standards call for the minimum level of structural integrity and operational performance recommended in accepted engineering practice, when a higher level would result in less disaster damage. Obviously, a balance must be reached between structural integrity, operational reliability, and short- and long-term costs associated with upgrading facility codes and standards.

It is possible to design and operate facilities that are virtually "disaster-proof." However, in many cases it is not economically feasible to do so. Too extensive of increases in integrity and reliability can result in prohibitive increases in cost. It is often too expensive to upgrade infrastructure codes and standards much beyond their current levels. However, in those cases where recurring, severe damage and system down-time occur due to natural or technological hazard events, it makes sense to explore the possibility of enhancing infrastructure design, construction, and operational codes and standards. The State of Michigan, in concert with public and private utility providers, is in the beginning phases of doing so through its statewide hazard mitigation efforts.

As Michigan's public and private utility infrastructure systems continue to age, infrastructure disasters will undoubtedly become more common. Because many of these systems were developed decades ago, the costs of repairing and replacing aging sections and/or components have greatly increased. As a result, many communities cannot afford to do the maintenance work necessary to keep the system in ideal operational mode. Increasing demands on the systems also lead to increased deterioration, and many components have far exceeded their useful service life. This creates a situation of increasing risk from infrastructure-related disasters, either as a primary event, or as a secondary event from floods, windstorms, snow and ice storms, or other natural or technological hazards. When those disasters do occur, they cause great inconvenience to the affected population and they can also create severe public health and safety concerns. Some urban deterioration includes missing manhole covers, sewer grates, chain link fences, and the occasional disappearance of signs from city streets. This type of issue is found more often in blighted neighborhoods. Cities already lacking in funds are forced to spend time and resources to mark the exposed manholes and sewers with construction barriers before they cause harm to vehicles and pedestrians. Workers also are forced to bolt down the covers and grates of cities' metal coverings.

The national economic downturn that began in 2007 has affected Michigan as much as any other state in the country, having the highest unemployment rate in the nation for many consecutive quarters. There will be less tax revenue, due to people leaving the state, the loss of jobs (particularly within the auto industry), and declines in property values, risking a loss of funding for construction/repairs. Michigan roads also suffer because of the fixed per-gallon gas tax (used to match federal funding and pay for road work) which stays constant, even when the costs of fuel and materials increase. Gas tax, diesel fuel tax, and vehicle registration fees collected in 2008 were the same as the amount collected in 1998. The effects of inflation contribute to a substantial reduction in the amount of (real) funds available for repairs. The 1946 to 1964 baby boom age cohort (defined by the United States Census) is currently approaching retirement age, or has already retired, and many may move to the southern United States for warmer weather, newer infrastructure, etc. which further threatens state tax revenue levels.

According to the Michigan Asset Management Council, the condition of 10,000 miles of Michigan's federal aid eligible roads went from either "good" or "fair" to "poor" between 2004 and 2007. According to the US Census Bureau, Michigan has been ranked in the bottom ten of all states for over 40 years in its level of funding. After a decade of stagnant revenues in road funding, the Michigan Department of Transportation (MDOT) showed an additional 15 percent decline in funding between 2008 and 2011. Another challenge for Michigan's roads and bridges is the annual winter freeze and thaw cycle that causes a continual breakdown of road and bridge surfaces. According to the July 2008 report by the Citizens Advisory Committee on Transportation Funding, Michigan's roads and bridges will require an estimated annual investment of $6.1 billion, which is nearly two times the current funding level, for basic improvements to its road and bridge system.

Transportation Funding Task Force (TF2)

The Transportation Funding Task Force was created in response to Public Act 221 of 2007 (P.A. 221 or Act 221), legislation which passed both the Michigan Senate and House of Representatives with a bipartisan majority and was signed into law in December 2007. The purpose of the Task Force, as defined by P.A. 221, is to "review the adequacy of surface transportation and aeronautics service provision and finance" in Michigan, review strategies for maximizing the returns on transportation investment, and evaluate the potential of alternative strategies to

replace or supplement transportation taxes and fees. A major and consistent focus of the group has been the need to stimulate economic activity and enhance personal mobility.

What the Task Force ultimately determined was that Michigan is approaching a crisis of infrastructure funding caused by the steady erosion of purchasing power, continued inflation in materials costs, and a decline in fuel-tax revenues due to spikes in gas prices, reduced travel, and a slowed economy. The decline in revenues, and a corresponding increase in demand for travel alternatives, has exposed the structural problems within the current mechanisms for transportation finance. For the past several years, the transportation revenue stream has been enhanced with bond revenues to provide a more robust level of investment. As a result, Michigan has made progress, particularly in improving the condition of the most highly used highways and bridges, but that bonding cannot continue without additional revenue.

Based on the information at their disposal, the Task Force could only conclude that much more investment in transportation is absolutely necessary. The Task Force learned that transportation agencies have been relentlessly vigilant in stretching their shrinking revenue. Their efforts may go unnoticed, because cost-cutting measures are designed not to disrupt service or impose on customers. Given the current state of the national economy, there is no guarantee that the federal government will come to Michigan's transportation rescue. Even if they did, Michigan is not in a position to take advantage of new federal funding. 2008 was the last year Michigan had enough state and local matching funds to claim all the federal transportation funding made available to the state. Some local agencies are already unable to make use of all federal transportation funding. In 2010 this became true across all transportation modes. Michigan must increase investment in transportation or past investment will be put at risk, and necessary infrastructure and transportation services will deteriorate.

The National Surface Transportation Policy and Revenue Study Committee recommended that investment in transportation by all levels of government should be at least $225 billion per year, an increase of 161 percent compared to national capital investment today of $86 billion. Michigan may lose up to $1 billion in federal funds each year, if transportation agencies do not have enough revenue to provide the required matching funds. The condition of Michigan's infrastructure would deteriorate, with 30 percent of Michigan roads predicted to decline into poor or fair condition during the next decade. The condition of airport pavement will also decline, with the average airport pavement already needing rehabilitation as of 2012, and crucial aviation safety programs threatened with termination or reduction in scope. Existing local transit services and intercity passenger rail services will be reduced, and intercity bus service to rural areas might be eliminated.

Restoring Michigan's investment in transportation has the potential to accomplish valuable and much needed changes. According the referenced study, the "good" level of investment was predicted to sustain 126,000 Michigan jobs, attract new businesses, and open new global markets for Michigan products and services. It will yield roughly $41 billion in other economic benefits for all sectors of the Michigan economy. For highways, roads and bridges, "good" investment will ensure that the most frequently used roads and bridges remain largely in good condition. For passenger transportation, a "good" investment level will allow transit agencies to begin replacing aging buses with greener, more fuel-efficient vehicles. It is estimated that congestion, poor pavement conditions, and crashes cost Michigan drivers and truckers $7 billion annually in wasted fuel, lost time, vehicle maintenance costs, medical costs, lost productivity, and property damage. Based on economic analysis conducted by the University of Michigan, the Task Force estimates that investment at the "good" level would provide an average Michigan household with an additional $2,000 per year in increased personal income and savings through reduced travel time and vehicle maintenance, and increased safety.

Two recent major engineering studies provide a glimpse of the extent of the infrastructure repair and rebuilding effort required just for Michigan to keep up with current and anticipated demand. The first study, completed by the American Society of Civil Engineers (ASCE) in 2009, found the results listed below.

Michigan's Top Three Infrastructure Concerns as of September 2008

1) Roads
2) Wastewater Infrastructure
3) Bridges

Key Infrastructure Facts

- 38% of Michigan's roads are in poor or mediocre condition, rated the 3rd worst state in the United States.
- In 2005, 39% of Michigan's urban highways were congested, compared to 23% in 2000.
- Michigan Department of Transportation will have a 15% decline in funding between 2008 and 2011.
- Michigan has the 8th worst road system in the nation, based on overall performance.
- Michigan is 6th in the nation in the total cost of road miles needed.
- A total of 23,000 road lane miles will need to be repaired or replaced by 2015, while expected funding will pay for only 876 lane miles, just 4% of what is needed.
- 25% of Michigan's bridges are structurally deficient or functionally obsolete.
- By 2030, unless additional roadway capacity is added, rush hour travel in major urban areas will take up to 50% longer to complete in Michigan.
- Driving on crumbling roads costs Michigan motorists a total of $2.6 billion per year.
- An additional 30% of Michigan roads will decline to fair or poor condition over the next decade.
- Under current funding mechanisms, Michigan stands to lose nearly $1 billion in federal funds each year, because its transportation agencies will not have enough revenue to provide the required matching funds.
- Michigan's drinking water infrastructure needs $11.3 billion over the next 20 years.
- Michigan's wastewater infrastructure needs $6 billion over the next 20 years.
- Michigan Department of Environmental Quality estimates that less than 40% of the State's stormwater infrastructure has even been reviewed for its impact on water quality.
- 52% of Michigan's schools have at least one inadequate building feature.
- There are 84 high hazard dams in Michigan. A high hazard dam is defined as a dam whose failure would cause a loss of life or significant property damage.
- A significant portion of the state's primary water distribution system is nearly 100 years old, with 80% of the city of Detroit's piping system having been installed before 1940.
- In 2007 alone, 26 billion gallons of raw or partially treated sewage spilled into surface waters in the state of Michigan, and 23 billion gallons, or 88% of the state total of sewage spilled into surface waters, were located in Detroit.

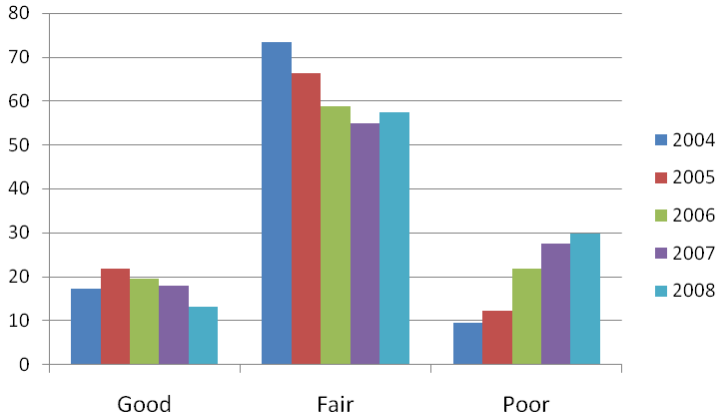
The ASCE study found a common thread nationwide of an increase in demands on public infrastructure without a corresponding increase in funding to perform the necessary maintenance and repairs on facilities, and to rebuild aging or dilapidated facilities.

Another study by the Southeast Michigan Council of Governments (SEMCOG), in 2005, estimated that the costs of replacing aging infrastructure and accommodating new growth in Southeast Michigan will likely top $26 billion over the next three decades, and may go as high as $70 billion when inflation and interest rates are added in. The study estimated that 60-70% of the region's sewers are more than 30 years old and will need extensive repairs or replacement to remain functional. (Nationwide, studies have shown it will cost $1 trillion to fix just the sewer problems alone in the United States over the next two decades.)

The Southeast Michigan Council of Governments (SEMCOG) showed survey data from 2004-2008 that documented a steady decline in the overall pavement condition of the major roads in Southeast Michigan.

Approximately 4,000 miles (10,660 lane miles) of the region's major roads were visually evaluated in 2008. Results of this survey indicate that 13 percent of the road network is in good condition, 57 percent is in fair condition, and 30 percent is in poor condition. SEMCOG also determined that gas tax revenues are declining in both the Federal Highway Trust Fund (HTF) and the Michigan Transportation Fund (MTF) because of higher gas prices causing people to drive less, increases in motor vehicle fuel efficiency and hybrid vehicles, and economic recession.

Road condition trends, 2004-2008, by percent of lane miles

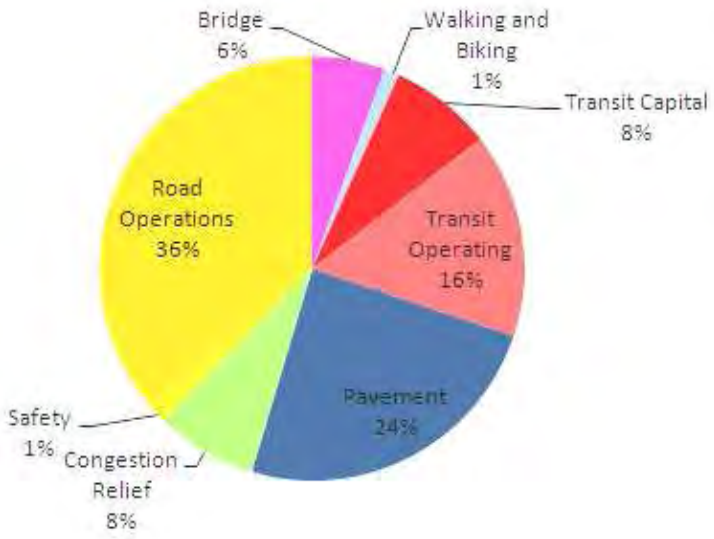


Southeast Michigan Council of Governments (SEMCOG): Direction2035

Direction2035 is the southeast Michigan region's long-range vision for transportation. It demonstrates how the transportation system can lend itself to improving the region overall by contributing to transportation goals, economic recovery, environmental health, community revitalization and stability, and quality of life. It consists of 1,850 transportation projects anticipated over the next 26 years, as well as policies and initiatives to be carried out by both SEMCOG and its partner agencies to keep moving the region in the right direction.

It is estimated that the region would need approximately $2.8 billion per year to address all identified transportation needs; but unfortunately, the region anticipates having only $1.3 billion per year available, a more than a 50 percent shortfall. Direction 2035 shows a need to make sure the region is using its limited funding wisely by addressing the highest priorities first, focusing on preservation of the existing system and implementation of the regional transit vision, and making transportation serve higher regional ideals. Direction 2035 has established the following transportation goals and objectives: enhance accessibility and mobility for all people; enhance accessibility and mobility for freight while maintaining community integrity; strategically improve the transportation infrastructure to enhance community and economic vitality; promote a safe and secure transportation system; and protect the environment, both natural and built.

The mixture of projects is designed to maximize regional goals and improve performance in those areas deemed most important for the region, including bridges, biking and walking facilities, transit, pavement, congestion, and safety. Also, Direction2035 calls for developing a regional transit authority to oversee an advanced transit system, helping local communities become safer and more walkable, coordinating transportation with water and sewer infrastructure needs, and maintaining a high level of security at our borders, ports, and airports. Projects are funded with a variety of federal, state, and local funds.



Michigan is a highly developed state. As such, it is highly dependent on public and private utility systems for the provision of essential life-supporting services, for the movement of people and goods, and for communications and the transmission of information. As a result, the possibility of infrastructure failure must be addressed in every Michigan community through wise system design and community development practices, and through prudent emergency preparedness that takes into account the issues and needs specific to infrastructure failures. In addition, the State of Michigan needs to continue to push for greater system reliability through its infrastructure-related hazard mitigation efforts. Although the problem of infrastructure failure will never be completely eliminated, it can certainly be greatly diminished through proper planning, design, construction, and maintenance practices.

Impact on the Public

Many forms of infrastructure are relied upon by the public, to provide the essential components of a productive modern lifestyle. The supply of fresh water (for drinking, cleaning, washing, cooking, and other uses) may sometimes be interrupted by pipe freezes, breaks, or water main failures. In addition to the need for citizens to find alternative sources of water, there is the potential for certain types of water system failures to allow contaminated water to be delivered and consumed, causing negative public health impacts. Pipe or water main failures may also cause localized damage, erosion, and flooding.

A failure of electric power systems may cause severe problems for persons who rely on medical equipment for their very survival, or for the maintenance of good health. A properly functioning power supply is also essential to maintain the safety of citizens who are working, traveling, attending to domestic matters, or involved in certain types of recreational activities. A sudden power failure may cause (1) traffic lights to stop functioning, (2) traffic patterns to slow dramatically (resulting in traffic jams and delays in emergency response capabilities), (3) interference with important communication networks and needed machinery (including other important infrastructure, such as sewer lift stations and hospital equipment), or (4) sudden darkness when vital operations are taking place or dangerous activities are being performed as a part of people's ordinary occupations and activities. Food storage and safety relies heavily on an ongoing supply of electrical power. A great many community events, business operations, and tourist attractions are similarly reliant upon electrical infrastructure.

Communication systems are vital for emergency response and operations, as well as a great many business functions and personal matters. Failure of communication systems may include (1) an area's mass media (conveying important emergency, health, public awareness, educational, recreational, and economic information), (2) its emergency 9-1-1 systems (allowing residents to quickly call for emergency assistance or to report

hazardous conditions), (3) its land-based and/or cellular telephone systems (inhibiting a great number of valuable communications), (4) the internet (an increasingly important means of communicating and running business operations), or (5) specialized radio communication systems (such as those used by police, EMS, and other vital service networks). The impacts include great inconvenience, lost personal and business opportunities, and various degrees of added risk throughout citizens' lives.

Drainage infrastructure failures may cause normally safe areas to become flood-prone, causing all the impacts of that hazard (described previously), but in locations beyond those that are recognized as floodplain and wetland areas. Often, "urban flooding" is the result, in which the drainage capacities of a built-up area are exceeded, and polluted waters back up into streets, basements, yards, parking areas, etc. This causes transportation and access problems, property damages, potential injuries and ill-health, cleaning costs and inconvenience, and the loss of irreplaceable records, artwork, photos and historic documents, and other personal articles. Another type of potential impact is environmental, when sewage processing capabilities cannot be adequately maintained and result in the deposition of untreated sewage into some part of the local environment, such as an area river.

The impacts of transportation infrastructure failures are dealt with in separate subsections elsewhere in this document, under categories such as transportation accidents, pipeline accidents, and hazardous material releases.

Impact on Public Confidence in State Governance

The failure of water systems, including "boil water" advisories or reports of actual or potential contamination, may have a disgruntling effect on some residents' confidence in government, although this would not necessarily be connected with Michigan state government unless it involves inadequate regulations or oversight of local utility providers. (Many water sources are private rather than public.) Some communities have decided to include water contamination issues as a hazard, in their local hazard mitigation plans.

Failure of the electrical power system would likely be similar to that of a water system in its effect, with some citizens being disgruntled and blaming "government," while others are served by private utilities that may be held responsible instead. So long as a power failure is very short and infrequent, most citizens probably have no problem overlooking it.

Failure of transportation systems, on the other hand, is generally considered to be an area of clear governmental responsibility, although the blame for failures will depend upon what kind of failure had taken place. Road maintenance can have local, state, and federal components. Transportation planning tends to involve both local and regional decisions, overseen by state and federal guidelines and regulations. When the safety of major bridges, highways, airports, and railroads comes into question, significantly more weight tends to be placed upon the role of higher-level (e.g. state and federal) agencies than local ones. A bridge collapse like the one that occurred in Minnesota would be expected to result in substantial amounts of dissatisfaction with government, and that event may have increased general concerns about the adequacy of bridges, nationwide. Otherwise, the public is probably more focused upon road conditions and individual driving behavior, rather than larger-scale transportation-related systems and regulatory issues (e.g. airlines, trains, ferries). Please refer to the Transportation Accidents subsection that follows.

Failure of communication systems is not likely to be extensively connected with confidence in government, due to the number of private firms involved, except where these systems are necessary for efficient emergency response and public warning functions during a hazardous situation.

Drainage and sewage infrastructure is most associated with local/county governments, and any dissatisfaction with the capacity of those systems is likely to be directed toward the appropriate agencies at that level, rather than toward the state and federal government. (Also see the subsections on dam failure and flooding, elsewhere in this document.)

Impact on Responders

Many forms of infrastructure are used by responders before, during, and after an emergency event. A good supply of water is needed for firefighting, and for certain types of hazardous materials response operations. Clean water is also used in the provision of emergency medical care, but special reserves of such water may have to be transported to the response sites (or special staging areas, in larger events), if the local water supply has been damaged or found to be insufficient. Water infrastructure failure may severely impede the normal operation of medical facilities, and may also lead to water contamination that poses the risk of public health emergencies.

Electrical power systems are used in most modern activities, and their failure may severely affect responders' notification, warning, and communications systems during an emergency event. Power failures that affect traffic signals can cause traffic jams that interfere with emergency response. Important equipment may need to be run by generator (or other alternative power sources) and thus cause certain types of operations to become more complicated to stage, and less effective. During nighttime events, extra difficulties may be created by the need to find alternative sources of artificial light, and the difficulties of dealing with looters may also be compounded.

Communication systems are vital for emergency operations and response, but are often very difficult to effectively sustain in an organized fashion during emergency events. An inability to convey messages between responders, officials, and the general public may cause preparedness, response, and recovery operations to be severely handicapped. Alternative means of communication are usually less effective and efficient, involving extra time and effort to be expended by responders who could otherwise be engaged in other productive activities.

Failures in drainage infrastructure may cause normally safe areas to become flood-prone, thus potentially causing flood hazards (described earlier) to interfere with responders' effectiveness, safety, and efficiency. The impacts of transportation failures are dealt with in separate subsections in this document (fog, transportation accidents, etc.)

Impact on the Environment

Public and private utility infrastructure failures can negatively impact the environment, as with wastewater collection and treatment facilities discharging various pollutants, contaminants, and raw sewage into the natural environment. Surface water and groundwater discharge facilities can negatively harm the environment with suspended soil sediments, dissolved chemical substances, or biological material, for example. Sewage disposal systems can back up or overflow, causing basement flooding. When sewage processing capabilities cannot be adequately maintained, it may result in the deposition of untreated sewage into some part of the local environment, such as an area river. Pollutants can lead to the poisoning of aquatic wildlife or the creation of vast dead zones, in receiving lakes and waters where there isn't enough oxygen for marine life to survive.

County and watershed drainage systems, and water conveyance and treatment systems, range from small agricultural drains to massive urban storm and sanitary sewer systems. These can contaminate the environment in the event of an infrastructure failure. Detention and retention basins, dams, flood pumps, irrigation diversions, and erosion control structures are also part of the infrastructure. These facilities vary from rural open channels, with drainage areas of several hundred acres, to large river systems with drainage areas of several hundred square miles.

Electric power and telecommunication facilities and systems can have environmental impacts stemming from tree trimming and clearance, the installation and maintenance of overhead lines, or when placing new distribution systems underground.

Significant Infrastructure Failures

Unfortunately, Michigan has had its share of infrastructure failures, mostly due to the effects of natural disasters such as snow and ice storms, severe cold, windstorms, tornadoes, and floods. Michigan has had numerous widespread and severe electrical power outages, caused mostly by severe weather such as windstorms or ice and

sleet storms. (Note: Refer to those sections for more information on specific events.) Michigan has had several power outages in recent years that left upwards of 500,000 people (roughly 5% of the State's population) without power for periods lasting from several hours to several days at a time. Fortunately, most of those occurred during months when severe cold temperatures were not a problem. If they had occurred during the cold winter months, there certainly would have been a potential for loss of life – especially among the elderly and other more vulnerable members of society.

Significant Infrastructure Failures in Michigan

1978, 1980 Macomb Co., Oakland Co. Sewer Main Collapse

In 1978, and again in 1980, a large sewer main that served nearly 300,000 residential and business users in northern Macomb and Oakland Counties partially collapsed. The collapses were of such magnitude that continued sewer service to 300,000 users was in peril. Fortunately, officials were able to install temporary sleeves within the damaged main until it could be properly repaired. However, in order to relieve the back-pressure and keep basements from filling with sewage, officials were forced to divert millions of gallons of raw sewage into the Clinton River, fouling miles of Lake St. Clair beaches. Eventually, the damaged sections of sewer main were repaired, but this unfortunate incident caused tremendous disruption and environmental damage to the area. It showed how serious a large-scale sewer infrastructure failure in a densely populated area could be.

December 1989 Monroe County Water Supply Infrastructure Failure

The December 15, 1989 water emergency in Monroe was the result of a water intake in Lake Erie being blocked by ice build-up and Zebra Mussel crustaceans. Officials issued water conservation and boil-water advisories, and schools and most large businesses were closed. Local hospitals limited their activity to emergencies only and referred new patients to out-county hospitals. The hospitals operated on bottled water for the duration of the incident. The fire service was also adversely impacted, invoking mutual aid and stationing tankers throughout the city in case a fire occurred. The city eventually completed an emergency hookup with the Toledo, Ohio water system, which helped alleviate most of the water supply problems. The city also had three pumps drawing water from the River Raisin and pumping it to the water treatment facility. Emergency measures continued for three days. By December 18, the flow of water was back to normal. This incident showed how a vast public infrastructure system can be made inoperable – and thousands of people inconvenienced or even imperiled – by something as small as an aquatic mollusk.

July 7, 1991 Electric Power Infrastructure Failure

One of the major electrical blackout events due to storms was on July 7, 1991 when a powerful wind storm affected a large portion of central North America and knocked out power to over 1 million customers from Iowa to Ontario. Almost the entire lower half of the lower penisula of Michigan was affected by the derecho, with wind gusts of 65 to 85 mph. Electrical power was cut off to around 850,000 customers in Michigan alone, which was the largest number of customers to lose power from a single storm up to that time.

November 1992 Lansing Water Supply Infrastructure Failure

A Lansing water emergency occurred on November 15, 1992 when a transformer exploded, causing a power outage to portions of the city. Because a water pumping station was affected, officials were concerned about the loss of pressure and possibility of contamination within the water distribution system (which served Lansing and Delhi Township). Officials issued a boil-water advisory, and bottled water was distributed at four locations in the city. Local hospitals also had to be supplied with bulk supplies of fresh water to meet their normal operational needs. The water emergency was terminated the next day when tests indicated no contamination in the water supply.

Winter of 1993/94 Northern Michigan Water Supply and Sewer Infrastructure Failures

The underground freeze disaster in northern Michigan in 1994 provided an indication of how vulnerable our public water and sewer infrastructure can be to the adverse effects of natural phenomena. Due to a prolonged period of severe cold weather that caused ground frost to greatly increase beyond normal depths, municipal water and sewer systems in ten counties partially failed, disrupting service to over 18,000 homes and businesses and causing over $7 million in infrastructure damage. Some of the homes and businesses were without normal water and sewer service for several weeks. At final count, over 3,200 water and sewer lines had been frozen and/or broken, making this infrastructure failure not only unusual but also unprecedented in U.S. history in terms of scope and magnitude. This disaster showed how vulnerable our underground infrastructure can be when the "right" set of natural conditions occurs. Furthermore, these types of disasters may occur with greater frequency in the future, as our public infrastructure ages and thus becomes more fragile (and since most systems are not built to be "disaster resistant/disaster proof" in the first place).

June 1996 Thumb Area Drainage Infrastructure Failure

The June 1996 flood in the Thumb area, which resulted in a Presidential Disaster Declaration for seven counties, also can be considered an infrastructure disaster due to the severe impact on the drainage system in the region. Because the region's topography is relatively flat, there is extensive use of sub-surface tile and open drainage channels to make the land productive and usable. These drains are critical to the development of the region. Without them, much of the area would become economically useless swampland. The 1996 floods proved just how critical these drainage channels are to the local economy (both agricultural and non-agricultural) and to the citizens of the area. When the drains overflowed, surrounding farm fields were flooded—many for days—killing the crops that had just been planted and preventing further planting and cultivation. In addition, hundreds of culverts were damaged or destroyed and many roads and bridges were washed out, resulting in numerous road closures. The cumulative effects of these events included severe economic losses to both agricultural enterprises and supporting businesses and services. In addition, essential services and daily travel were disrupted, and physical damage to drains, culverts, roads, bridges and other essential facilities resulted in tremendous repair and replacement costs for the affected local jurisdictions.

December 1998 Detroit Natural Gas Infrastructure Failure

Sometimes, failure of one type of utility infrastructure is directly caused by a failure in another type of utility infrastructure. That was the case in Detroit on December 12, 1998, when a 30-inch water main in the downtown area burst, crushing a nearby 12-inch gas main and flooding it with water. Approximately 200,000 gallons of water flooded nearly 20 miles of gas line, shutting down gas service to hundreds of downtown Detroit businesses and residents on both sides of I-375. Officials estimated that 600 buildings (including hotels, offices, restaurants, shops, and residences) were affected by the gas service shutdown. Crews from Michigan Consolidated Gas worked around the clock for the next four days to drain water from the gas lines and hundreds of gas meters, to get gas service restored. Even after restoration was complete, problems and service interruptions continued to plague some structures for several days until more permanent repairs could be made. Michigan Consolidated Gas called the water contamination incident the worst in the company's 150-year history. Economic losses for the affected hotels, restaurants, and other businesses were substantial because the incident occurred during the normally profitable pre-Christmas holiday period.

May 31, 1998 Southern Michigan Electric Power Infrastructure Failure

On May 31, 1998 a derecho with winds averaging 60 to 90 mph (the highest being 130 mph) raced across lower Michigan, causing about 860,000 customers in Michigan to lose electrical power, and around 2 million across the United States. The 860,000 customers became a new historical record in Michigan, slightly exceeding the number of customers that lost power during the Southern Great Lakes Derecho of 1991. Some would not get power back for 10 days. For Consumers Energy utility company, which serves much of western and middle Lower Michigan, this derecho event was considered to be the most destructive weather event in its history.

June 1999 Oakland County Water Supply Infrastructure Failure

On June 7, 1999 a drilling company, hired to relocate fiber optic cable for a new highway interchange, accidentally broke a water main in the city of Auburn Hills, setting off a week-long water emergency that closed hundreds of businesses and schools and forced thousands of residents to boil water, or drink bottled water, until repairs could be made. Local officials estimated that 118,000 residents in over 44,000 households in Auburn Hills, Orion Township, Lake Orion, and Rochester Hills were affected by the water emergency. The crisis forced the closure of several major business enterprises, including the DaimlerChrysler headquarters and technology center, the Palace of Auburn Hills sports arena, and the 200-store Great Lakes Crossing Mall, idling thousands of workers. Businesses outside Oakland County were also affected because of a shortage of parts from suppliers with plants in Auburn Hills and Rochester Hills. Economic losses associated with the water emergency were so extensive that local officials gave up trying to calculate the costs. However, officials estimated that the weeklong ordeal likely caused losses in the tens of millions of dollars.

January 1, 2000 Statewide Y2K – Electric Power Infrastructure Failure

The most anticipated electric power failure in the history of humankind never actually occurred. The much-celebrated year 2000 (commonly known as Y2K) computer conversion crisis was considered by many to be the biggest "non-event" ever. Actually, several years of mitigation and preparedness efforts had paid off on the morning of January 1, 2000, when the electric power grid and other critical public utility systems remained operational – stemming fears that there would be widespread power outages, resource shortages, and economic and social chaos. The electrical grid in Michigan and across the country continued to operate on January 1 and beyond, without so much as a hiccup – a testament to the proactive efforts of the electric power industry.

June and August 2000 Detroit Electric Power Infrastructure Failure

Detroit fell victim to two significant power outages in 2000—one that began on June 13 and lasted for 4 days, and another that occurred from August 31-September 1. The two outages—the third and fourth major power failures in the city since 1991—caused significant disruptions in commerce and city services and (in the midst of impacts from other wind, storm, and flood events) again put the city in a negative national spotlight during a time of crisis.

The June 13-16 outage actually began on June 12, when one of three main lines connecting Detroit Edison to the Detroit Public Lighting Department failed. During the process of repairing the line on June 13, a cable connection failed, setting off a chain reaction that completely disabled the two remaining connections. The resulting outage cut power to 1,250 traffic lights, 42,000 street lights, Detroit Receiving Hospital, four senior housing complexes, all public housing, Detroit City Airport, the Renaissance Center, Wayne State University, Wayne County Community College, the Detroit Institute of Arts, the U. S. District Courthouse, the City-County Building, and most city buildings and schools. Businesses and homes that received electricity directly from Detroit Edison were not affected. The outage affected a total of 4,500 buildings, idled over 167,000 school children, caused significant business and parking revenue losses, and forced the city to pay out millions in overtime costs for city workers. The power outage also left some public schools without their electronic alarm systems, which resulted in four being broken into and vandalized.

The August 31 outage occurred when the Detroit Public Lighting Department cut electrical service to parts of the city (to avoid a widespread outage like the June 13-16 incident) after two generators failed due to high demand caused by hot weather. Power to municipal buildings and services was lost on much of the city's west side, and large portions of the east side, including schools, police stations, street and traffic lights, government offices, hospitals, and Wayne State University. Power was restored the next day. Follow up investigation revealed that a squirrel jumping on an electrical conductor may have caused an explosion at a substation that eventually led to the power failure.

July 2000 Mackinac Island Electric Power Infrastructure Failure

Beginning on July 22, 2000, Mackinac Island began to experience intermittent power outages that escalated into a complete power blackout two days later. The outage continued until July 28, when several large generators were brought to the island by Edison Sault Electric Company to provide temporary power until the island's electrical infrastructure could be repaired. The cause of the outage was later determined to be the overheating of five of the seven underwater cables that provided power to the island from the mainland. The damaged cables were subsequently replaced.

The outage came at the worst possible time for the residents, visitors, and businesses on Mackinac Island—at the height of the tourist season (with more than 35,000 tourists on the island) and during the week of the popular Chicago to Mackinac yacht race. Somehow, the island's businesses and visitors managed to cope, but not without significant inconvenience, additional operating costs, and some loss of revenues.

September 2000 Genesee County Drainage Infrastructure Failure

Heavy rainfall in Genesee County on September 22-23, 2000 caused the Thread Creek to flood and inundated the city of Grand Blanc's storm and sanitary sewer systems, as well as Genesee County's secondary sewer system. The city of Grand Blanc received 4.5 inches of rain in eleven hours, and the resulting flooding damaged nearly 50 homes and businesses. The Governor requested, and received, an SBA Disaster Declaration for this event, making available low-interest disaster loans to affected residents in Genesee County and the contiguous counties of Lapeer, Livingston, Oakland, Saginaw, Shiawassee, and Tuscola.

September 2000 Oakland and Wayne Counties Drainage Infrastructure Failure

On September 10 and 11, 2000, unusually heavy rainfall occurred in southeast Michigan, overwhelming municipal storm drainage systems and causing damage to 130,000 homes and businesses in Wayne and Oakland Counties. The majority of the flooding was due to sewer backups into homes and businesses, caused by short-term power failures at pumping stations, and by the capacity of the stormwater collection system being exceeded. As a result, raw sewage backed up into basements in at least 15 Wayne County communities, creating serious public health and safety concerns and causing widespread property losses. Due to the extensive damage and public health and safety threats, a Governor's Disaster Declaration was granted to Wayne County on September 20. On October 17, a Presidential Major Disaster Declaration was granted to Wayne County, making available disaster assistance to individuals and businesses that had incurred flood damage. On October 27, Oakland County was added to that Major Disaster Declaration.

February 2001 Genesee County Pump Station Failure

On February 14, 2001 a pump station in Genesee County went down for 34 hours, causing 2.5 millions gallons of raw sewage per hour to go into the Swartz Creek and Flint River. A health advisory was issued for high bacterial counts in the water. Power was lost, homes were evacuated, and nearly 1,000 reports were received regarding flooding. About 60 to 100 roads and bridges were temporarily closed and impassible due to the flood waters. There was nearly $2,000,000 in damage from pump station failures.

A total of over $213 million in disaster relief assistance was provided to individuals to pay for temporary housing, to repair flood related damages and replace essential household items, and for other necessary disaster related expenses. An additional $30 million in hazard mitigation assistance was also made available to the state, bringing the total public cost of this disaster to nearly $250 million.

March 2002 Wayne County Emergency Dispatch Failure

A small construction vehicle operated by a waterproofing worker accidentally ruptured a water line in the garage of police headquarters in Detroit. The water drained down into the basement, where it shorted out electricity and the telephone system in the dispatch center and on two other floors. Callers could not get help through the city's 911 police-and-fire dispatch center for more than two hours until a back-up call-in system was activated at Detroit City Airport.

September 2002 Oakland County Water Main Failure

A five foot diameter water main ruptured, lowering pressure to several thousand homes in southern Oakland County. A 20-by-20-foot section of pavement collapsed on 12 Mile Road, in Farmington Hills, as the water washed away the supporting soil. The pavement fell on top of a gas main, forcing the evacuation of a dozen nearby homes. Nearby trees were washed away and several utility poles were destabilized by the rushing water.

February 2003 Western Lower Peninsula Electrical Blackout

A break in a major transmission line caused a 60-mile electrical blackout that stretched over parts of six counties. The break cut electricity to tens of thousands of customers in the counties of Montcalm, Mecosta, Oceana, Newaygo, Muskegon, and northern Kent. The customers included hospitals, retirement homes, and schools. The power outage apparently started in the Croton-Hardy Dam area in Newaygo County. The power line that was cut normally supplies electricity to about 70 substations in the affected counties.

May 5, 2003 Wayne County Underground Explosions

In the City of Detroit, a massive explosion occurred just before noon, sending a couple of heavy manhole covers flying up above the ground in the area of Michigan and Griswold. It was believed that methane gas had leaked from a sewer line and accumulated, until ignited by a spark. Underground line insulation burned under the streets at Shelby and Lafayette. A firefighter who had been parked in a nearby fire truck was injured when the blast shattered the truck's windshield and side window and caused punctured eardrums. The explosions were at least four in number, and some electrical power had to be turned off in the area, in order to extinguish the fire.

August 2003 Northeastern United States Electrical Blackout

On Aug. 14, 2003, most residents of the northeast United States and Ontario were hit by the largest blackout in North America's history. Electricity was cut to 50 million people, bringing darkness to customers from New York to Michigan. Some essential services remained in operation in most of these areas, although backup generation in some cities was not up to the task. The phone systems remained operational in most areas; however, the increased demand by people phoning home left many circuits overloaded. Water systems in several cities lost pressure, forcing boil-water advisories.

Cellular telephones experienced significant service disruptions as their transmission towers were overloaded with a sudden increase in the volume of calls. Television and radio stations mostly remained on the air, with the help of backup generators, or by relaying their broadcasts through the Grimsby transmission towers, which were online throughout the blackout. Most interstate rail transportation in the United States was shut down, and the power outage's impact on international air transportation and financial markets was widespread. Meanwhile, the reliability and vulnerability of all electrical power grids were called into question. Total costs of the blackout have been estimated at between 4 and 10 billion dollars.

May 2004 Macomb County Water Main Failure

On May 18, 2004, a 36-inch water main broke in Macomb Township, leaving thousands of customers without water. It was the fourth time that this same water main had broken in the past four years. The break forced 20 schools to close, and shut down restaurants and other businesses. A boil-water advisory was put into in effect for several days.

July 2004 Marquette County Water Main Failure

One of two pipes, 16 inches in diameter, ruptured lengthwise just inches from the footing of the city's water treatment center. Water gushed out of the city's grid at a rate of 9,000 gallons per minute, drained both of the 500,000 gallon water towers, and eliminated pressure in all 85 miles of city pipeline. Electric service was not interrupted, although the city briefly shut down its power units, which are cooled with water, and reverted to a backup generator. A boil-water advisory was put into effect for several days.

January 2005 Muskegon County Water Main Failure

In January of 2005, most of the residents of the city of Muskegon Heights lost water service for a brief time. The cause of the failure was determined to be a broken water main.

August 2005 Crawford County Water Main Failure

A contractor working in the City of Grayling broke a 10 inch water main, causing a total disruption of water to the city as all well sites had to be shut down. Residents were told to boil water for several days, and water was restored to the city after repairs the next day.

May 3, 2006 Macomb County Underground Explosions

The downtown area was disrupted by underground power line explosions, when an excessive load was placed upon an old power cable. One blast sent a heavy manhole cover shooting through the air, but no injuries were reported from the incident. Persons were evacuated from the downtown area, amidst smoke from the blast. Electricity was restored by the next day, after maintenance crews worked on the problem overnight.

March 2007 Muskegon County Sewer Main Break

On Friday March 2, 2007 a break occurred in a 66 inch underground sewer main in Muskegon Township, resulting in flood damage to several homes and sending 25 million gallons of raw sewage into Muskegon Lake. The county hired crews to repair the ruptured pipe as soon as possible. Around 30 homes had to be evacuated. The county spent $38 million to replace eight and a half miles of underground sewer main.

September 2008 Genesee County Sewage Flooding

A September 13-14, 2008 weekend of pounding rain in Genesee County sent water and sewage flooding into hundreds of area homes and caused large-scale discharges into area rivers. There were over 400 calls of flooding, and water and sewage back ups in basements. There were also concerns about E. Coli bacteria in the water.

December 2008 Genesee County Sewage Spill

Over the weekend of December 27-28, 2008, an estimated 61 million gallons overflowed from a Flint retention pond into the Flint River. This was the county's biggest sewage spill in 2008. The spill was the result of melting snow and heavy rains over the weekend.

January 2009 Gogebic County Water Main Failure

On January 8, 2009, a 16 inch water pipe (a main that supplied the city) cracked due to pipe degradation. All schools in Ironwood were closed. Local health officials issued an advisory to conserve and boil drinking water, due to the water main break. Potable and non-potable water was available through Ironwood

Public Safety for delivery and pickup, and Gogebic Community College was open for assistance as well. Eventually, in the afternoon of January 12, 2009, all water was returned to normal.

December 31, 2010 – January 3, 2011 Wayne County Water Main Failure

Seventeen thousand residents of Highland Park lost running water over the 2011 New Year's weekend. In the early afternoon of December 31, 2010 a key water pump failed in the Highland Park treatment system, and that triggered the backup system, which draws from nearby Lake St. Clair. The inundation of water in the Highland Park system caused a massive rupture, leading to the loss of water pressure throughout the city. Residents were left without water for cooking, cleaning or flushing toilets. Those with water boiler systems lost their heat during the frigid temperatures. Spontaneous protests erupted in front of the city hall that afternoon, as residents became aware of the lack of water. A "boil water alert" was issued, warning residents that the water could be contaminated, and a state of emergency was declared in the city. The public schools were closed on the following Monday to avoid health concerns from the boil water advisory. The crumbling infrastructure throughout the Detroit area is becoming increasingly dangerous to the population, and upgrades or replacements to the system are needed.

February 23, 2011 Kalamazoo County Water Main Failure

A water main leak sent an estimated one million gallons of water flowing into a residential area on the west side of Kalamazoo, causing damage to homes and prompting police to close parts of West Main Street for about four hours. An estimated 40 homes had flooding damage to varying degrees.

June 9-10, 2011 Wayne County Electrical Blackout

Aging power transmission lines failed under the stress of high demand for electricity, due to multiple days of at least 90 degree heat. Some of Detroit's public buildings (including the municipal and court offices, a convention center, and Wayne State University) were blacked out on June 9-10th, 2011. Traffic signals were also blacked out, causing traffic issues, especially during the evening rush hour. The blackout provided a stark reminder of deteriorating infrastructure in a city already struggling to provide basic services.

Bridge Failures

As Michigan's bridge infrastructure systems continue to age, infrastructure disasters will undoubtedly become more common. Because many of these systems were developed decades ago, the costs of repairing and replacing aging sections and components of bridges have greatly increased. As a result, many communities cannot afford to do the maintenance work necessary to keep the system in an ideal operational mode. Michigan is fortunate not to have suffered a major bridge collapse, but many areas in the United States have suffered such catastrophic failures, with casualties. A quarter of Michigan's bridges have been determined to be structurally deficient or functionally obsolete. Preparation for and awareness of a potential failure is important for mitigation purposes, so the following list covers the most significant bridge disasters in the United States (that might similarly occur at some point in Michigan).

Significant Bridge Failures in the United States

December 1967 Point Pleasant, West Virginia Bridge Failure

On December 15, 1967, the Silver Bridge collapsed while it was full of rush-hour traffic, resulting in the death of 46 people. The bridge, constructed in 1928, connected Point Pleasant, West Virginia and Kanauga, Ohio, over the Ohio River. Investigation of the wreckage identified the cause as the failure of a single eye-bar in a suspension chain, due to a small defect 0.1 inch deep. Analysis showed that the bridge was carrying much heavier loads than it had originally been designed for, and that it was poorly maintained.

May 1980 Tampa, Florida Bridge Failure

On May 9, 1980 in Tampa, Florida, during a blinding spring squall, the freighter Summit Venture rammed into the Sunshine Skyway and knocked out a 1,200-foot length of the bridge across the mouth of Tampa Bay. Thirty-five people, most of them in a Greyhound Bus, died as a result of the accident.

October 1989 Oakland, California Bridge Failure

On the afternoon of October 17, 1989, the Cypress Street (Viaduct) Freeway bridge in Oakland, California collapsed as a result of the Loma Prieta earthquake. The braces that held the upper-level to the lower-level broke in two and then fell outward, dropping the upper-level down on top of the lower-level with a force of approximately two million tons. Autos, trucks, and buses were crushed, along with their occupants. The collapse started in the northern sections of the freeway, and like a domino effect, each adjacent section began to collapse in turn. The collapse resulted in 42 fatalities.

September 2001 South Padre Island, Texas Bridge Failure

In the early morning hours of September 15, 2001, four loaded barges crashed into one of the Queen Isabella Causeway's support columns in South Padre Island, Texas, resulting in three 80-foot sections of the bridge falling into the water and leaving a large gap in the roadway. The collapsed sections were near the highest point of the causeway, making it difficult for approaching drivers to notice. Eight people were killed as their cars fell 85 feet into the water. Five vehicles were recovered from the water, along with thirteen survivors.

August 2007 Minneapolis, Minnesota Bridge Failure

On August 1, 2007 the I-35W Mississippi River bridge, a steel truss arch bridge that carried Interstate 35W across the Mississippi River in Minneapolis, collapsed during the evening rush hour. It collapsed into the river and onto the riverbanks beneath, killing 13 people and injuring another 145. The bridge was Minnesota's fifth busiest, carrying 140,000 vehicles daily. The NTSB cited a design flaw as the likely cause of the collapse, and asserted that additional weight on the bridge at the time of the collapse contributed to the failure.

Immediately after the collapse, help came from emergency response mutual aid within the seven-county Minneapolis-Saint Paul metropolitan area, and from charities and volunteers. City and county employees managed the rescue, using post-9/11 techniques and technology that may have saved additional lives. This failure stemmed from a major recent flaw and showed how this could happen in any location in the United States, including Michigan, with its significant number of "structurally deficient" bridges.

Structural Collapse (not terrorist or criminally motivated)

The collapse of part or all of any public or private structure or building is considered a structural failure. The level of damage and severity of the impacts is dependent on factors such as the size of the building, the number of occupants of the building, the time of day, day of week, the type of building use, on-site chemical storage, weather conditions, and the quantity of products stored in the structure. Along with misuse, accidents, and weather-related loads, the causes of failure may be found in deficiencies of design, detailing, material, workmanship, or inspection. Detroit is home to some of the oldest skyscrapers in the nation, with a total of 13 buildings over 300 feet tall that were constructed before 1930. The age of the structure is sometimes not related to the cause of the failure. With the aging of buildings, crumbling, deterioration, and collapse can occur at any height, either in the building's interior or its exterior. Funding is needed to repair several of the older structures. Enforcement of building codes can better guarantee that structures are designed to hold-up under normal conditions. Routine inspection of older structures may alert inspectors to "weak" points and will lessen the probability of a failure.

Physical hazards from electrical equipment, downed electrical lines, fire, explosion, noise, vehicles and heavy equipment, sharp objects, falling objects, hazardous materials, and uneven or unsteady working surfaces are a major cause of fatalities involving building collapses. Chemical and biological hazards can occur as well. The primary biological hazards include blood-borne pathogens and water-borne pathogens that present risks only in the event of direct contact with bodily fluids. Pathogens include bacteria, viruses, or fungi. Water-borne pathogens are organisms transmitted through direct contact with water sources that are most often contaminated with sewage. Blood-borne pathogens are transmissible only when blood or other body fluids from an infected person (living or dead) enter another person.

Fortunately, there has not yet been a major mass-casualty event in Michigan due to a building collapse, or even a partial collapse, but there have been incidents in other parts of the United States that resulted in numerous fatalities, some of which include criminal and terrorist attacks. Below is a list of structural collapses resulting in multiple fatalities from non-criminal and non-terrorist causes.

July 1981 Kansas City, Missouri Walkway Collapse

The Hyatt Regency hotel walkway collapse was a major disaster that occurred on July 17, 1981 in Kansas City, Missouri, killing 114 people and injuring more than 200 others during a tea dance. Approximately 2,000 people had gathered in the atrium to participate in and watch a dance contest. At 7:05 PM, the walkways on the second, third, and fourth floor were packed with visitors as they watched over the active lobby, which was also full of people. The fourth floor bridge was suspended directly over the second floor bridge, with the third floor walkway set off to the side, several meters away from the other two. The connection failed and both walkways crashed—one on top of the other, and then into the lobby below.

The cause of the accident was a flawed design change that doubled the load on the connection between the fourth floor walkway support beams and the tie rods carrying the weight of both walkways. This new design could barely handle the dead load weight of the structure itself, much less the weight of the spectators standing on it. The serious flaws of the revised design were further compounded by the fact that both designs placed the bolts directly in a welded joint between two facing C-channels, the weakest structural point in the box beams. Investigators concluded that the basic problem was a lack of proper communication between stakeholders. In particular, drawings that were only preliminary sketches had been interpreted as finalized drawings. The initial design had been accepted without performing basic calculations that would have revealed its serious flaws.

April 1987 Bridgeport, Connecticut. Building Collapse

On April 23, 1987, 28 construction workers were killed when a 16 story residential project under construction in Bridgeport, Connecticut, collapsed. Its partially erected frame completely collapsed, probably as a result of high concrete stresses on the floor slabs which resulted in cracking and a kind of punch-through failure. It was believed that this accident highlighted the deficiencies of the lift slab construction techniques used at that time.

June 2003 Chicago, Illinois Balcony Collapse

On June 29, 2003 in Chicago, Illinois, the deadliest balcony collapse in United States history occurred. Thirteen people were killed and another 57 were injured when an overcrowded balcony at a party collapsed. The second floor balcony collapsed onto the first floor, which itself collapsed into the basement below (30 foot total drop), carrying a total of around 100 persons between them.

Initial inquiries suggested that the collapse was probably due to overcrowding, but it was ultimately determined that poor construction was to blame. The balcony was one foot wider than codes had permitted, giving it too large an area. The balcony also had inadequate supports, was floored with undersized lengths of wood, and was attached to the walls with screws that were too short. The effects of age on the structure also played a role.

Programs and Initiatives

Following are brief synopses of <u>some</u> of the laws, programs and special initiatives aimed at preventing or greatly reducing the impacts of utility infrastructure failure in Michigan:

State and Federally-Assisted Infrastructure Mitigation Projects

The State of Michigan has been very proactive in its mitigation efforts for public infrastructure. Since 1994 the State has allocated over 32 million in federal Hazard Mitigation Grant Program (HMGP) funds for about 100 projects designed to address vulnerabilities in water, sewer, storm drainage, telecommunications, radio communications, and highway transportation infrastructure. For details, please refer to Attachment C in the 2011 Michigan Hazard Mitigation Plan.

Water Distribution Systems

Michigan's public water supplies are regulated under the Federal Safe Drinking Water Act. The Michigan Department of Environmental Quality, as a primary agency for the Federal government, provides supervision and control of Michigan's public water supplies (including their operation and physical improvements) under the Michigan Safe Drinking Water Act (1976 PA 399).

The Drinking Water and Radiological Protection Division of the MDEQ regulates, through a permit process, the design, construction, and alteration of public water supply systems. Water supply construction must be conducted within the framework of the Michigan Safe Drinking Water Act, as well as the Architecture, Professional Engineering and Land Surveying Act (1937 PA 240, which requires professional engineers to prepare construction documents for water works construction that costs over $15,000). Most communities in Michigan have, in conjunction with the MDEQ, developed water system master plans that conform to the requirements of the Michigan Safe Drinking Water Act. From a hazard mitigation standpoint, this is important because it helps ensure that all new water system construction, and alterations to existing systems, will conform to the minimum standards set in the Act. While not making water infrastructure "disaster-proof," the standards provide at least a basic level of design, structural, and operational integrity to new or renovated portions of a community's water supply system.

Wastewater Collection and Treatment Systems

The Federal Clean Water Act regulates discharge from community wastewater collection and treatment systems. The regulatory aspects of the Act that pertain to municipalities have been delegated to the MDEQ Surface Water Quality Division, for surface water discharge facilities, and the MDEQ Waste Management Division, for groundwater discharge facilities. Authority for the oversight of planning, facility design review, and construction permitting of sewerage systems collection, transportation, and treatment facilities is derived from Part 41 of the Michigan Natural Resources and Environmental Protection Act (1994 PA 451), and Administrative Rules promulgated under the authority of Part 41. The two MDEQ divisions assist local communities with the development and maintenance of their wastewater collection and treatment systems. In addition, they monitor and regulate these systems to ensure that pollution abatement and health conditions are met. Although the regulatory authority vested in the MDEQ is primarily aimed at preventing the pollution of the waters of the state, there are requirements in place under 1994 PA 451 regarding the design, construction, operational integrity, and reliability of wastewater collection and treatment systems.

The U.S. Environmental Protection Agency's (EPA) Technology Transfer Program, the "Recommended Standards for Sewage Works" developed by the Great Lakes-Upper Mississippi River Board of State Sanitary Engineers, and other technical references all provide important technical information to MDEQ personnel about the design and operation of wastewater collection and treatment system components. This information is used extensively by the MDEQ to review designs and operational procedures for the municipal wastewater program. Included within this guidance are basic minimum standards that help ensure an adequate level of structural and operational integrity for wastewater systems.

Surface Drainage Systems

Michigan's first drain laws appeared on the books as Territorial laws, years before Michigan had achieved statehood. After attaining statehood in 1837, the State passed its first drain law in 1839. Since that time, there have been 45 separate acts passed regarding drainage, up to the most recent recodification of drain law in 1956.

Since 1956, the present drain code has been amended over 200 times—an indication of how important and dynamic the issue of drainage continues to be in Michigan.

The Michigan Drain Code provides for the maintenance and improvement of the vast system of intra-county (county) and inter-county drainage facilities. Each drain has a corresponding special assessment district (watershed), a defined route and course, an established length, and is conferred the status of a public corporation with powers of taxation, condemnation, ability to contract, hold, manage and dispose of property, and to sue and be sued. Drainage districts and drains are established by a petition of the affected landowners and/or municipalities. County drains, with a special assessment district entirely within the county, are administered by the locally elected County Drain Commissioner. Inter-county drains, with a special assessment district in more than one county, are administered by a drainage board that consists of the drain commissioners of the affected counties, and is chaired by the Director of the Michigan Department of Agriculture and Rural Development (MDARD) or an MDARD Deputy Director.

The intra-county and inter-county drainage program, administered by county drain commissioners and the MDARD, operates, maintains, and improves water conveyance and treatment systems—ranging from small agricultural drains to large urban storm and sanitary drains. (Note: Some drains are constructed of pipes that range in size from 12 inches in diameter to over 16 feet in diameter, with massive pumping stations that carry storm and/or sanitary sewage and serve thousands of residents. Other drains are open channels or ditches that vary from several feet in width, and being dry during part of the year, to large river channels in excess of 100 feet in width. Floodwater-retarding dams, flood pumps, erosion control structures, storage basins, and wastewater treatment structures are also part of the infrastructure constructed under the Michigan Drain Code.) Statewide, there are over 18,000 established drainage districts with an estimated combined length of over 40,000 miles of channel. These facilities vary from rural agricultural open channels, with drainage areas of several hundred acres, to large river systems with drainage areas of several hundred square miles.

As Michigan's villages, towns, and cities have grown, the drains that were primarily designed to serve agricultural needs have also been used to carry stormwater from municipalities and subdivisions, as well as to serve as outlets for sanitary treatment plants and a variety of other permitted discharges. The operation, maintenance, and improvement of drains in suburban and urban areas now provides for the management of stormwater, combined sanitary overflows, and sanitary sewage collection and treatment. Increasing demands on the drainage system in many areas of the State require that continuous improvements be made to enhance drain capacity and flow characteristics, reduce sedimentation, and improve structural integrity.

The Michigan Drain Code allows for landowners and/or municipalities to petition for the maintenance or improvement of drainage systems. Drain commissioners or drainage boards, in the absence of a petition, are allowed to maintain the drainage systems but are limited by law in the amount of money they are allowed to expend. The maintenance limit is equal to $2,500 per mile of established drain. This amount is generally sufficient for ordinary operations and maintenance, but is inadequate during times of widespread damage such as that which happens during a disaster. Because drainage districts stand on their own, money (or the maintenance limit) cannot be shared between districts. This greatly limits flexibility and can severely constrict drain reconstruction, improvement, and damage mitigation efforts in a post-disaster setting. Efforts are underway to amend the Michigan Drain Code to more adequately address current and anticipated future problems and concerns, and to make it more applicable to modern land development circumstances.

Electrical Systems

Disaster-related damage to electric power facilities and systems is a concern that is being actively addressed by utility companies across the state. DTE, Consumers Energy and other major electric utility companies have active, ongoing programs to improve system reliability and protect facilities from damage by wind, snow and ice, and other hazards. Typically, these programs focus on trimming trees to prevent their encroachment on overhead lines, strengthening vulnerable system components, protecting equipment from lightning strikes, and placing new

distribution systems underground. The Michigan Public Service Commission (MPSC) monitors the reliability of power systems to help minimize the scope and duration of power outages.

Telecommunications Systems

Like electric utility companies, telecommunications companies are concerned with the issue of protecting facilities and systems from disaster-related damage. Major telecommunications companies have programs to improve system reliability and physically protect facilities and system components from wind, snow and ice, and other hazards, using many of the same techniques as the electric utility companies.

Sewage System Overflows/Backups

Public Act 222 of 2001, Government Liability for Sewage Disposal Systems Backup, provides that under certain circumstances, governmental agencies that own or operate sewage disposal systems may be held liable for the overflow or backup of the system (e.g. basement flooding). The Act requires that persons seeking compensation for personal injury or property damage must show that all of the following existed at the time of the event:

- The municipality (at the time of the event) had owned or operated, or directly or indirectly discharged into, the portion of the sewage disposal system that allegedly caused damage or injury.
- The sewage disposal system of the municipality had a construction, design, maintenance, operation, or repair defect.
- The municipality knew, or in the exercise of reasonable diligence should have known, about the defect and failed to take reasonable steps in a reasonable amount of time to repair, correct or remedy the defect.
- The defect must be 50% or more of the cause of the event and the damage or injury.

Michigan Public Service Commission

The goal of the Michigan Public Service Commission is to assure safe and reliable energy, telecommunications, and transportation services at reasonable prices. In January of 2004, the Michigan Public Service Commission adopted new rules that require electricity providers to restore power to customers within 16 hours of a catastrophic event. Under the new guidelines, utility companies also must restore power within eight hours to customers who have lost it, if there is no catastrophic event. If the guidelines are not met, the utilities could face up to $20,000 for the first offense, up to $40,000 for the second violation, and up to $50,000 for a third offense. If companies do not restore power within 16 hours, homeowners will get a $25 credit, paid by the utilities, unless there is a catastrophe. A catastrophe is defined by the commission as severe weather conditions that knock out power to more than 10 percent of a utility company's customers; or when a state of emergency is declared by a local, state or federal government.

On September 1, 2009, the Michigan Public Service Commission completed a document called the Report on Status of Power Quality, to review performance measurements for evaluating the service, quality, reliability, and power plant generating cost efficiency of the electric utilities operating in Michigan.

Protection of Critical Michigan Infrastructure

The EMHSD/MSP spearheaded a statewide effort to identify and compile information on critical infrastructures in Michigan. Partners in this multi-faceted initiative include state agencies, local governments, federal agencies, and key private sector utilities, such as the electric power and communications industries. This multiyear effort is resulting in the development of a comprehensive list of critical public and private sector infrastructures that will provide the basis for subsequent actions designed to reduce the likelihood or potential impacts of a terrorist attack or other homeland security threats.

National Association of Regulatory Utility Commissioners (NARUC)

NARUC is an association representing the State public service commissioners who regulate essential utility services, such as electricity, gas, telecommunications, water, and transportation, throughout the country. As

regulators, the members are charged with protecting the public and ensuring that the rates charged by regulated utilities are fair, just, and reasonable.

U.S. Army Engineer Research and Development Center (ERDC)

The Mission of the Engineer Research and Development Center (ERDC) is to provide scientific knowledge, technology, and expertise in engineering and environmental sciences to support the Armed Forces in their missions. ERDC has a featured service section specifically dealing with infrastructure-related issues, including programs such as the Concrete Technology Information Analysis Center (CTIAC), High-Performance Materials and Systems Selection, Materials Testing Center (MTC); and the Soil Mechanics Information Analysis Center (SMIAC).

ENERGY EMERGENCIES

An actual or potential shortage of gasoline, electrical power, natural gas, fuel oil, or propane—of sufficient magnitude and duration to potentially threaten public health and safety, and/or economic and social stability.

Hazard Description

An adequate energy supply is critical to Michigan's (and the nation's) economic and social well-being. The American economy and lifestyle are dependent on an uninterrupted, reliable, and relatively inexpensive supply of energy that includes gasoline to fuel vehicles, and electricity, natural gas, fuel oil, and propane to operate homes, businesses, and public buildings. Energy emergencies became a serious national issue in the 1970s, when two major "energy crises" exposed America's increasing vulnerability to long term energy disruptions. Americans have always dealt with short term energy disruptions caused by severe weather damage (i.e., downed power lines and poles), broken natural gas and fuel pipelines, and shortages caused by the inability of the energy market to adequately respond to consumer demand and meet needed production levels. However, the Oil Embargo of 1973-74, the natural gas shortage of 1976-77, the 1979 major price increases in oil resulting from the Iranian Revolution, the Gulf War in 1991 (after Iraq invaded Kuwait and destroyed many of its oil fields), and the aftermath of the September 11, 2001 terrorist attacks all forced the country to recognize its vulnerability to energy disruptions. That vulnerability was again exposed during the Great Blackout of 2003, when about 50 million electric customers in the northeast United States lost power due to a power grid malfunction. The oil price increases during 2007 and 2008 pushed American gasoline prices to over $4 a gallon and caused major economic and energy related issues as well.

There are three types of energy emergencies. The first and most frequent type of energy emergency involves physical damages to energy production or distribution facilities, caused by severe storms, tornadoes, floods, earthquakes, or sabotage. Michigan has experienced a number of these short-term energy disruptions in recent history, mostly due to high winds associated with severe thunderstorms, or damage caused by ice storms. While there have been only a few incidents of sabotaged energy systems in this country, networks supporting terrorist activity exist throughout the world and the possibility of more frequent incidents in the United States is always present. This category of energy emergency also covers short-term disruptions caused by human error, accidents or equipment failure, such as the power outages that occurred in Detroit in December 1998 and the Summer of 2000, the Wolverine Pipeline Company pipeline rupture in Jackson County in June 2000, the Mackinac Island power failure in July 2000, and the Great Blackout of 2003 that affected over 50 million energy customers. (Refer to the Infrastructure Failures, Pipeline Accidents, Severe Winds, and Ice/Sleet Storms sections of this document for additional information on short-term energy emergencies caused by weather, accidents, and equipment failure.)

The second type of energy emergency involves a sharp, sudden escalation in energy prices, usually resulting from a curtailment of oil supplies. Michigan experienced this type of energy emergency in the 1970s, due to events in the world oil market, and in 1990, following Iraq's invasion of Kuwait. The winter of 2000/2001 saw a sharp spike in natural gas costs, due to reduced availability. However, many Michigan customers were unaffected, due to a price freeze on Michigan's major gas utilities. When oil reserves in Louisiana were blocked during Hurricane Katrina (August 2005), the effects were felt in Michigan and the Governor issued a State of Energy Emergency due to a gasoline shortage. Since 2001, energy costs for the average U.S. household have more than doubled, and sharply escalating gasoline prices have again strained the budgets of lower and middle class families. The summer of 2008 had the highest oil prices on record, following a dramatic rise in prices from 2007 to 2008, and gasoline prices peaked at more than $4 per gallon. This contributed to the economic downtown beginning in 2007, as well as a move toward more fuel-efficient vehicles.

The third type of energy emergency is a sudden surge in energy demand caused by a national security emergency involving mobilization of U.S. defense forces. National defense, in a time of crisis, will demand an increase in

energy. Although the regulated natural gas and electric utilities have approved state and federal priority allocation systems that are in place, regulatory changes to introduce competition into natural gas and electric markets have not fully addressed how such shortages might be managed once these markets are fully opened.

Michigan uses coal, nuclear power, natural gas, renewable power, petroleum, and hydroelectric power for energy. The following table describes the usage of each type in Michigan, and compared to the rest of the United States.

Types of Energy Used: Michigan vs. U.S

Type	Michigan	U.S.
Coal	62.6%	51.0%
Nuclear	23.3%	20.1%
Natural Gas	10.2%	17.2%
Renewable Power	2.5%	2.1%
Petroleum	0.8%	2.8%
Hydro	0.6%	6.8%

Source: Michigan Public Service Commission

Hazard Analysis

America's early 21st Century energy situation is at a crossroads. Although energy issues came to the forefront in the aftermath of the 1970s "energy crisis," many energy issues still remain to be addressed. There have been tremendous strides in energy efficiency in homes and home appliances, and with automobile fuel efficiency, saving billions of dollars in energy costs, and our dependence on foreign oil imports has been decreasing, now roughly 45% of total oil consumption. World demand for oil is projected to increase 37% over 2006 levels by 2030, according to the 2007 U.S. Energy Information Administration's (EIA) annual report. Cars and trucks are predicted to cause almost 75% of the increase in oil consumption by India and China between 2001 and 2025. Auto sales in China have continued to grow and now match U.S. levels, resulting in part from economic growth rates around 10 percent for many years in a row. Although the Strategic Petroleum Reserve and other mechanisms have been put in place to reduce the negative consequences of another oil embargo or similar supply disruption, the possibility always remains for an event of near-equal magnitude and impact.

Total U.S. energy consumption has increased by more than 28% since the early 1970s – due mostly to relatively healthy economic growth, changes in commuter patterns, and an increase in the use of home and office computers and other electronic devices. In addition, a commuter-oriented lifestyle has also increased in Michigan. However, during that same period, the U.S. share of world energy consumption actually decreased from 31% in the early 1970s to approximately 25% in the late 1990s. In the 1990s, Michigan's total energy consumption grew over 14%. While this growth was slower than overall economic growth in Michigan due to increasing energy efficiency, growing economies have usually required increasing amounts of energy.

On the electric energy front, electric power system restructuring efforts, currently ongoing in Michigan and across the country, may be considered experiments involving increased competition, lower electrical rates, and increased production and reliability. According to the MPSC's Semi-Annual Appraisal of Energy Markets, issued in September 2008, Michigan's peak electrical demand will grow by 1.2% per year for the next 20 years, but this calculation was made before the 2007-2009 recession, which reduced electrical demand. As economic recovery continues, the demand for electricity should rise. This growth requires at least one new power plant by 2015, and at least three more plants built at a similar frequency, if renewable energy mandates and energy conservation measures are not employed. On the natural gas front, increases in the price of natural gas in Michigan and elsewhere, coupled with spot shortages of natural gas, are likely to renew the emphasis on home, commercial, and industrial energy conservation measures for that energy source.

Despite all these efforts, Michigan still remains vulnerable to short-term energy shortages, as was evidenced by the sharp price increases and decreased supply of gasoline caused by the June 2000 pipeline break in Jackson County and Hurricane Katrina in September 2005. Although other factors contributed to the shortages and price increases, the pipeline break again demonstrated our dependence on an uninterrupted energy supply to sustain our economy. The frequent short-term utility outages caused by severe weather, accidents, or equipment failure are another reminder of our dependence on energy in our daily lives. Although we eventually recover from these short-term energy shortages, it often involves considerable inconvenience and expense. The energy shortages faced by California in 2000/2001, in the wake of its electrical deregulation plan, proved that the country is vulnerable to power deficiencies. While California made many mistakes that have not been duplicated in Michigan and elsewhere, its situation again proves how critically important energy is to our national and economic security. In 2003, the Great Northeast Power Blackout provided another example of the vulnerability of our energy supply system in the United States. The late 2000s oil price increases have played a major role in the worst economic recession since the Great Depression, as well as the move for the automakers to build more fuel efficient and electric/hybrid vehicles.

Michigan has an excellent energy emergency planning program through the Michigan Public Service Commission. Many mechanisms have been put in place to reduce the impacts caused by short- and long-term energy disruptions. Indeed, Michigan's position as a major business, agriculture, educational, tourism, and industrial center requires that we continue to do so. However, even with those efforts, the threat of both short and long-term energy emergencies still exists in Michigan, due to our dependence on large-scale energy distribution systems to provide us with power.

Impact on the Public

Energy emergencies could cause the public, including small business owners and self-employed persons, to experience significant financial impacts from higher prices or limited/curtailed energy supplies. Business and commuting costs would be likely to increase temporarily. Persons with special medical needs may have difficulty traveling or otherwise having those needs met.

Impact on Public Confidence in State Governance

Portions of the public tend to infer government control and efficacy over market-related economic aspects of the situation. That is, many persons are unclear in their knowledge about limitations in the government's authority, responsibility, and effectiveness in situations that are substantially defined and shaped by a competitive private sector.

Impact on Responders

Energy emergencies may potentially affect response capabilities, through limitations or shortfalls in resources, and in the amount of expense associated with the use of such resources. A good example could be a shortage of fuel that is needed to operate fire trucks. The budgets of involved agencies may become overburdened. Resources may need to be carefully shared between agencies, or supplemented with special state or federal assistance.

Impact on the Environment

Principal air emissions involve substances that could cause a negative impact on the environment, such as particulate matter, sulfur oxides, nitrogen oxides, hydrocarbons, and carbon monoxide. Each of these pollutants varies in its emission rate and potential opportunities for reduction. Fossil fuel consumption is closely linked to greenhouse gas emissions and therefore climate change. The burning of fossil fuels results in the conversion of carbon to carbon dioxide, which contributes to the atmospheric greenhouse effect and global warming. Nuclear power plants generate radioactive by-products that can be harmful to the environment and must therefore be carefully stored in selected locations. The use of hydroelectric dams can also create negative consequences for aquatic wildlife, such as preventing fish from traveling upstream.

Energy Emergencies Affecting Michigan and Other States

Following are some energy emergencies that occurred in or affected Michigan and other states. Although the term "emergency" is used, it is important to note that not all of these events were officially declared as "emergencies" (e.g., "State of Emergency" or "State of Energy Emergency") under the applicable federal or state statute. However, each event fits one of the classifications outlined above.

Chronology of Energy Emergencies Affecting Michigan and Other States

November 9, 1965 – Northeast United States: "Great Northeast Blackout."

On November 9, 1965, the largest electrical blackout in U.S. history to that time occurred in the Northeastern United States when a single transmission line tripped near Niagara Falls, New York, setting off a series of failures that ultimately left 30 million people without power for as long as 13 hours. The outages occurred throughout New York, Ontario (Canada), most of New England, and parts of New Jersey and Pennsylvania. The lessons learned from this single event changed the way electric utility systems are designed and operated today. In addition, the National Electric Reliability Council – now called the North American Electric Reliability Council (NERC) – was formed in the wake of the 1965 Northeast Blackout to promote the reliability of the electricity supply for North America. (Refer to the Programs and Initiatives section below for more information on the NERC.)

October 1973-March 1974 – Entire United States: Middle East (OPEC) Oil Embargo

In October 1973 the Organization of Petroleum Exporting Countries (OPEC) – a Middle East oil cartel composed of most of the world's major oil producing countries – halted the flow of oil to the United States in retaliation for U.S. support of Israel in the 1973 Arab-Israeli War. From October 1973 to March 1974, OPEC maintained an embargo on oil imports to the United States and other Western nations that supported Israel, causing gasoline shortages and inflated oil prices. The embargo had a particularly negative effect on the U.S. economy and was one of the primary causative factors of the economic recession that plagued the country from 1973 to 1975. The OPEC embargo put the term "energy crisis" in the forefront of the news for months and forced the United States to seriously reevaluate its reliance on foreign oil imports and overall use of energy.

Winter of 1976-77 – Entire United States: Natural Gas Shortage (declared National Energy Emergency)

A natural gas shortage during the bitter winter of 1976-77 forced President Carter to proclaim a national energy emergency on February 2, 1977. President Carter did not mince words in his address to the nation on April 18, 1977 when he declared that combating the energy shortage was the "moral equivalent to war." Carter went on to urge the country to learn to prudently manage its shrinking energy supplies or be faced with potential future disaster. Carter proposed a plan that included strict conservation of fuel supplies, higher prices for oil and natural gas to reduce consumption, penalties for wasteful use of energy, and tax credits for the installation of solar energy devices. Carter also suggested that expansion of nuclear power should be the nation's last resort in seeking solutions to its energy problems. (Fortunately, Michigan was not as seriously affected by this emergency as many other states.)

July 13, 1977 – New York City: Electrical Blackout

On the night of July 13, 1977, New York City and parts of Westchester County to the north were plunged into darkness by an electric power blackout caused when four lightning strikes knocked out vital power lines feeding the city's power grid. Neighboring electric utility companies in New Jersey, New England and Long Island were automatically disconnected from the Con Edison power grid serving the city to prevent damage to their own systems, leaving the city's power grid as an "island" of electricity, separated from all outside sources of generation. (Con Edison is the utility that provides electric service to New York City.) The blackout, which lasted in some neighborhoods for 25 hours, came at a troubled time for New York City, and the reaction of the city's residents to the situation was marked with both resilience and violence. In many areas, neighbors helped neighbors and strangers helped strangers. However, other neighborhoods exploded into violence. Dubbed by some in the media as the "night of terror," the blackout brought out the worst in many of the city's residents as stores were ransacked, looted and destroyed, buildings were set on fire, and cars were stolen. The police, for the most part, could not stop the mayhem. Although they made over 3,700 arrests, most accounts indicate that thousands of perpetrators escaped before being caught. At the height of the blackout, over 1,000 fires burned throughout the city – six times the average rate – while at the same time the fire department was responding to 1,700 false alarms. Ironically, Con Edison had (and still has) one of the most reliable, least interrupted electric power systems in the United States.

March 28, 1979 – Harrisburg, Pennsylvania: Three Mile Island Nuclear Power Plant Accident

On March 28, 1979 the most serious nuclear reactor accident ever to occur at a commercial power plant in the United States occurred at the Three Mile Island nuclear power plant near Harrisburg, Pennsylvania. This incident resulted from a plant malfunction, combined with operator override of automatic safety systems. These errors resulted in a partial meltdown of the reactor core. Utility, state, and local personnel implemented response plans to protect the public in the area around the plant, while onsite efforts were undertaken to cool the reactor and eliminate any possible release of radioactive material. While this accident resulted in no off-site health consequences, it had a major negative impact on the continued development of the nuclear power industry in the United States.

Coincidentally, the Three Mile Island accident occurred two weeks after the release of the movie "The China Syndrome," which portrayed a nuclear reactor disaster. The combination of the movie, the accident, and a jury verdict later that spring against a Kerr-McGee nuclear facility in Oklahoma regarding plant safety raised new doubts in the mind of the public about official assurances of nuclear safety. As a result, support for nuclear power took a severe nosedive. In Michigan, plans by Consumers Power Company (now Consumers Energy Company) to complete a nuclear power plant in Midland were curtailed due to the public perceptions and constantly escalating development costs. Instead, the plant was converted to a natural gas fired facility.

1979-80 – Entire United States: Oil Price Increases

In 1979, the revolt in Iran against the rule of the Shah (dubbed the "Iranian Revolution") reduced world oil production and the OPEC nations announced a 14.5% increase in oil prices. By June 1979, OPEC again raised the average price of a barrel of oil by more than 50%, forcing the price of gasoline and fuel oil for American consumers to skyrocket, creating panic conditions in many parts of the country and causing a nationwide strike by independent truckers. The energy price increases resulted in long lines at gasoline stations, higher inflation, and signaled a reaffirmation of America's energy vulnerability.

During this time, federal price and allocation controls moderated the price increases and caused oil companies to allocate supply. For a period of several months, customers were only able to purchase 70 to 80% of their historical amounts. Under the federal allocation program, states had the authority to direct up to 3% of the monthly gasoline supply to meet the needs of priority users such as police, fire and emergency medical services, in addition to other emergency hardship needs. The State of Michigan redirected over 100 million gallons of gasoline, heating oil, and diesel fuel. The peak of the supply shortfall occurred in May 1979. Longer lasting, and ultimately more serious, was its role in the "double dip" economic recession of 1980 and 1981-1982, in which many lost jobs and manufacturing output was seriously depressed.

In response to the situation, President Carter proposed a plan, delayed by Congress for almost a year, which included conservation of existing fuel supplies, a long-range decrease in foreign oil imports, and the development of new sources of energy. Carter further proposed the deregulation of domestic oil prices in

order to stimulate domestic oil production. However, Carter's deregulation plan didn't work as planned and instead resulted in American oil companies significantly raising gasoline prices. The combination of the higher price levels set by OPEC and the American oil companies caused gasoline and fuel oil prices to nearly double. The start of war between Iran and Iraq in 1980 further boosted oil prices. By the end of 1980, the price of crude oil stood at 19 times what it had been just ten years earlier.

December 1998 – Detroit: Natural Gas Main Failure

On December 12, 1998 in Detroit, a 30-inch water main burst in the downtown area, crushing a nearby 12-inch gas main and flooding it with water. Approximately 200,000 gallons of water flooded nearly 20 miles of gas line, shutting down gas service to hundreds of downtown Detroit businesses and residents on both sides of I-375. Officials estimated that 600 buildings (including hotels, offices, restaurants, shops, and residences) were affected by the gas service shutdown. Crews from Michigan Consolidated Gas worked around the clock for the next four days to drain water from the gas lines and hundreds of gas meters and restore gas service. Even after restoration was complete, problems and service interruptions continued to plague some structures for several days, until more permanent repairs could be made. Michigan Consolidated Gas called the water contamination incident the worst in the company's 150-year history. Economic losses were substantial for the affected hotels, restaurants, and other businesses, because the incident occurred during the normally profitable pre-Christmas holiday period.

1999-2000 – Northeastern United States: Home Heating Oil Shortage

In mid-January 2000, a combination of adverse weather conditions, low heating oil inventories, natural gas capacity and delivery constraints, and production problems created rapid price increases in fuel oil and natural gas markets in the Northeast United States. When colder weather hit, consumers increased their demand for home heating oil and natural gas, and prices rose significantly. The temperature change increased weekly heating requirements by about 40%. Because fuel oil stocks were below normal levels, available supplies were limited and prices responded sharply to the increase in demand. The surge in home heating oil prices lasted for approximately four weeks and then subsided. However, the level and duration of the price increase prompted the President to ask the Secretary of Energy to examine opportunities for converting factories and major users from oil to other fuels, helping to free up oil supplies for use in heating homes. (Michigan also saw increased prices as supply was pulled from the Midwest in response to the higher prices in the Northeast.)

The federal government also took other actions to address the surge in heating fuel prices, including releasing funds from the Low Income Home Energy Assistance Program (LIHEAP) to relieve some of the financial burden to low income households. (Michigan was also a recipient of emergency funding from the LIHEAP.) The most significant action, however, occurred on July 10, 2000 when the Department of Energy established the Northeast Heating Oil Reserve. The reserve is intended to reduce future risks presented by home heating oil shortages from events such as this one. The maximum inventory of heating oil in the reserve will be two million barrels, which should provide relief from weather-related shortages for approximately ten days—the time it takes ships to bring heating oil from the Gulf of Mexico to New York Harbor.

June 2000 – Jackson County: Petroleum Product Pipeline Rupture

On the morning of June 7, 2000 a Wolverine Pipeline Company pipeline ruptured in Jackson County's Blackman Township, releasing 75,000 gallons of gasoline into the environment and forcing the evacuation of more than 500 homes in a one square mile area around the spill. The leak was detected when a drop in pressure was recorded at a metering station along the 80-mile pipeline that runs through Blackman Township from Joliet, Illinois to Detroit.

In addition to causing significant environmental and public safety problems, the spill shut down 30% of the state's gasoline transportation capability for nine days. The ruptured pipeline was capable of carrying approximately seven million gallons of gasoline per day. (This is equivalent to having 467 tanker trucks with a capacity of 9,000 gallons each making daily round trips from Jackson to Detroit.) While the pipeline was being repaired, tanker trucks from several surrounding states were brought in to help make up for the loss of the pipeline. As truck deliveries could not fully replace the pipeline transportation capacity, drivers began falling behind on deliveries and a growing number of gas stations were without one or more grades of gasoline for periods of time. The pipeline was not returned to service until June 17, and then at only 80% of capacity.

The pipeline rupture caused short-term supply problems in Southeast Michigan and, along with other factors, contributed to an increase in gasoline prices from an average of $1.68 per gallon, when the pipeline broke, to over $2.00 per gallon in the ensuing weeks of June. One of the major contributing factors to the shortages and price increases was that Michigan had very low gasoline inventories going into that summer. In some areas of the Midwest, inventories were 13.5% below average in May 2000—their lowest levels since 1981. The closing of the Total Refinery in Alma in December 1999 also contributed to the supply problem. The Alma refinery's capacity of just under one million gallons per day had satisfied approximately 8% of Michigan's average daily gasoline demand. The closing of the refinery increased Michigan's reliance on the Chicago area gasoline markets, thereby increasing the dependence on the Wolverine pipeline. A final contributing factor was a reduction in transportation capacity caused when one of the two barges supplying petroleum products to marine terminals in Traverse City, Cheboygan, and Bay City was in dry dock for repairs. Supply problems in northern Michigan and Bay City were eased once the barge returned to service in early June 2000. All of these factors combined to make gasoline supplies very tight even before the Wolverine pipeline ruptured.

June and August, 2000 – Detroit: Electrical Blackouts

Detroit fell victim to two significant power outages in 2000 – one that began on June 13 and lasted for 4 days, and another that occurred from August 31-September 1. The two outages (the third and fourth major power failures in the city since 1991) caused significant disruptions in commerce and city services and put the city in a negative national spotlight during a time of crisis (winds, storms, and flooding).

The June 13-16 outage actually began on June 12, when one of three main lines connecting Detroit Edison to the Detroit Public Lighting Department failed. During the process of repairing the line on June 13, a cable connection failed, setting off a chain reaction that completely disabled the two remaining connections. The resulting outage cut power to 1,250 traffic lights, 42,000 street lights, Detroit Receiving Hospital, four senior housing complexes, all public housing, Detroit City Airport, the Renaissance Center, Wayne State University, Wayne County Community College, the Detroit Institute of Arts, the U. S. District Courthouse, the City-County Building, and most city buildings and schools. Businesses and homes that received electricity directly from Detroit Edison were not affected. The outage affected a total of 4,500 buildings, idled over 167,000 school children, caused significant business and parking revenue losses, and forced the city to pay out millions in overtime costs for city workers. The power outage also left some public schools without their electronic alarm systems, resulting in four being broken into and vandalized.

The August 31 outage occurred when the Detroit Public Lighting Department cut electrical service to parts of the city (to avoid a widespread outage like the June 13-16 incident) after two generators failed due to high demand caused by hot weather. Power to municipal buildings and services was lost on much of the city's west side and large portions of its east side, including schools, police stations, street and traffic lights, government offices, hospitals, and Wayne State University. Power was restored the next day. Follow up investigation of the cause of the outage revealed that a squirrel jumping on an electrical conductor may have caused an explosion at a substation that eventually led to the power failure.

July 2000 – Mackinac Island: Electrical Blackouts

Beginning on July 22, 2000 Mackinac Island began to experience intermittent power outages that escalated two days later into a complete power blackout. The outage continued until July 28, when several large generators were brought to the island by Edison Sault Electric Company to provide temporary power

until the island's electrical infrastructure could be repaired. The cause of the outage was later determined to be overheating damage to five of the seven underwater cables that provide power to the island from the mainland. The damaged cables were subsequently replaced to mitigate future problems.

The outage came at the worst possible time for the residents, visitors, and businesses on Mackinac Island—at the height of the tourist season (with more than 35,000 tourists on the island) and during the week of the popular Chicago to Mackinac yacht race. Somehow, the island's businesses and visitors managed to cope, but not without significant inconvenience, additional operating costs, and some loss of revenues.

2000-2001 – State of California: Electrical Blackouts

The energy deregulation efforts in California which began in 1996 took a nasty turn in late 2000 and early 2001 when the state began to experience power shortages and blackouts caused by the state's inability to purchase sufficient electric power supplies to satisfy demand. The blackouts often affected hundreds of thousands of customers at a time and created havoc for homeowners, business and industry, schools, banks, television stations, traffic control systems, and other major electrical users. The root cause of the energy emergency was the way in which California had designed and administered its deregulation plan in the first place. Under the plan, private utilities in the state had to sell their power plants and buy electricity on the open market, an approach that supposedly would result in lower electrical rates. However, the state's two largest private utilities—Pacific Gas and Electric Company and Southern California Edison—had lost at least $10 billion because of soaring wholesale prices for electricity and because rate caps imposed under deregulation had prevented them from passing those costs on to customers. As a result, both utilities were consistently short on power, as well as cash to pay their bills, and teetered on bankruptcy.

California's rapid growth in the 1990s (13.8%), coupled with the fact that no new power plants had been built since the mid-1980s, also contributed to the energy emergency. Had there been a glut of electricity on the West Coast, California's plan might well have worked as planned. Since there wasn't, the state's utilities had to compete for scarce, expensive power on the open market and then were not able to pass the extra costs on to customers.

Recognizing the seriousness of the situation, California's Governor declared a "state of emergency" in January 2001 and ordered the state Water Resources Department to temporarily buy up to $1 billion in power from electric wholesalers and provide it to the two utilities, to prevent continued blackouts. The Governor also signed a bill to amend the requirement that utilities sell their power plants under the state's deregulation plan.

California's energy deregulation experience provides an example of how problematic deregulation efforts can be if not properly designed and implemented. This has ramifications for states that have energy deregulation plans. In 2000, the Michigan Legislature passed the Michigan Customer Choice and Electricity Reliability Act and its companion Securitization Act (141 and 142 PA 2000). The two laws restructured Michigan's electric power supply system and gave the state's 3 million electrical customers the option of choosing their electricity supplier by January 1, 2002. Unlike California's plan, however, Michigan's deregulation plan does not impose strict rules on where the state's major utilities can purchase the power they sell. In addition, Michigan has a number of power plants that have been recently completed or are under construction.

December 2000 – State of Michigan: Propane Supply Problems

Going into the Winter of 2000-2001, propane supplies were very tight and inventories were low. In the Midwest, propane inventories in mid-October 2000 were 44% below the levels of one year earlier. In December 2000, the state experienced record cold weather. Heating degree-days showed that temperatures were 27 degrees colder than normal—the second coldest December on record and the snowiest on record. The propane industry found it increasingly difficult to maintain deliveries in light of the high levels of demand. In response to industry requests and in view of the heavy snows and very cold weather, the Chair of the Michigan Public Service Commission, in consultation with the Emergency Management and Homeland Security Division of the Michigan State Police, requested a 10-day waiver of limits on driver hour restrictions from the Regional Administrator of the Federal Motor Carrier Safety Administration. Waivers were granted for Michigan (and also Indiana, at their request). The extremely tight supply, coupled with additional demand to use propane as a substitute for natural gas (which also had a sharp run-up in prices), caused residential propane prices to reach a record high in Michigan of $1.76 per gallon in January 2001 before declining to $1.00 per gallon by the end of the heating season. A significant warming trend in January allowed the industry time to replace seriously depleted supplies. Had this not occurred, the situation could have become much more serious.

August 2003 – Northeastern United States Electrical Blackout

On Aug. 14, 2003, much of the northeast United States and Ontario was hit by the largest blackout in North America's history, exceeding the Great Northeast Blackout of 1965. Electricity was lost by 50 million people, bringing darkness to customers from New York to Michigan. Some essential services remained in operation in most of these areas, although backup generation in some cities was not up to the task. The phone systems remained operational in most areas, but the increased demand by people phoning home left many circuits overloaded. Water systems in several cities lost pressure, forcing boil-water advisories. Cellular telephones experienced significant service disruptions as cellular transmission towers were overloaded with a sudden increase in the volume of calls. Television and radio stations mostly remained on the air with the help of backup generators, or by relaying their broadcasts through Grimsby transmission towers, which were online throughout the blackout. Most interstate rail transportation in the United States was shut down, and the power outage's impact on international air transportation and financial markets was widespread. Meanwhile, the reliability and vulnerability of all electrical power grids was called into question.

On November 19, 2003, the U.S.-Canada Power System Outage Task Force released an interim report placing the cause of the blackout on First Energy Corporation's failure to trim trees in part of its Ohio service area. The report said that a generating plant in the Cleveland, Ohio, area went off-line amid high electrical demand, and strained high-voltage power lines that later went out of service when they came in contact with overgrown trees. The report also found that First Energy did not take remedial action or warn other control centers until it was too late, because of a bug in the Unix-based General Electric Energy's XA/21 system that prevented alarms from showing on their control system, and they had inadequate staff to detect and correct the software bug. The cascading effect that resulted ultimately forced the shutdown of more than 100 power plants.

August 2005 – State of Michigan: Petroleum Product Supply Problems

On August 31, 2005, Governor Granholm issued three executive orders to address the energy-related issues in Michigan caused by Hurricane Katrina. The massive hurricane had blocked off oil refineries stationed in Louisiana and affected the supply in Michigan. Executive Order 2005-16 declared a State of Energy Emergency in accordance with 1982 PA 191. Executive Order 2005-17 temporarily waived regulations relating to motor carriers and drivers transporting gasoline, diesel fuel, and jet fuel. Executive Order 2005-18 provided for a temporary suspension of rules for gasoline vapor pressure. The State of Energy Emergency was in effect until November 29, 2005.

Winter of 2005-2006 – United States: Natural Gas Price Increases

During the winter of 2005-2006, Michigan saw record-high natural gas prices. Eighty percent of Michigan homes rely on natural gas as their primary heating source, and Michigan's average monthly residential heating bill from November to March increased from $128 a month the previous winter to $180 during 2005 and 2006. The reason for the high prices was largely due to both the lingering effects of Hurricane Ivan, in 2004, and 2005's Hurricanes Katrina and Rita. Substantial disruption of natural gas production in the Gulf of Mexico had reduced supply, driving up prices. There was further uncertainty about the prospect of even higher prices, depending on how long it might take to return natural gas production from the Gulf of Mexico to normal levels. Fortunately, prices did go down, averaging $152 a month for the 2006-2007 winter and the 2007-2008 winter. (Refer to the Natural Gas Prices Monthly Average table from 2000-2009 for further details.)

2007-2008 – United States: Oil Price Increases

Crude oil prices reached an all-time high in Michigan in July-September 2008. During 2003, the price rose above $30 a barrel in the peak summer months, and reached $60 a barrel by August 2005 nationally. The dramatic rise in oil prices began in March of 2007, with a steady increase that included little break during the 2007-2008 winter's traditional low point. March of 2008 started a very large increase in oil prices, at just over $80 a barrel, then clearing $100 a barrel in May, and finally peaking at $147 a barrel in July 2008. Following the July peak, oil prices then took a dramatic dive, and by November 2008 returned to just under $40 a barrel, the lowest level since March 2005. (Refer to the Oil Price, January 2003-December 2008 table for further details.) The increase in prices led to gasoline prices of over $4 a gallon during the summer of 2008. Commentators attributed these price increases to many factors, including reports from the United States Department of Energy and others, the decline in petroleum reserves, concern about high demand for oil, Middle East tension, and oil price speculation. Also, deferred maintenance on refineries that escaped hurricane damage led to an increase in fires and accidents in 2007 and disrupted supplies. A reduction in routine refinery maintenance was made necessary by the need to operate near full capacity, to make up for a loss in refinery capacity from the 2005 Atlantic hurricane season. In 2008, Hurricane Ike played a role in the price spike. Rising demand from U.S. consumers had stretched refinery capacity to the limit and made the whole system more vulnerable to disruptions.

Winter of 2008-2009 – United States Natural Gas Price Increases

During the winter of 2008 and 2009, Michigan saw nearly record high natural gas prices, similar to that of the 2005-2006 winter. State regulators attributed higher heating costs to the increased price of crude oil. Regulators said Michigan fared better than other states because Michigan stores some natural gas in underground tanks. The economic recession's higher unemployment rate, combined with higher heating costs, caused utility companies to shut off more power or natural gas because of unpaid bills. The number of gas shutoffs were up 39 percent in Michigan. (Refer to the Natural Gas Prices Monthly Average table at the end of this chapter for further details.)

Programs and Initiatives

The federal government has put into place a significant legislative and programmatic infrastructure, with and through the state governments, to address energy emergencies. Following are some of the more important components of that infrastructure:

Department of Energy Organization Act of 1977

The energy crisis of the 1970s demonstrated the need for a unified energy organization at the federal level. The Department of Energy Organization Act of 1977 (P.L. 95-91) brought the federal government's various energy agencies and programs into a single agency. The Department of Energy, established on October 1, 1977, assumed the responsibilities of the Federal Energy Administration, the Energy Research and Development Administration, the Federal Power Commission, and parts and programs of several other agencies. The Department of Energy coordinates and administers the federal government's energy functions, including research and development of energy technology, federal power marketing, energy conservation, the nuclear weapons program, energy regulatory programs, and a central energy data collection and analysis program.

Strategic Petroleum Reserve

America's "first line of defense" against a cutoff in oil supplies is the Strategic Petroleum Reserve (SPR) – an emergency supply of crude oil stored in huge underground salt caverns along the Gulf of Mexico. As of November 2010, the Strategic Petroleum Reserve had an inventory of 726 million barrels. This equates to 34 days of oil, at current daily US consumption levels of 21 million barrels a day. This system currently has the capacity to hold 727 million barrels. It is the largest emergency oil stockpile in the world, representing a $20 billion national investment in product and facilities. The total value of the crude in the SPR is approximately $66 billion. The price paid for the oil is $20.1 billion (an average of $28.42 per barrel).

The need for a national oil storage reserve was first recognized in the early 1940s. However, it took the 1973-74 OPEC oil embargo and the economic shock waves that followed to finally get the SPR established. President Ford set the SPR into motion when he signed the Energy Policy and Conservation Act (P.L. 94-163) on December 22, 1975. The legislation set forth a U.S. policy to establish a reserve of up to one billion barrels of petroleum. In July of 1977, the first oil was delivered to the SPR.

The Strategic Petroleum Reserve reduces the nation's vulnerability to the economic, national security, and foreign policy consequences of petroleum supply interruptions, such as was experienced in 1973-74. Decisions to withdraw crude oil from the SPR during an energy emergency are made by the President under the authorization of the Energy Policy and Conservation Act. In the event of an energy emergency, SPR oil would be distributed by competitive sale. The value of the SPR was tested in 1991, when President Bush ordered the first ever emergency drawdown of the SPR to dampen oil price hikes during the Persian Gulf War. The U.S. government's stated

policy to withdraw oil early in a potential energy supply emergency makes the SPR a significant deterrent to oil import cutoffs, and a key tool of foreign policy.

National Energy Act of 1978

President Carter's goal of a comprehensive national energy program was achieved, at least in part, with the passage of the National Energy Act of 1978, which consisted of several separate pieces of legislation. The National Energy Conservation Policy Act (P.L. 95-619) set standards and provided financing for energy conservation in public and private buildings. The Power Plant and Industrial Fuel Use Act (P.L. 95-620) encouraged the transition from oil and gas to coal, in industrial and power plant boilers. The Public Utilities Regulatory Policies Act (P.L. 95-617) provided Congress with authority over the interstate transmission of electric power. The Natural Gas Policy Act (P.L. 95-621) unified the natural gas market and promoted the deregulation of the natural gas industry. The Energy Tax Act (P.L. 95-618) approved tax credits for the installation of solar, wind, and geothermal energy devices to promote energy conservation.

State Energy Conservation Program Improvement Act of 1990

Under the State Energy Conservation Program Improvement Act of 1990 (P.L. 101-440), states are required to submit to the U.S. Department of Energy an energy supply emergency planning program, consistent with applicable federal and state laws. The contingency plan provided by this program must include an implementation strategy or strategies (including regional coordination) for dealing with energy emergencies. In Michigan, this energy emergency planning requirement falls under the purview of the Michigan Public Service Commission (MPSC), an agency within the Michigan Department of Licensing and Regulatory Affairs. (See "Michigan Public Service Commission Energy Emergency Program" below for additional information.)

Michigan Public Service Commission Energy Emergency Program

The Michigan Public Service Commission (MPSC) is responsible for energy emergency planning and response in Michigan. The three MPSC divisions that are involved in energy emergency planning and response activities are the Management Services Division, the Regulated Energy Division, and the Operations and Wholesale Markets Division. The energy emergency responsibilities of these divisions can be grouped into four broad categories:

- Monitor Michigan's energy supply system for the purpose of detecting unusual imbalances that may indicate the potential for an energy emergency, and advise the appropriate state officials of such events.
- Develop, administer, and coordinate energy emergency contingency plans.
- Act as the communications focal point for federal, state, and local activities related to energy emergency planning and management.
- Maintain ongoing contact with the petroleum, natural gas, and electric industries concerning Michigan's energy situation.

In the event of an energy emergency, or in anticipation of such an emergency, the Chairman of the MPSC may consult with or convene and chair the MPSC Energy Emergency Management Team (EEMT), which consists of senior MPSC staff. The EEMT will monitor developments, prepare assessments, and develop responses. The MPSC Chairman will be responsible for consulting with or convening the EEMT, assigning tasks to its members, and providing information developed by the EEMT to the Governor. In general, the EEMT's responsibilities include the monitoring of developments, preparation of assessments, and implementation of responses on a day-to-day basis.

Pursuant to 1982 PA 191 (The Declaration of State of Energy Emergency Act), the Governor may declare a State of Energy Emergency and order mandatory energy conservation actions following such a declaration. (See below for more information on 1982 PA 191.) In addition to declaring a State of Energy Emergency, the Governor may also declare a State of Emergency or State of Disaster under 1976 PA 390, as amended (The Michigan Emergency Management Act), and direct necessary actions through the Emergency Management and Homeland Security Division, of the Michigan Department of State Police. In that scenario, the MPSC plays a supporting role with situation monitoring, communications, and other activities. If a national energy emergency occurs, the MPSC is

the primary coordinating agency with the U.S. Department of Energy's Office of Emergency Operations—the federal agency responsible for national contingency planning and response in the event of a nationwide energy shortage.

Public Act 295 of 2008

The Act promotes the development of clean and renewable energy and energy optimization through the implementation of standards that will cost-effectively provide greater energy security and diversify the energy resources used to meet consumers' needs. The Act encourages private investment in renewable energy, energy efficiency, and the improvement of air quality. Michigan Public Service Commission Temporary Order U-15800 was approved to implement the Act. It outlined formats for renewable energy plans, provided guidelines for requests for proposals (for gas and electric suppliers covered by plans), and addressed energy optimization plan implementation issues.

State Emergency Relief (SER)

The State Emergency Relief (SER) program provides a wide range of energy-related emergency services. The cost for SER energy services is covered with state and other federal funds. The SER program is administered by the Department of Human Services (DHS). An application is needed to request assistance and an appointment is generally required. Eligibility for SER energy services is based on a household's demonstration of immediate need for assistance with home heating fuel, electricity, or energy-related home repairs. This may involve a declared need for a deliverable fuel (such as fuel oil, liquid propane, gas, wood, or coal), presentation of a shut-off notice for natural gas or electricity, or a verified need for an energy-related home repair. In addition to immediate need, SER energy services eligibility is based on income to be received in the 30-day period following application. All households will have their income compared to the SER Income Need Standard that estimates the costs of shelter, heat, utilities, personal and incidental needs.

Energy Emergency Plans / Procedures

The MPSC develops and maintains three emergency procedure manuals for responding to energy emergencies pertaining to electricity, natural gas, and petroleum. (It is important to note that these three plans do not fully cover the wide range of events that could create an energy emergency in Michigan. For example, events involving military mobilization are not covered, nor are plans for responding to shortages of propane or fuel oil for residential users. If emergencies were to occur in those areas, the MPSC and other relevant state agencies would develop additional response actions as needed.)

The Michigan Motor Fuels Shortage Response Plan outlines a series of options that could be considered if Michigan is faced with a serious gasoline shortage, including measures designed to manage limited supplies and to reduce the demand for gasoline.

The Michigan Emergency Electrical Procedures consists of three sets of procedures for dealing with electricity shortages, each appropriate to a particular situation. The first set addresses *sudden or unanticipated short-term capacity shortages*, such as those experienced in the aftermath of severe weather that damages electrical production or distribution facilities. The second set addresses *anticipated or predictable short-term capacity shortages*, such as those experienced during short-duration periods of hot weather when system demand is expected to exceed capacity. The third set addresses *long-term capacity shortages*, when it becomes necessary to live with a reduced supply for an extended period of time (more than a week).

The Michigan Natural Gas Procedures Manual outline procedures for addressing a long-term national gas shortage or an isolated disruption within the transmission or distribution systems.

State Energy Emergency Response

As indicated above, the Chairperson of the MPSC may convene the MPSC's internal Energy Emergency Management Team (EEMT) to coordinate response to an actual or anticipated energy emergency. Energy emergencies involving petroleum products, electricity, and natural gas supplies require specific actions unique to

each. However, the MPSC has developed a series of response actions that are the same regardless of the energy source involved. The MPSC response to an energy emergency can be described in four phases, each phase specifying an appropriate level of mobilization to address a potential or developing emergency situation:

MPSC Response Phases

Phase I – Monitor and Alert

- Monitor/forecast supply, demand, and price.
- Alert of incipient problems.

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Phase II – Assess and Decide

- Assess the magnitude and implications of an emergency.
- Increase monitoring of the affected system/region.
- Evaluate available programs to deal with the emergency in economic, technical, and social terms.
- Select an appropriate program of response.

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Phase III – Action and Feedback

- Implement emergency programs.
- Continue monitoring.
- Evaluate output to determine if the contingency plan is successful.
- Initiate remedial action to plan, if required.

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Phase IV – Review and Lessons Learned

- Phase-out of emergency operations.
- Prepare after-action reports and conduct special analyses.
- Revise plans, if necessary.
- Resume routine monitoring.

Energy Supply Monitoring

Understanding and responding appropriately to an energy emergency depends on the availability of quantified information. For that reason, the MPSC monitors energy supplies and demand as a part of its emergency preparedness program. The MPSC tracks energy developments affecting Michigan, the region, and the nation through industry contacts, the DOE Energy Information Administration, the Internet, trade publications, and various statistical reports.

Historical and forecast data are published by the MPSC semi-annually in the *Michigan Energy Appraisal*, which provides an overview of the balance between energy supply and demand in Michigan and across the region. In the event of an actual or anticipated energy emergency, special updates to this basic publication can be issued to the EAC and MPSC EEMT as required to aid in decision-making during the response effort.

Public Information and Crisis Communications

As part of its energy emergency planning program, the MPSC maintains a public information program designed to help prevent confusion and uncertainty as well as enlist the support and cooperation of the public during an actual or anticipated energy emergency. The public information program is implemented at the discretion of the Governor and Chairperson of the MPSC at such time as a government response (whether voluntary or mandatory) is required. The public information program will provide the public with two basic sets of information: 1) an educational campaign to inform citizens about ways to minimize their use of energy and the inconvenience resulting from a disruption; and 2) an informational campaign to provide clear and concise information on the problems, and the steps being taken in response. In accordance with the Michigan Emergency Management Plan (MEMP), public information activities will be coordinated through a state Joint Public Information Team (JPIT) and Joint Public Information Center (JPIC).

Michigan Customer Choice and Electrical Reliability Act of 2000

Signed into law on June 3, 2000, the Michigan Customer Choice and Electrical Reliability Act (141 PA 2000) and its companion Securitization Act (2000 PA 142) heralded a new era of electrical energy restructuring in Michigan. The two laws cut electric rates for residential customers by 5%, imposed a 2 to 4 year rate cap for residential, commercial and industrial customers, created more competition among electrical suppliers, and increased electrical generation and reliability of the power supply. Acts 141 and 142 provided the foundation that allowed Michigan to restructure and deregulate its electric power supply system.

North American Electric Reliability Council (NERC)

The NERC was originally created in 1968, in the aftermath of the Great Northeast Blackout of 1965, as the National Electric Reliability Council, and was renamed the North American Electric Reliability Council. The North American Electric Reliability Corporation (NERC), was formed on March 28, 2006 as the successor to the North American Electric Reliability Council (NERC). This association is composed of eight separate regional electric reliability councils. The purpose of the NERC is to ensure that electric utilities and other electricity suppliers work together to develop and maintain an adequate electric supply to meet the country’s needs. NERC's primary responsibilities include working with stakeholders to develop standards for power system operation, monitoring and enforcing compliance with those standards, assessing resource adequacy, and providing educational and training resources as part of an accreditation program to ensure that power system operators remain qualified and proficient. The NERC and its regional reliability councils do this by reviewing past practices for lessons learned, monitoring present practices for compliance with applicable policies, criteria, standards, principles and guidelines, and assessing the future reliability of the nation’s electric systems.

North American Electric Reliability Council

Map of Electrical Regions

<u>The Declaration of a State of Energy Emergency Act of 1982</u>

The Declaration of a State of Energy Emergency Act (1982 PA 191) provides the Governor with the authority to declare a State of Energy Emergency to formulate an appropriate state response to an actual or anticipated energy emergency. The Governor may declare a State of Energy Emergency which remains in effect for the duration of the emergency or for 90 days, whichever is shorter. The State of Energy Emergency may be extended upon the approval of the Michigan Legislature, and it may be terminated by a majority vote of both houses of the Legislature.

When a State of Energy Emergency declaration is in effect, the Governor is authorized to:

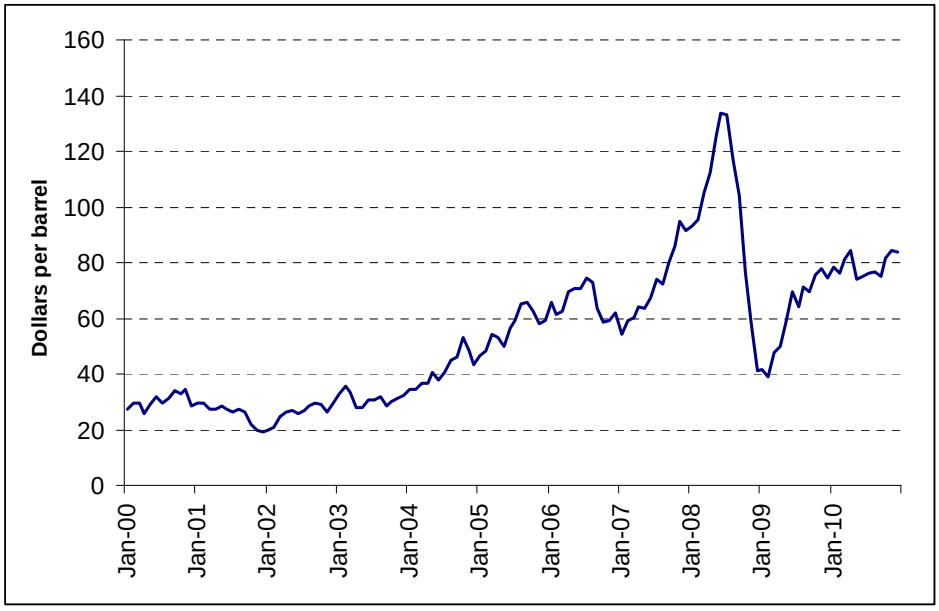
1. Order specific restrictions on the use and sale of energy resources, which may include:
   - Restrictions on the interior temperature of buildings.
   - Restrictions on the hours and days during which buildings may be open.
   - Restrictions on the conditions under which energy resources may be sold.
   - Restrictions on lighting levels and the use of display and decorative lighting.
   - Restrictions on the use of privately owned vehicles, or a reduction in speed limits.
   - Restrictions on the use of public transportation, including directions to close a public transportation facility.
   - Restrictions on the use of pupil transportation programs operated by public schools.

2. Direct an energy resource supplier to provide an energy resource to a health facility; school; public utility; public transit authority; fire or police station or vehicle; newspaper or television or radio station (for the purpose

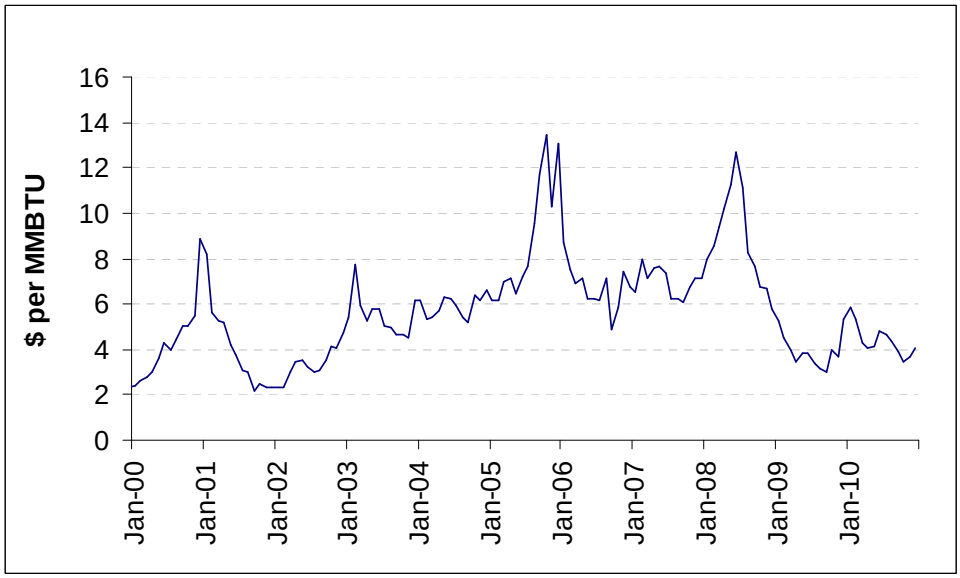
of relaying emergency instructions or other emergency message); food producer, processor, retailer or wholesaler; and to any other person or facility which provides essential services for the health, safety, and welfare of Michigan residents.

3. By Executive Order, suspend a statute or an order or rule of a state agency, or a specific provision of a statute, rule, or order, if strict compliance with the statute, rule, or order, or a specific provision of the statute, rule, or order will prevent, hinder, or delay necessary action in coping with the energy emergency.

West Texas Intermediate Crude Oil Price
January 2000 – December 2010
(U.S. EIA Short Term Energy Outlook)



Natural Gas Prices (Monthly Average, 2000-2010)
(Henry Hub pricing point)



Midwest Energy Consumption Patterns

NOTE: Energy Market Maps, Energy Infrastructure Maps, and Renewable Energy Maps were no longer provided publicly on the Energy Information Administration (EIA) web site, for national security reasons, and thus are not included in this document.

TRANSPORTATION ACCIDENTS

A crash or accident involving an air, land, or water-based commercial passenger carrier.

Hazard Description

Air Transportation Accidents

There are four circumstances that can result in an air transportation accident: 1) an airliner colliding with another aircraft in the air; 2) an airliner crashing while in the cruise phase of a flight due to mechanical problems, sabotage, or other cause; 3) an airliner crashing while in the takeoff or landing phases of a flight; or 4) two or more airliners colliding with one another on the ground during staging or taxi operations. When responding to any of these types of air transportation accidents, emergency personnel may be confronted with a number of problems, including: 1) suppressing fires; 2) rescuing and providing emergency first aid for survivors; 3) establishing mortuary facilities for victims; 4) detecting the presence of explosive, radioactive, or other hazardous materials; and 5) providing for crash site security, crowd and traffic control, and protection of evidence.

Major Land Transportation Accidents

A major land transportation accident in Michigan has the potential to create a local emergency event, or to seriously strain or overwhelm local response and medical services. It could involve a commercial intercity passenger bus, a local public transit bus, a school bus, or an intercity passenger train. Although these modes of land transportation have a good safety record, accidents do occur. Typically, bus accidents are caused by the bus slipping off a roadway in inclement weather or colliding with another vehicle. Intercity passenger train accidents usually involve a collision with a vehicle attempting to cross the railroad tracks before the train arrives at the crossing. Unless the train accident results in a major derailment, serious injuries are usually kept to a minimum. Bus accidents, on the other hand, can be quite serious—especially if the bus has tipped over. Numerous injuries are a very real possibility in those types of situations. Sometimes, "ordinary" highway crashes can be of unusual significance, when they either involve a large number of vehicles or in some manner cause the entire shut-down of a major highway for a significant period of time. (For example, on July 3, 2010, in the City of Flint, a tanker accident and fire caused I-475 to be closed down for many hours, in both directions.)

Michigan's High Speed Rail Program

In 1999, Michigan began the implementation of its High Speed Rail Program. As one of the first projects, train speeds will be increased from 79 miles per hour to over 100 miles per hour on a segment of Amtrak's passenger train route between Detroit and Chicago. The existing rail corridor between Kalamazoo and Grand Beach has been upgraded with improvements to the track, the signal and communication system, and the at-grade crossing warning devices. The state-of-the-art signal and communication system uses advanced technology to communicate between the at-grade crossings and the train, and also uses a Differential Global Positioning (DGP) train location system. These improvements will ensure the highest level of passenger safety. The goal of Michigan's High Speed Rail Program is to reduce travel time on the entire Detroit-to-Chicago rail corridor from approximately six hours to three and one-half hours. Future plans also include an increase in trip frequencies along the corridor, from the current four daily round trips up to eight or possibly even 10 daily round trips.

The fastest passenger trains now operating in the United States are on the Northeast Corridor, traveling between Washington D.C. and New York City at approximately 125 miles per hour. Although this high-speed passenger rail service is relatively new to the United States, similar systems have been in place for quite some time in Europe and Japan, with an outstanding safety record.

From a hazard perspective, the higher-speed train service will provide new challenges for communities on the Detroit-to-Chicago rail corridor to address in their emergency planning and preparedness efforts. To ensure that all communities are adequately prepared, the Federal Railroad Administration (FRA), the Michigan Department of State Police (MSP), the Michigan Department of Transportation (MDOT), and the affected communities'

emergency managers have all been working with the Operation Respond Institute to install an emergency information system along the corridor. This system is designed to quickly provide detailed railroad equipment information to emergency responders.

Water Transportation Accidents

A water transportation accident involving one of the 20 commercial marine passenger ferries operating from Michigan's Great Lakes shoreline communities could have significant life safety consequences. Most of these marine ferry services operate on a seasonal basis (typically May through November). Vessel sizes vary, but it is not uncommon for 100-200 passengers or more to be on board many of the ferries at the peak of tourist season. In a typical year, these ferries make thousands of trips across Great Lakes waters. Although the vessels have an excellent safety record and must pass rigorous Coast Guard inspections, the potential for an accident is always present. Accidents in other states or countries involving similar vessels validate the need for rigorous emergency preparedness actions to prevent loss of life in an open water setting such as the Great Lakes. For instance, the Ethan Allen tour boat that capsized in Lake George, New York, in 2005 took the lives of 20 senior citizens.

Hazard Analysis

The one commonality all transportation accidents share, whether air, land, or water-based, is that they can result in mass casualties. Air transportation accidents, in particular, can result in tremendous numbers of deaths and injuries, and major victim identification and crash scene management problems. Water transportation accidents, on the other hand, may require a significant underwater rescue and recovery effort that few local jurisdictions may be equipped or trained to handle. Michigan's fourteen Regional Planning Offices may have already performed an analysis of transportation in a particular area, and should be consulted for more information.

Air Transportation Accidents

Statistics from the NTSB and the airline industry show that the majority (over 75%) of airplane crashes and accidents occur during the takeoff or landing phases of a flight. As a result, developed areas that are adjacent to major airports, and along airport flight paths, are particularly vulnerable to this hazard. Accordingly, the greater the number of landings and takeoffs, the greater the probability of a crash or accident. The challenge for jurisdictions with a passenger air carrier airport is to develop adequate procedures to handle a mass casualty incident that could result from an airplane crash or accident.

The map at the end of this section shows the locations of Michigan's airports. Those airports are classified as transport airports, which are the most highly developed facilities in the state and have paved runways capable of handling jet aircraft. According to MDOT statistics, in 2010 these airports collectively handled over 28.2 million passengers (24.4 million from Detroit Metro alone). Nineteen airports have a greater probability of experiencing a commercial passenger airplane crash or accident, either at the airport or in the immediate vicinity of the airport, since these are the main takeoff and landing spots for such commercial flights.

Land Transportation Accidents

More than 130 certified intercity carriers provide passenger, charter, commuter, and special bus service directly to 220 Michigan communities. Of these carriers, six offer regular route service. Michigan's intercity rail passenger system consists of 568 route miles, along three corridors, serving 22 Michigan communities. (See the maps at the end of this section.)

Although these modes of land transportation have an excellent safety record, the combination of large numbers of passengers, unpredictable weather conditions, potential mechanical problems, and human error always leaves open the potential for a transportation accident involving mass casualties. Such an incident could occur with any of the aforementioned transportation modes, in any of the communities served by these systems. Nationally, an average of about six persons die each year in charter and commuter bus crashes, and 11 school children die in school bus accidents. About 8,500 children are injured each year in school bus crashes. Communities served by

any of these systems should plan for a land transportation-related mass casualty incident in their emergency preparedness efforts.

High Speed Rail: Future Challenges

The new high speed rail service between Detroit and Chicago will provide special challenges for communities located along that rail corridor. Although the rail infrastructure will be greatly enhanced and state-of-the-art safety improvements will be instituted, the possibility of a high speed collision between the train and an automobile or truck will still exist. Of special concern are the 360 public and private at-grade crossings in place along the 279 mile corridor. An at-grade crossing always involves the potential for a collision between the train and a vehicle attempting to drive across the tracks.

The U.S. Department of Transportation, through the Federal Railroad Administration, regulates the speed at which trains operate over highway/railroad at-grade crossings. These regulations allow trains to operate at up to 110 miles per hour over highway-railroad at-grade crossings with conventional warning devices only (cross buck signs, side of street and/or overhead flashing lights, and/or gates). At speeds between 110 and 125 miles per hour, positive barriers must be installed at highway-railroad crossings. At speeds above 125 miles per hour, all highways and railroads must be grade separated. These regulations were developed by evaluating the risk of accident damage, using the following philosophy:

- Up to 110 miles per hour: The highway vehicle occupant is most at-risk.
- 110 to 125 miles per hour: Possible injury to the train's occupants, due to rapid deceleration.
- Above 125 miles per hour: Greater likelihood of injury to train occupants, and the train may be derailed.

Amtrak, and high speed train manufacturers, have done computer simulations of accidents that could cause a significant rapid deceleration (similar to a highway vehicle-train accident). These simulations predict only minor injuries to the train's occupants. Based on the passenger train accident history in the state, the FRA regulations, and the computer simulations, the likelihood of a serious passenger rail transportation accident that results in significant casualties appears to be low. However, any collision between a train and a vehicle could result in casualties. Over a 10 year period from 2000 to 2009, there were 787 collisions in Michigan between trains and vehicles. It is only prudent that communities along the rail corridor be prepared to handle a mass casualty passenger rail accident as a worst-case scenario, and to plan for that contingency in their emergency preparedness efforts.

Water Transportation Accidents

A map at the end of this section shows the locations of Michigan's 20 marine passenger ferry services. These services have a good safety record, having never suffered a serious accident that resulted in loss of life or property. Nonetheless, given the large number of trips that are made over Great Lakes waters every year, the possibility of a water transportation accident involving one of these vessels is still a possibility. Furthermore, should such an accident occur, the often-turbulent Great Lakes waters, coupled with the potentially large number of passengers on board, could pose tremendous obstacles to carrying out an effective water rescue and recovery operation.

The U.S. Coast Guard, local law enforcement marine safety units, and the ferry operator would provide primary rescue response to a Great Lakes marine passenger ferry accident. These agencies are highly trained and skilled in water rescue operations, but their resources may not be sufficient or their efforts timely enough to save everyone should a fully loaded ferry sink. Even with on-board life saving equipment, some loss of life might be inevitable—especially in inclement weather and/or rough lake waters. In addition, hypothermia is a real concern—even in balmy Great Lakes waters in the middle of summer.

Impact on the Public

Although automobile crashes tragically kill many hundreds of Michigan residents each year, this analysis necessarily focuses on the types of accidents that are large enough in scale to potentially cause an emergency or disaster-level situation. Airplane crashes and train derailments pose the largest problems, with the potential to cause mass casualties and significant local property destruction—especially since these modes of transportation pass through densely populated urban areas. On a smaller scale, but still potentially devastating to smaller or rural areas, would be major highway accidents involving passenger buses that result in heavy casualties, with the potential to overwhelm smaller emergency medical systems in those areas. An event that might go almost unnoticed in a large and wealthy metropolitan area might easily overwhelm the resources of a poor or rural community. In certain cases, power equipment or other infrastructure may be damaged by such accidents, causing additional impacts (please refer to the section on infrastructure failures). Marine accidents have the most direct impact on human life, but may also discourage water-related tourism, if they receive enough negative publicity. Certain types of marine accidents may also involve a release of hazardous or environmentally damaging industrial materials (see hazardous materials section).

Impact on Public Confidence in State Governance

There may be a sense that improper regulation, authorization, or oversight was maintained by the state, following an event of significant size or impact involving mass transit providers such as trains, airplanes, ships, buses, or trolley/monorail systems. In the case of major accidents involving the highway system, there is often a perception that roadway capacities are too limited—either by design, lack of sufficient funding, or the effects of annual construction projects. Some may perceive that greater enforcement of laws and regulations (e.g. motor carrier) might have prevented a major incident from taking place.

Impact on Responders

Routine "fender benders" or personal vehicle accidents are usually handled by law enforcement officers and are not considered to be community-level emergency events (although they may cause traffic jams and delays that impede emergency response). Only when large numbers of vehicles or persons are involved would motor vehicle accidents be considered large-scale events with the need to engage community-wide response efforts. In very small or rural communities, an overturned bus could be considered a major transportation accident, if such an incident caused enough injuries that local emergency medical capabilities could not adequately handle the situation. Thus, in many ways, this sort of incident is an example of a "mass casualty" event that local and state emergency management programs train to handle.

The impact on responders in highway events is usually limited to the risks of being in and around moving traffic streams, and the diversion of limited resources into the handling of a single large incident. Larger-scale and more unusual events involve the crashing or breakdown of large air, rail, or marine transportation vehicles. A bridge or tunnel collapse, or huge interstate pileup involving dozens of vehicles, may also cause an emergency-level event to occur. In the case of large plane crashes or train derailments, responders may be exposed to fires and hazardous materials, and may encounter problems with looters. In cases involving marine transportation accidents, special rescue operations may occur under perilous weather and lake conditions, in a time-sensitive effort to rescue persons stranded in (usually chilly or freezing) lake waters before they drown or suffer harmful effects from hypothermia or exposure. In all major transportation incidents, which take place in the outdoors, responders will be exposed to the elements and may be plagued by extreme temperatures, hail, winds, or lightning for extended periods of time, when managing these events. (Each of these hazards is described more fully in other subsections of this document.)

Impact on the Environment

Transportation accidents on land, in air, or in water may impact the environment if toxins or chemicals are released. The burning of petroleum, in an accident that involves an explosion, will quickly release sulfur dioxide, oxidized nitrates, and carbon monoxide into the air. These gases contribute to climate change, ozone depletion,

and acid rain. Accidents involving watercraft may also cause a chemical release to occur. Similarly, an aircraft accident could spread petroleum and debris on land or in water.

Significant Passenger Transportation Accidents

As the following listings indicate, passenger transportation accidents occur with some regularity in Michigan. Fortunately, Michigan's recent transportation accidents have not been as deadly as accidents in many other parts of the country or around the world, but the possibility always exists for a major accident that results in multiple casualties.

October 28, 1942 Hamtramck (Wayne County) School Bus and Passenger Train Collision

During the morning of October 28, 1942, a major transportation accident occurred in Hamtramck when a school bus collided with a passenger train. The accident resulted in 16 fatalities and 27 injuries, and of the total of 45 bus passengers, only three were not injured. The driver of the bus claimed he did not see the approaching train because of an overcrowded doorway blocking clear visibility. The majority of the fatalities occurred near the back of the bus, and many of them were children headed for school.

January 14, 1950 Gaylord (Otsego County) Passenger Bus Accident

A bus collision during a severe snowstorm killed five persons and injured several others. A chartered bus returning 20 members of the Michigan Tech hockey squad from East Lansing to Houghton crashed head-on with a southbound Greyhound bus driving around an "S" curve. Both buses had bad damage, with the sides of each ripped open and some passengers thrown. All available ambulances and state police cruiser cars from the area and from neighboring cities were rushed to the scene. Some of the injured stayed in a hospital in Gaylord over the succeeding weeks.

August 19, 1951 Alpena (Alpena County) Passenger Bus Accident

A Greyhound bus, jam-packed with 40 vacationers bound from Mackinac City to Detroit, crashed head-on with a large beer truck in the outskirts of Alpena on highway US-23. The crash resulted in 10 fatalities and 27 injuries, and many of the bodies were reportedly so mangled that identifications were almost impossible.

Easter Sunday, 1958 Saginaw (Saginaw County) Passenger Airplane Crash

Prior to the August 1987 crash of Northwest Airlines Flight 255, Michigan's worst commercial passenger airplane crash had occurred on Easter Sunday, 1958, at Saginaw Tri-City International Airport. In that incident, which resulted in 47 fatalities, ice had built up on the plane's directional systems and the pilot was unable to reach the runway on the landing approach.

September 1976 Alpena (Alpena County) Military Airplane Crash

During one morning in September 1976, a military airplane tanker on a routine training mission crashed in a densely wooded swampy area. The violent crash had an expolsion described as a large ball of fire, followed by several more explosions which pulverized the plane into hundreds of pieces ranging from mere inches to ten feet in length. The accident resulted in 15 fatalities, but despite the severity of damage, there were five survivors.

March 4, 1987 Detroit (Wayne County) Passenger Airplane Crash

On March 4, 1987, a plane bound from Cleveland to Detroit crashed and skidded into three ground vehicles and caught fire. The cause of the accident was the captain's inability to control the airplane while descending on the final approach for landing. Nine of the 22 passengers died from a post-crash fire, lack of fire-blocking material, and poorly designed aircraft components.

August 16, 1987 Romulus (Wayne County) Passenger Airplane Crash

Michigan's worst commercial passenger airplane crash, and the seventh worst in U.S. aviation history (see the table below), occurred on August 16, 1987, at Detroit Metropolitan Airport. In that incident, Northwest Airlines Flight 255 was unable to gain sufficient altitude at takeoff and crashed onto nearby highway I-94, killing 156 passengers and crew. A small child was the lone survivor. A Governor's Disaster Declaration was granted to the City of Romulus and numerous state resources were mobilized to assist in the recovery.

December 3, 1990 Romulus (Wayne County) Passenger Airplane Crash

An unfortunate example of an airliner ground collision occurred on December 3, 1990, when two Northwest Airlines aircraft (Flight 299 and Flight 1482) collided with one another in heavy fog on a runway at Detroit Metropolitan Airport. The Flight 1482 aircraft was heavily damaged and caught fire. Eight persons died and 21 were injured in that incident.

March 10, 1993 Comstock (Kalamazoo Co.) Passenger Train Accident

On March 10, 1993, an Amtrak passenger train with 45 passengers collided with a liquid propane tanker truck in Comstock Township, killing the driver of the truck and injuring the train's engineer. The truck had been exiting a private drive when it slid into the path of the train, which was traveling eastbound at approximately 62 miles per hour. Upon impact, the liquid propane tank exploded with a large fireball. The train engine received considerable damage from the impact and explosion. The windows were blown out, causing the train engineer to receive second degree burns from the fireball. One passenger was transported to a nearby hospital for treatment. The private crossing at which this accident occurred, 11 other private crossings, and a public highway crossing in this area were all eliminated in 1996.

January 9, 1997 Monroe County Passenger Airplane Crash

On January 9, 1997 Comair Flight 3272, a commuter jet from Cincinnati, Ohio, bound for Detroit Metropolitan Airport, crashed on final approach in Monroe County, killing its 26 passengers and 3 crew. The plane was flying at approximately 4,000 feet on its approach when it suddenly and inexplicably did a barrel roll and nose dived, striking the ground 17 seconds later. The cause of the crash was determined by the National Transportation Safety Board to be failure on the part of the crew to adequately manage ice buildup on the wings.

July 9, 1999 Harrison (Clare County) Passenger Bus Accident

A tour bus filled with international exchange students slid off of rain-slicked highway U.S. 27 near Harrison, injuring 40 passengers. Most of the injured were treated and released at a nearby hospital. One passenger was hospitalized overnight, with an eye injury.

July 31, 1999 Marine City (St. Clair County) Passenger Airplane Crash

A commercial skydiving plane crashed shortly after its takeoff from Marine City Airport, killing all 10 persons aboard. The plane was carrying its pilot and nine skydivers, who were about to make an early morning jump. The plane cleared a 90-foot power line on takeoff, then sharply veered left before crashing

and exploding in a hay field adjacent to the end of the runway. The National Transportation Safety Board determined that pilot error was the probable cause of the crash.

September 14, 2000 Wixom (Oakland County) School Bus Accident

A Northville High School bus carrying 34 football players, 14 cheerleaders, and several coaches collided with an automobile. The car's driver was killed and the car's passenger was injured. Ten bus passengers suffered injuries.

October 16, 2000 St. Clair County Passenger Bus Accident

A semi-trailer smashed into the rear of a charter bus on Interstate 94 in St. Clair County, injuring 44 senior citizens aboard (three critically).

December 17, 2000 Battle Creek (Calhoun County) Passenger Train Accident

An Amtrak passenger train with 161 passengers partially derailed near the train station in Battle Creek, forcing the closure of the railroad tracks in both directions for an extended period of time. The train, composed of a locomotive and five coach cars, was traveling at a low rate of speed when the locomotive and first coach car ran off the tracks a half mile east of the Battle Creek station. The entire train remained upright and the derailed cars were lifted by crane back onto the track. No injuries were reported.

January 21, 2002 Muskegon County School Bus Accident

One person was killed and nearly two dozen high school students were injured when a school bus collided with two cars. About 22 persons were taken to area hospitals with injuries.

October 10, 2002 Monroe County School Bus Accident

A school bus on a field trip was carrying 43 children and 17 adults, and pulled in front of a steel-hauling truck, causing a major collision. Almost all of the passengers were sent to a nearby hospital. Five children were reported to be in critical condition.

June 13, 2003 Detroit (Wayne County) City Bus Accident

At least 20 people were injured when a car ran a red light and crashed into a city bus. Fortunately, none of the people who were transported to local hospitals sustained life-threatening injuries.

August 15, 2006 Kincheloe (Chippewa County) Passenger Airplane Crash

In August 2006, a plane crash occurred outside the Chippewa Correctional Facility in Kincheloe, resulting in four fatalities. Federal officials say that pilot error caused the twin-engine plane to crash. This incident is more significant than many similar small airplane crashes due to the fact that it had hit the outer perimeter fence of the Chippewa Correctional Facility. Had the crash been closer to the facility, the magnitude of its effects would have been much greater.

June 4, 2007 Lake Michigan Passenger Airplane Crash

An unfortunate incident occurred when a plane carrying a team of surgeons and technicians from Milwaukee to Ann Arbor crashed into Lake Michigan. All six passengers died in the incident, including the two pilots, two University of Michigan surgeons, and two technicians due to prepare an organ for transplant surgery at the University of Michigan Health System hospital in Ann Arbor that same afternoon. The National Transportation Safety Board said that one of the pilots had reported severe difficulty steering the plane because of trouble with its trim system, which controls bank and pitch.

August 16, 2008 Grayling (Crawford County) School Bus Accident

A school bus accident occurred while taking kindergartners and preschoolers to a field trip, resulting in 12 injuries. The driver was going too fast, crossed to the other side of the road, and smashed into a pickup truck, injuring both drivers.

October 9, 2008 Washtenaw County Passenger Bus Accident

On the afternoon of October 9, 2008, an accident on highway US-23 occurred when a tractor-trailer crashed into an overloaded bus carrying members of an Amish church, sending 14 of the 21 total passengers, including a number of children, to a hospital in nearby Ann Arbor. Six passengers from the bus that had tipped over on its side were considered to be in serious condition.

February 6, 2009 Grand Rapids (Kent County) Passenger Bus Accident

A school bus carrying about 40 students in Grand Rapids collided with a car, resulting in 16 injures.

February 16, 2009 Detroit (Wayne County) Passenger Bus Accident

Fifteen people were injured when a van drove through a stop sign and crashed into a Detroit Department of Transportation bus on Detroit's West side.

March 1, 2010 Detroit (Wayne County) Passenger Train Accident

On March 1, 2010, a Chicago-bound Amtrak train, with 76 people aboard, struck a Detroit fire truck that had stopped on the tracks in southwest Detroit. The fire truck was responding to a previous crash involving a car and a semi truck. Several passengers sought treatment for minor injuries like head and back pain, and there was $600,000 damage to the ladder truck.

February 7, 2011 Detroit (Wayne County) Passenger Bus Accident

Eleven people were injured when a Detroit City bus crashed into a mail truck in Detroit.

March 24, 2011 Detroit (Wayne County) Passenger Bus Accident

A Detroit Department of Transportation bus hit a car, then slammed into a building in Detroit, resulting in 13 injuries.

Top 10 Worst Aviation Disasters in the United States

Fatalities	Date	Location	Carrier	Type
2740*	9/11/2001	New York, New York	American / United Airlines	B767 / B767
273	5/25/1979	Chicago, Illinois	American Airlines	B747
265	11/12/2001	Belle Harbor, Queens, New York	American Airlines	A300
230	7/17/1996	off of East Moriches, New York	Trans World Airlines	B747
217	10/31/1999	off of Nantucket, Massachusetts	Egypt Air	B767
189	9/11/2001	Arlington, Virginia	American Airlines	B757
156	**8/16/1987**	**Romulus, Michigan**	**Northwest Airlines**	**MD82**
153	7/09/1982	Kenner, Louisiana	Pan American World	B727
144	9/25/1978	San Diego, California	Pacific Southwest / Private	B727 / C172
135	8/02/1985	Fort Worth-Dallas, Texas	Delta Air Lines	L1011

*Two separate planes hit the World Trade Center, minutes apart. The total number of fatalities includes passengers and crew on both planes, and those killed in the buildings and on the ground.
Source: Planecrashinfo.com

Train Accidents and Vehicle–Rail Crashes in Michigan: 1990-2009

Year	Vehicle-Rail Crashes	Fatalities
1990	203	N/A
1991	176	N/A
1992	153	N/A
1993	133	N/A
1994	147	N/A
1995	121	N/A
1996	119	N/A
1997	124	N/A
1998	90	N/A
1999	110	N/A
2000	125	N/A
2001	97	9
2002	89	7
2003	104	7
2004	89	9
2005	67	4
2006	57	6
2007	61	3
2008	54	4
2009	44	10

The 2009 total of 44 vehicle-train crashes marked a decrease of 64.8 percent over the preceding 10 year period.

Michigan Great Lakes Ship Accidents

Due to the large size of the Great Lakes, there have been many shipwrecks during Michigan's history. The lakes are prone to sudden and severe storms, especially from late October to early December, resulting in hundreds of ships having met their end on the lakes. Reefs are also a common cause of shipwreck disasters. The greatest concentration of shipwrecks in Michigan lies near Thunder Bay, on Lake Huron, near the point where eastbound and westbound shipping lanes converge. Also, on Lake Superior, the vicinity of Whitefish Point became known as the "Graveyard of the Great Lakes" because more vessels have been lost in there than in any other part of Lake Superior. The Whitefish Point Underwater Preserve serves to protect the many shipwrecks in the area. The Great Lakes Shipwreck Museum uses the approximate figures of 6,000 ships and 30,000 lives lost. There are a total of 12 protected underwater preserves in the State of Michigan Great Lakes areas, with a total surface area of over 2,400 square miles. The Michigan Underwater Preserve Council oversees activities relating to all of Michigan's Underwater Preserves. Michigan's Underwater Preserves are considered to be "underwater museums" and protect concentrations of shipwrecks, unique geologic features, and other submerged sites through public awareness and

interest. The program does not currently receive any funding from the State of Michigan and does not offer any extra legal protection for the sites in the preserves. However, it is a felony to remove or disturb underwater artifacts in the Great Lakes.

Michigan's Underwater Ship Preserves

Source: Wikipedia online encyclopedia

The number of shipwrecks occurring in the Great Lakes has decreased dramatically from the 1800s to around the 1930s. Not only have travelers tended to favor other means of transportation in recent years, but the decrease in marine accidents can be credited to better weather prediction and communication abilities, radar technologies, and improved ship designs and construction quality. The most recent significant accident occurred with the sinking of the Edmund Fitzgerald in 1975. The U.S. Coast Guard and Canadian Coast Guard maintain stations around the Great Lakes. To prevent fatal accidents in the Great Lakes, lighthouses, ship lighting, shipping regulations, floating navigation aids, and LORAN stations have been implemented and enhanced over time. Also, the U.S. Army Corps of Engineers and other agencies maintain the harbors and seaways to limit groundings, through dredging and seawall projects. Below is a table of some of the most significant shipwreck disasters (primarily those with at least 10 known fatalities) occurring in Michigan's portion of the Great Lakes:

Date	Location	Name	Fatalities
November 10, 1835	Mt. Clemens, MI	Bridget	14
November 25, 1839	Little Point Sable, MI	Neptune	18
November 19, 1846	Lake Erie (Pt. Mouillee, MI)	Lexington	13
June 13, 1847	Munising, MI	Merchant	14
November 20, 1847	**Lake Michigan (Sheboygan, WI)**	**Phoenix**	**161+**
September 13, 1848	Lexington, MI	Goliah	18
June 17, 1850	**Lake Erie (near Cleveland, OH)**	**G.P. Griffith**	**250 to 325**
August 20, 1852	**Lake Erie**	**Atlantic**	**150 to 250 (of 600+)**
November 24, 1853	Beaver Island, MI	Robert Willis	10
October 8, 1854	Detroit River	E.K. Collins	23
December 7, 1854	Lake Michigan	Westmoreland	17
August 8, 1855	Lake Michigan	L.M. Hubby	10
April 27, 1856	Port Austin, MI	Northerner	12 (of 142)
September 24, 1856	**Lake MI (Port Washington, WI)**	**Niagara**	**70+ (of 140)**
October 22, 1856	Lake MI (Port Washington, WI)	Toledo	40 to 55

October 30, 1856	Pictured Rocks Lakeshore, MI	Superior	35
November 4, 1856	St. Joseph, MI	John V. Ayer	10
November 26, 1856	Manistee, MI	Cherokee	10
October 19, 1857	Big Sable Point	Reindeer	23
October 24, 1859	Pte. Aux Barques, MI	Troy	23
September 7, 1860	**Winnetka, IL (Lake Michigan)**	**Lady Elgin**	**297 (of 400)**
November 6, 1860	Lake Michigan	Globe	16
November 10, 1861	Port Austin, MI	Keystone State	33
August 9, 1862	Munising, MI	Oriole	12
August 28, 1863	Keweenaw Point, MI	Sunbeam	28
November 11, 1863	Au Sable, MI	Water Witch	28
November 8, 1864	Lake Michigan	Mojave	10
August 9, 1865	**Thunder Bay, MI**	**Pewabic**	**75 to 100**
April 9, 1868	**Lake Michigan (Waukegan, WI)**	**Seabird**	**102**
September 8, 1868	St. Joseph, MI	Hippocampus	26
September 16, 1868	Lake Huron	Persian	10
November 5, 1869	Lake Huron	J.B. Martin	10
November 15, 1869	Lake Superior	W.W. Arnold	11
November 17, 1869	Straits of Mackinac	Robert Burns	10
September 22, 1871	Lake Michigan	Charles H Hurd	11
October 15, 1871	Pte. Aux Barques, MI	R.G. Coburn	32
September 15, 1873	Grand Haven, MI	Ironsides	20
December 4, 1873	Saginaw Bay	City of Detroit	20
October 22, 1874	Wyandotte, MI	Brooklyn	22
August 26, 1875	Whitefish Bay	Comet	11
September 10, 1875	Lake Michigan	Equinox	25
September 10, 1875	Lake Michigan	Mendota	12
July 9, 1876	Ontonagon, MI	St. Clair	26
November 22, 1879	Lake Huron	Waubuno	22
August 29, 1880	Alcona, MI	Marine City	9 to 20 (of 158)
October 15, 1880	**Lake Michigan**	**SS Alpena**	**100+**
November 24, 1880	Lake Huron	Simcoe	13
September 10, 1881	Frankfort, MI	Columbia	16
November 26, 1881	Lake Huron	Jane Miller	30
May 18, 1882	Lake Huron	Manitoulin	11 to 25
September 14, 1882	Lake Huron	Asia	123
December 1, 1882	Lake Michigan	R. G. Peters	14
May 20, 1883	Lake Michigan	Wells Burt	10
November 16, 1883	Lake Superior	Manistee	23
December 14, 1883	Lake Superior	Mary Ann Hulbert	20
May 24, 1881	**Thames River**	**Victoria**	**181 (of 600)**
November 7, 1885	Isle Royle	Algoma	37
June 16, 1887	Charlevoix, MI	Champlain	22
October 25, 1887	Lake Michigan	Vernon	36 to 41
August 30, 1892	Deer Park, MI	Western Reserve	26
October 1, 1892	Lake Michigan	W.H. Gilcher	21
October 4, 1892	Lake Huron	Nashua	15
November 7, 1893	Pte. Aux Barques, MI	Philadelphia	16 to 24
January 21, 1895	St Joseph, MI	Chicora	25
October 9, 1895	Lake Huron	Africa	13
October 24, 1898	Lake Michigan	L.R. Doty	17
May 24, 1901	Au Sable, MI	Baltimore	13
September 16, 1901	Eagle River, MI	Hudson	25
November 22, 1902	Lake Superior	Bannockburn	21
October 3, 1903	Menominee, MI	Erie L Hackley	11
September 2, 1905	Keweenaw, MI	Iosco	19

October 20, 1905	Lake Huron	Kaliyuga	17
November 22, 1906	Lake Huron	J.H. Jones	26
April 12, 1907	Big Sable Point	Arcadia	14
October 11, 1907	Deer Park, MI	Cyprus	22
December 1, 1908	Lake Superior	D.M. Clemson	24
May 1, 1909	Whitefish Bay	Adella Shores	18
July 12, 1909	Whitefish Bay	SS John B. Cowle	14
December 8, 1909	Lake Erie	Clarion	15
December 9, 1909	Marine City, MI	Badger State	15
May 23, 1910	Pte. Aux Barques, MI	Frank H. Goodyear	16
September 8, 1910	Lake Michigan	Pere Marquette 18	25
August 21, 1911	Lake Huron	C.C. Martin	10
November 26, 1912	Lake Michigan	Rouse Simmons	17
November 7-11, 1913	**Great Lakes Storm**	**12 ships sank**	**255+**
April 27, 1914	Lake Superior	Benj. Noble	22
November 19, 1914	Grand Marais, MI	C.F. Curtis	14
July 24, 1915	**Chicago River / Lake Michigan**	**SS Eastland**	**844**
May 8, 1916	Eagle Harbor, MI	S.R. Kirby	20
November 24, 1918	Lake Superior	Cerisoles	38
September 22, 1919	Muskegon, MI	City of Muskegon	29
November 13, 1919	Lake Superior	John Owen	23
November 23, 1919	Whitefish Bay	Myron	17
August 20, 1920	Whitefish Bay	SS Superior City	29
October 30, 1921	Lake Michigan	Rosa Bella	11
April 19, 1922	Whitefish Bay	Lambton	22
December 1, 1922	Lake Superior	Maplehurst	11
September 22, 1924	Oscoda, MI	Clifton	27
December 7, 1927	Twelve O'Clock Point, Isle Royale	Kamloops	22
September 15, 1928	Lake Huron	Manasoo	16 (+116 cattle)
September 9, 1929	Holland, MI	Andaste	25
October 22, 1929	Lake Michigan	Milwaukee	52
October 29, 1929	Lake Michigan (off Kenosha, WI)	Wisconsin	18
July 29, 1936	Lake Michigan	Material Service	15
November 11, 1940	Pentwater, MI	SS William B. Davock	33
November 11, 1940	Pentwater, MI	Anna C. Minch	24
September 24, 1942	Lake Huron	Wawinet	25
June 4, 1947	Isle Royale, MI	Emperor	12
September 17, 1949	**Lake Ontario**	**Noronic**	**119**
May 11, 1953	Isle Royale, MI	Henry Steinbrenner	14
November 18, 1958	Lake Michigan	Carl D. Bradley	33
May 7, 1965	Lake Huron	Cedarville	10
November 29, 1966	Lake Huron	SS Daniel J Morrell	28
November 10, 1975	Whitefish Bay	SS Edmund Fitzgerald	29
June 5, 1979	Copper Harbor, MI	Cartiercliffe Hall	7 (most recent)

Sources: http://www.boatnerd.com/swayze/shipwreck/a.htm and http://greatlakeshistory.homestead.com/Alpha.html

Michigan Boating Accident Statistics

Every year, the U.S. Coast Guard compiles statistics on reported recreational boating accidents. These statistics are derived from accident reports that are filed by the owners / operators of recreational vessels involved in accidents. The states, territories, and District of Columbia all submit accident report data to the Coast Guard for inclusion in the annual Boating Statistics publication. Modern boat accidents are common, as the following table shows.

Michigan Boating Accidents

Year	Total Accidents	Total Fatal Accidents	Total Deaths
1995	395	22	29
1996	478	19	20
1997	354	22	22
1998	451	21	25
1999	343	27	28
2000	227	26	31
2001	299	25	28
2002	226	36	37
2003	218	25	29
2004	143	26	27
2005	161	26	28
2006	185	24	30
2007	185	30	34
2008	187	30	34
2009	131	32	36

Michigan Transportation Trends

Michigan uses air, water, highway, and rail as its major means of transporting people and goods. Michigan has seen an increase in all sectors of transportation over the past few decades, except for the marine sector. As traffic in each sector of transportation increases, so does the risk of accidents. The following section describes the transportation trends in Michigan over the past few decades.

Air Traffic

Air traffic has increased significantly in recent years. With many travelers choosing to fly rather than drive, the airways have become more congested. As the following table shows, flying has also become a more popular way to ship cargo and mail. Total air operations in Michigan have increased greatly since 1990, making airways and runways more congested than in the past.

Indicator	1990	1995	2000	% Change (1990-2000)
Control Tower Airport Operations	2,077,400	2,019,389	2,191,931	**+ 5.5%**
Non-Towered Airport Operations	1,934,190	2,235,520	2,517,131	**+ 30.1%**
Total Scheduled Air Carrier Passengers	25,112,384	31,596,208	40,528,139	**+ 61.4%**
Air Cargo, Express and Package Freight (tons)	272,443	353,189	361,023	**+ 32.5%**
Air Carried Mail	78,955	130,322	99,718	**+ 26.3%**
Total Operations (includes all control tower activities)	4, 011,590	4,254,909	4,709,062	**+ 17.4%**

Highway

Highway travel in Michigan has increased at a far greater rate than the state's population. This increase in travel is attributed to the longer distances traveled to work and other places, and increases in tourism and recreation travel. Although the state highway system comprises only 8% of the Michigan roadway network length, it carries more than 53% of the total statewide traffic. (A map of highways appears at the end of this section.) MDOT traffic summary statistics indicate that I-696 from I-75 to Couzens Avenue was the busiest section of highway in 2001, carrying an average of 219,000 vehicles a day. I-696 actually had six out of the top eight busiest sections in the

state for 2001. Although traffic continues to increase in Michigan, the number of traffic crashes continues to decrease. There were 290,978 total crashes statewide in 2009, a 31.5 percent decrease from the 2000 total of 424,675. More importantly, the total number of fatal crashes has decreased by an even larger percentage. In 2009, there were 806 fatal crashes, down 41.7 percent from 1,382 in 2000.

Total Crashes (Including Total Fatal Crashes and Total Deaths):

Year	Total Crashes	Fatal Crashes	Total Deaths	Year	Total Crashes	Fatal Crashes	Total Deaths
1990	387,180	1,396	1,563	**2000**	424,852	1,237	1,382
1991	364,847	1,290	1,425	**2001**	400,813	1,206	1,328
1992	344,942	1,179	1,300	**2002**	395,515	1,175	1,279
1993	363,636	1,269	1,414	**2003**	391,485	1,172	1,283
1994	398,050	1,262	1,419	**2004**	373,028	1,055	1,159
1995	421,073	1,386	1,537	**2005**	350,838	1,030	1,129
1996	435,477	1,339	1,505	**2006**	315,322	1,002	1,084
1997	425,793	1,283	1,446	**2007**	324,174	987	1,084
1998	403,766	1,235	1,367	**2008**	316,057	915	980
1999	415,675	1,249	1,386	**2009**	290,978	806	871
% Change of Total Crashes (1990-2009) -33%							

Total miles traveled, in billions of miles:

Year	Travel (Billions of Miles)	Year	Travel (Billions of Miles)
1950	22.0	**2000**	94.9
1960	33.1	**2001**	96.5
1970	53.1	**2002**	98.2
1980	61.5	**2003**	100.2
1990	81.2	**2004**	101.8
1995	85.7	**2005**	103.2
1996	87.7	**2006**	104.0
1997	89.2	**2007**	104.6
1998	91.6	**2008**	100.9
1999	93.1	**2009**	95.9
% Change (1990-2009) + 15.3%			

Marine Traffic

The St. Lawrence Seaway and the Great Lakes form a maritime transportation system extending more than 2,000 miles from the Gulf of St. Lawrence on the Atlantic Ocean to the western end of Lake Superior. Michigan has roughly 3,200 miles of shoreline and more than 100 ports serving commercial and recreational navigation. (See the map at the end of this section.) There are also 20 routes of ferry service in Michigan's waterways. Michigan has seen a steady increase in air, rail, and highway transportation over the past few decades, but marine transportation has remained relatively constant. Marine commerce has actually seen a decrease since the 1960s and 1970s, although it has begun to pick up again and has had a 10 percent increase since 1990. Most of Michigan's waterborne traffic is generated by the steel and construction industries and is susceptible to variations in the general economy and the effects of restructuring in the steel industry.

Marine Shipping (Tonnage)

Year	Tonnage	Year	Tonnage
1960	99,684,998	**1981**	75,685,806
1961	88,815,641	**1982**	51,312,257
1962	90,959,374	**1983**	62,416,537
1963	97,730,256	**1984**	75,067,451
1964	109,139,474	**1985**	71,981,889
1965	107,500,170	**1986**	72,527,695
1966	113,716,689	**1987**	79,430,130
1967	110,767,016	**1988**	88,243,048
1968	108,668,893	**1989**	91,459,033
1969	109,328,660	**1990**	85,765,857
1970	110,397,756	**1991**	78,952,003
1971	103,879,534	**1992**	84,622,726
1972	103,555,651	**1993**	87,701,134
1973	106,598,408	**1994**	93,990,253
1974	101,393,927	**1995**	93,610,750
1975	91,411,396	**1996**	93,613,000
1976	97,380,680	**1997**	98,673,521
1977	92,834,512	**1998**	101,306,079
1978	101,788,264	**1999**	96,493,819
1979	102,225,008	**2000**	94,285,388
1980	82,409,928	**% Change (1990-2000) + 10%**	

Railroads (Entire U.S.)

Freight railroads are critical to the economic well-being and global competitiveness of the United States. They move 42% of the nation's freight and connect businesses with each other across the country and with markets overseas. The United States has seen recent increases in railroad cargo weight. Increased railroad traffic and cargo weight may increase the risk of railway accidents, especially highway/rail incidents. Passenger railroad traffic has also been increasing recently, encouraged by higher fuel prices and increasing congestion within other types of transportation networks.

Year	TOFC / COFC Loadings (in millions of units)
1990	6
1995	7.8
2000	9
% Change (1990-2000) + 50%	

Programs and Initiatives

Air Transportation

The Michigan Aeronautics Commission of the MDOT administers several programs aimed at improving aviation safety and promoting airport development. The Commission's safety programs include: (1) registering aircraft dealers, aircraft, and engine manufacturers, (2) licensing airports and flight schools, (3) inspecting surfaces and markings on airport runways, and (4) assisting in the removal of airspace hazards at airports. The Commission's airport development program includes the provision of state funds for airport development and airport capital improvements, many of which contribute to overall air transportation safety.

The Federal Aviation Administration (FAA) contracts with the MDOT for the inspection of the state's 238 public-use airports on an annual basis. The FAA has regulatory jurisdiction over operational safety and aircraft

worthiness. The National Transportation Safety Board (NTSB) investigates all aircraft crashes that involve a fatality, and regularly publishes reports on its findings (see the NTSB section below).

Local plane crash concerns may already have been analyzed by community airports or planners, in accordance with the Airport Zoning Act of 1950:
(see http://www.michiganlegislature.org/documents/mcl/pdf/mcl-act-23-of-1950-ex-sess..pdf).

Land Transportation

Bus Safety

School bus safety programs and initiatives generally fall into two categories: (1) driver skill enhancement and competency training, and (2) physical inspections of buses' mechanical and safety equipment. All school bus drivers in Michigan must pass a bus driver education and training program, and then take regular refresher courses to maintain their certification to operate a school bus. School bus drivers must also pass an annual medical examination.

Local transit and intercity bus safety falls under the purview of the Michigan Department of Transportation (MDOT). Generally, the issue of intercity and transit bus safety is handled on a partnership basis with service providers, with MDOT providing oversight of the initiatives undertaken by the providers to ensure mechanical and operational safety.

Railroad Safety

The MDOT is the state regulatory agency for railroad-highway at-grade crossing safety issues. In this role, MDOT conducts biennial, on-site crossing reviews for Michigan's 5,535 public crossings, and reports observed crossing maintenance deficiencies to the responsible railroad or roadway authority. In addition, MDOT conducts diagnostic study team reviews at selected crossings to determine whether the current level of warning device requires enhancement. At the present time, 42% of Michigan's public crossings at least have automatic side-of-street flashing light signals, and 16% have automatic gates.

In January 2001, an amendment (2000 PA 367) to the Michigan Vehicle Code went into effect, allowing the MSP, MDOT, or specified local officials to install video cameras at railroad crossings to serve as a deterrent to motorists who might attempt to go around or through activated railroad crossing lights and gates. Although the ultimate purpose of this law is to reduce pedestrian and vehicular deaths and injuries at railroad crossings, the law will also likely reduce passenger train accidents caused by collisions with vehicles on the tracks, which is a major cause of many passenger train derailments.

Michigan's "Operation Lifesaver" Coalition—part of a national, non-profit education and awareness program dedicated to ending tragic collisions, fatalities and injuries at highway-rail at-grade crossings and on railroad rights of way—has helped reduce the number of serious crashes at railroad crossings in the state. The Operation Lifesaver coalition in Michigan is spearheaded by the MSP and MDOT and is composed of state and local government officials, law enforcement, and employees of the railroad companies operating in Michigan. The Operation Lifesaver program emphasizes education and enforcement, and its efforts appear to be working. Since 1996, the number of crashes, injuries, and fatalities at railroad crossings in Michigan has shown a steady decline. Any reduction in vehicle-train crashes at railroad crossings helps reduce the likelihood of a passenger transportation accident involving buses and trucks. Another MDOT program that can help to improve rail safety is the Michigan Rail Loan Assistance Program. Established under Act 1997 PA 117, this program was initiated to help finance capital improvements on Michigan's rail infrastructure. Although the program is designed primarily to help preserve and improve rail freight service, any improvements made to a portion of rail infrastructure that also serves passenger rail service can only help to improve passenger rail safety. Track rehabilitation is one of the eligible projects that can be funded under this program, and the safety value of a project is one of the primary selection criteria.

Water Transportation

All marine passenger ferries operating on the Great Lakes must pass regular inspections by the U.S. Coast Guard, for vessel safety and worthiness. In addition, all personnel operating marine passenger ferries must be trained to Coast Guard standards and meet annual certification requirements. Passenger ferries are equipped with individual life preservers and other rescue gear on board, in addition to having marine radios to request help should the need arise. Prior to departure, all passengers using ferry services are given brief instructions on what to do should the vessel somehow become disabled to such a degree that it is in danger of sinking.

Fortunately, Michigan has not suffered a significant water transportation accident involving a marine passenger ferry. Even with this unblemished safety record, the potential always exists for a serious water transportation accident to occur on the Great Lakes. Such an event would have the potential to be a significant mass casualty incident and possibly require a massive water rescue and recovery effort.

National Transportation Safety Board

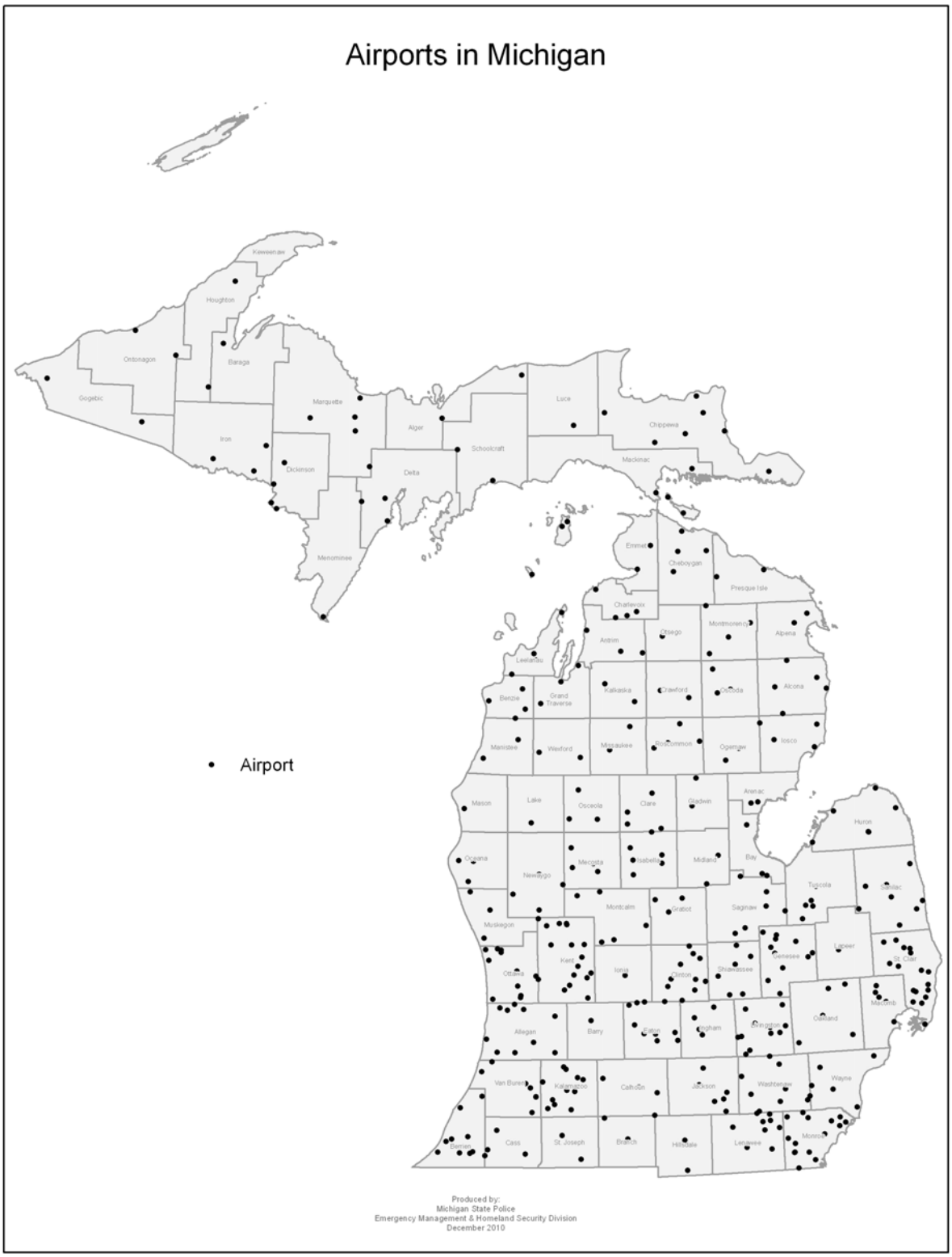
The National Transportation Safety Board is an independent federal agency responsible for promoting aviation, highway, railroad, marine, pipeline, and hazardous materials transportation safety. The NTSB is mandated to investigate significant transportation accidents, determine the probable cause of such accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies that are involved in transportation. The NTSB makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews. Although the NTSB has no regulatory or enforcement powers, it has nonetheless been successful in seeing the adoption and implementation of over 80% of its transportation accident recommendations.

An example of an NTSB recommendation being implemented is the agreement between the FAA and the Boeing Aircraft Company to redesign the rudder system on the company's popular 737 jetliners and to replace the rudder valve system in every one of the 737 jets in service. The rudder retrofit program cost Boeing nearly one-quarter of a billion dollars. (The 737 rudder system came under the close scrutiny of the NTSB after crashes of 737s in 1991 and 1994 had resulted in over 150 deaths. The NTSB believed that the rudder system on the two jets might have been a contributing factor in the crashes.)

Final Rule on the Reflectorization of Rail Freight Rolling Stock

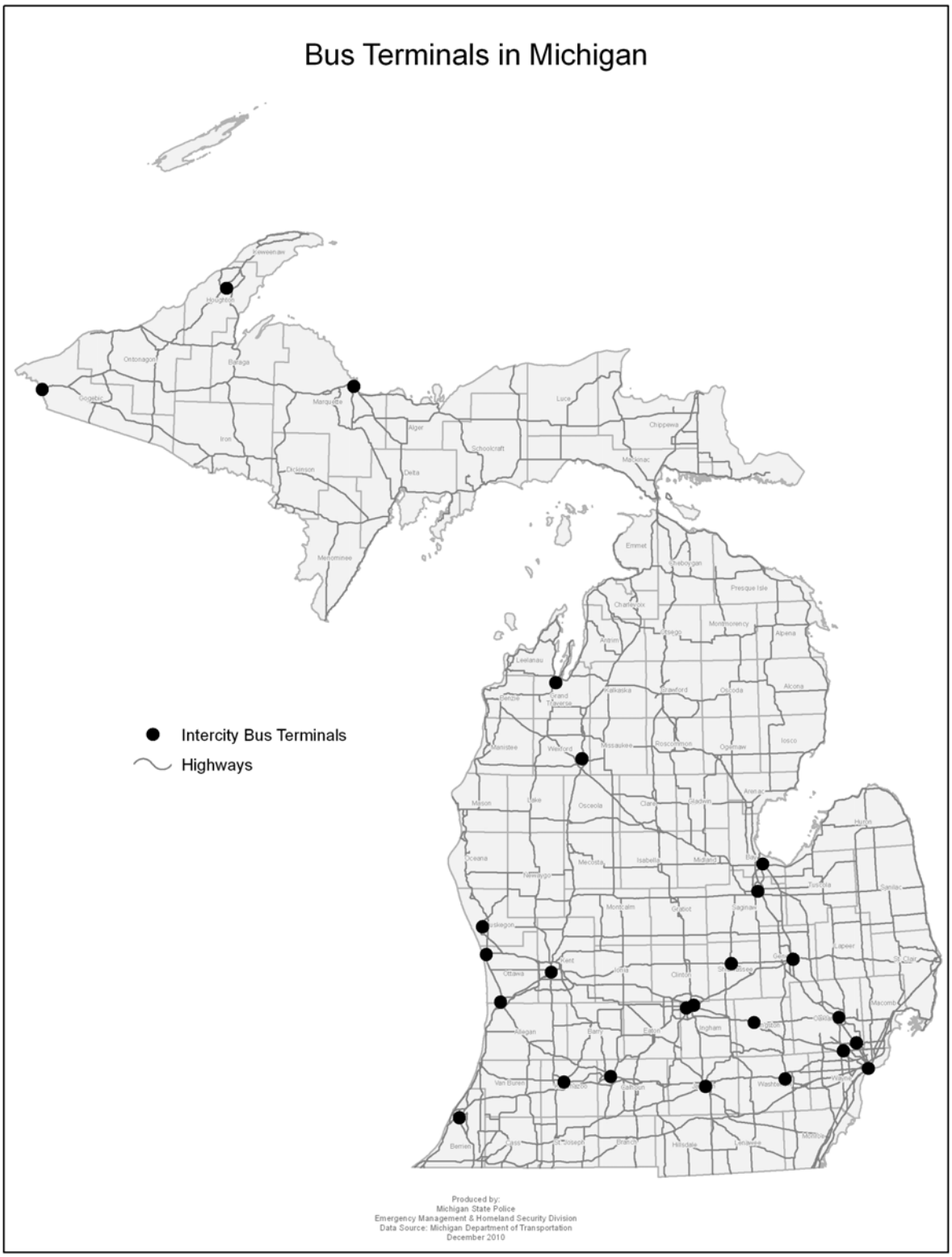
The Final Rule requires railroads and other companies owning rail cars to install yellow or white reflective materials on locomotives over a five-year timeframe, and on freight trail cars over a 10-year period. The reflective materials are to be installed on all newly constructed locomotives and freight rail cars, and on existing ones during periodic maintenance repair, unless alternate implementation plans have been developed that meet the deadlines. Nearly one quarter of all highway-rail crossing collisions involve motor vehicles running into trains occupying at-grade crossings. This new rule is the most recent effort by the Federal Railroad Administration (FRA) to increase the visibility of trains at highway-rail at-grade crossings.

Michigan's Airports

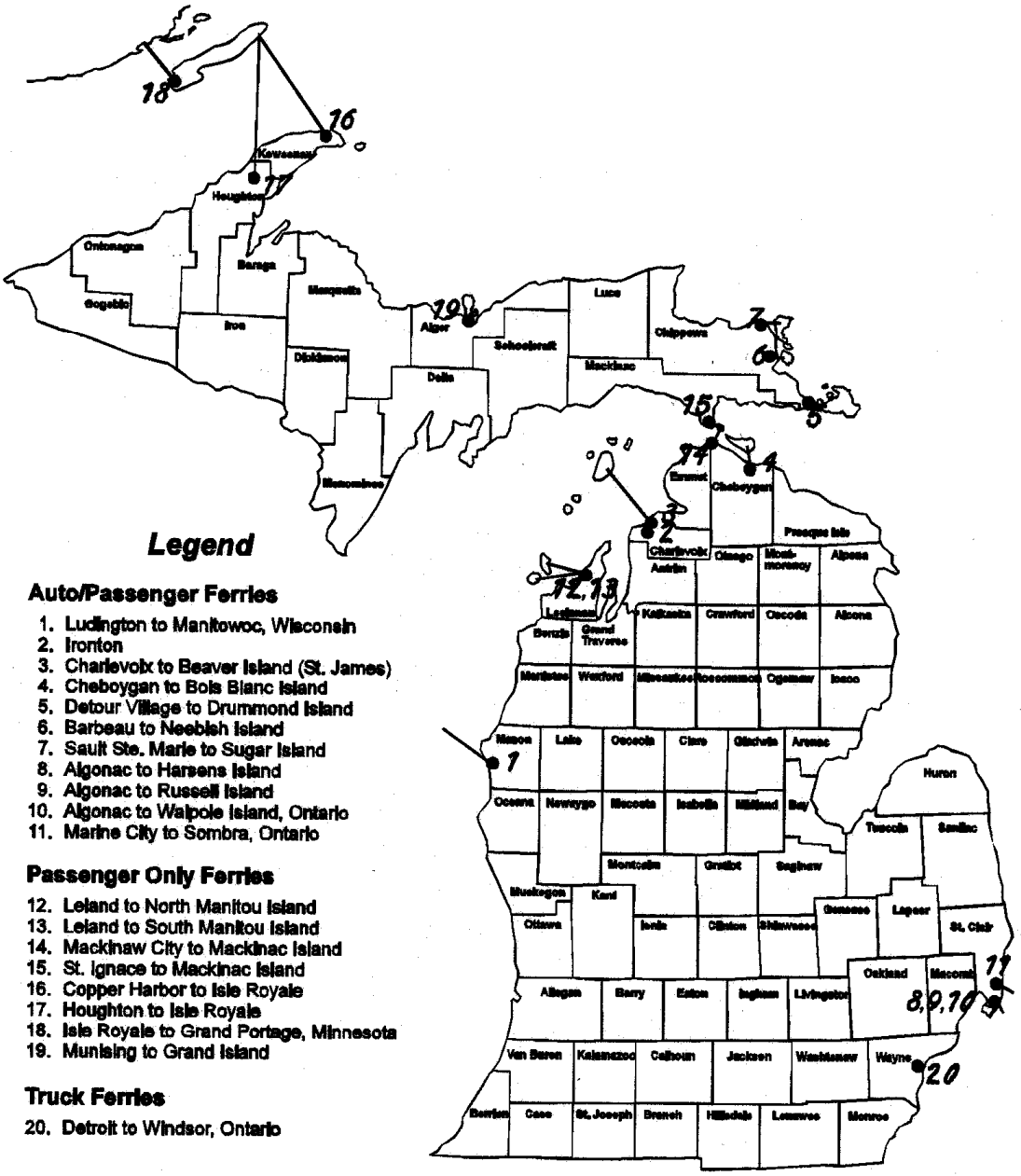


Michigan Intercity Rail Passenger Transportation System

Michigan Intercity Bus Passenger Transportation System



Michigan Marine Passenger Transportation System



Source: MDOT, Bureau of Transportation Planning, Travel Demand & Intermodal Services Section, Modal Services Unit

Principal Ports in Michigan

III. HUMAN-RELATED HAZARDS

The following list summarizes the significant human-related hazards covered in this section:

1. Catastrophic Incidents (National Emergencies)
2. Civil Disturbances
3. Nuclear Attack
4. Public Health Emergencies
5. Terrorism and Similar Criminal Activities

These hazards all tie in with each other in various ways, and by placing them all in the same section of this document, this updated 2012 edition of the Michigan Hazard Analysis intends to make it easier for planners and emergency management personnel to learn about and consider the many aspects of these threats, risks, activities, conditions, and incidents.

The new hazard section, Catastrophic Incidents (National Emergencies), was primarily inspired by some of the states of alert and response activities that Michigan had to adopt in the past decade for incidents that primarily took place outside of its own borders. The main examples were the 9/11/2001 terrorist attacks (and subsequent anthrax incidents and threats), and the Gulf Coast disaster involving Hurricanes Katrina and Rita in 2005. It makes sense to consider, in advance, these types of incidents as well as other types of large-scale disasters that could occur in the future, which require a large-scale national response even though the actual incident itself may occur only within the borders of a few states outside of Michigan's immediate environment. Preparedness, planning, exercising, and mutual aid arrangements are the main "mitigation" activities proposed for this hazard during its initial phase of consideration in this 2012 edition of the Michigan Hazard Analysis. Some catastrophic incidents may involve other types of human-related hazards. Some of the possibilities that led to the addition of this hazard as a new section include recent considerations of a major pandemic, terrorist attack, or nuclear strike—all of which are covered in more detail in subsections herein.

Although civil disturbances are usually handled at the level of local or state governments alone, some types of unrest may be related to broader patterns of criminal activities, or even terrorism. The civil disturbance hazard has been given broader treatment, to shift farther beyond the emphasis on prisons that had been a part of its original concept in earlier state planning documents. Although prison disturbances are still considered a hazard, several additional types of incident have been more extensively discussed and compared. Although consideration was given to a type of civil disturbance that could be called "disruption," it was decided that such a concept was already partially covered by the discussion of catastrophic incidents and other hazards. "Disruption" would have described human collective responses to large-scale catastrophes, such as warfare, widespread conflict, or disasters, that disrupt ordinary lifestyles and force people to cope using relatively spontaneous or grassroots activities to provide for social needs. There were few examples that were clearly relevant to today's contemporary circumstances, however, except for those already suggested in other sections, and so the idea was not included as a full consideration within this edition. Consideration was also given to economic and criminal problems, but these were not considered relevant enough to an emergency management planning perspective to include. Emergency management deals with recognized disasters and emergency events, rather than social problems more broadly, and therefore throughout this plan decisions had to be made about where the line might be drawn between specific disaster/emergency events and circumstances that are ongoing social, economic, political, and environmental issues in any society.

Although warfare and other types of conventional military attack were not given specific treatment here, the nuclear attack hazard has been retained, yet almost entirely rewritten to reflect post-Cold War geopolitical circumstances. In addition, a greater connection is now exhibited between the nuclear attack hazard and that of terrorism. Public health emergencies have taken on new importance recently, with the rise in concern about

global pandemic illnesses. Travel is so rapid and widespread today that quickly detecting and containing outbreaks of serious, even lethal, contagious diseases has been considered necessary and given higher priority by numerous levels of government, and their partnering agencies. Terrorism is one of the potential causes of widespread threats to public health, as well as nuclear attack and certain types of civil disturbances. The terrorism and similar criminal activities section has also been almost entirely rewritten in this 2012 edition of the Michigan Hazard Analysis, to reflect more recent knowledge about the involved topics. In many cases, it may not be immediately clear whether an incident was motivated by political causes, some other form of protest, criminal enterprises, or personal neurosis. A bomb blast event, for example, may have its origin in a hostile terrorist group, a riotous uprising, a murderous act involving organized crime, or the misguided activity of a mentally unbalanced individual. The act itself, and its effects, might constitute an emergency event regardless of the reasons that caused it to happen. In many cases, the determination of who organized such a bombing, and why, may take weeks of subsequent investigation, and may place the event (after the fact) within different hazard classifications, as they have been presented here. For that reason, it is recommended that the human-related hazards be studied together. At the very least, the civil disturbances and terrorism sections should be studied together, and those who are interested in terrorism should also give consideration to the nuclear attack and public health emergencies that can be caused by terrorist attacks.

During certain historical times and places, it might seem to make sense to include large-scale or widespread criminal activities as a type of hazard in itself. Gang warfare can certainly impose a serious toll upon the health and safety of an area, for example, and such enterprises may be used to raise funds for international terrorist activities. At this time, however, it was decided not to include large-scale organized crime as a specific type of hazard in this analysis, except where the purpose of that crime relates to terrorist activities (rather than the profit-oriented activities that are typical of criminal enterprises). Organized crime exists to try to make its participants wealthy, but terrorism aims to cause specifically destructive effects upon society—usually without any expectation or desire for personal profit or wealth or the part of the perpetrator(s). Dedicated law enforcement resources already exist specifically to combat crime of various types, and these ongoing activities usually do not involve emergency management personnel, declarations of disaster, or the type of public involvement and planning used for the mitigation of natural disasters and other-types of potentially large-scale hazards.

Overlap Between Human-Related Hazards and Other Sections of the Hazard Analysis

Terrorist and nuclear attack events can cause widespread infrastructure failures, hazardous materials incidents, transportation accidents, energy emergencies, nuclear power plant emergencies, structural fires, and oil/gas pipeline failures. Therefore, there is extensive overlap with the Technological Hazard sections. It is also possible that terrorist and nuclear attack events may cause dam failures and flooding, as well as wildfire events—two of the hazards that are addressed in Natural Hazards sections in this document.

In a reverse direction of causality, various natural and technological hazards may be expected to cause significant public health concerns. These include weather hazards such as extreme temperatures, hydrological hazards such as flooding and drought (both of which may affect the quality of drinking water in an area, as well as exacerbate the risks of contagious illness and food quality/contamination), and the ecological hazard of wildfires. Any disaster that can cause widespread homelessness and power failures may have a serious impact upon public health. Similarly, various types of incidents involving hazardous materials (including radiological incidents) may affect public health. Disasters with an extensive impact upon the environment may involve contamination that is a threat to public health.

With regard to natural or technological events that may cause violent incidents, the most probable circumstances may involve civil disturbances in reaction to other emergency or disaster circumstances, if overwhelming to or poorly handled by responders or government agencies. There are very few historical records of such incidents escalating to the point of a civil disturbance emergency in Michigan, and even then, the connection between natural and technological hazards and such disturbances has tended to be indirect and open to alternative interpretations. Most civil disturbance events have been rooted in other human circumstances. One of the

exceptions involves the potential for widespread infrastructure failures to develop into circumstances in which local citizens and police must take extra precautions against criminal activity such as looting. With a large enough event or over a long period of time, such conflicts may cause certain types of civil disturbances to occur. Another important scenario involves the handling of prisoners in correctional facilities, during incidents of any cause that may require the area's evacuation, or special in-place sheltering (as from a tornado or a severe hazardous materials incident). It is important for correctional facilities to have planned for how their institutions could handle such emergency events—providing an appropriate level of protection for the incarcerated while also maintaining the needed level of order, control, and surveillance over them.

CATASTROPHIC INCIDENTS
(National Emergencies)

A large-scale event that has severe effects upon large numbers of persons, across a wide area, and immediately overwhelms State, tribal, and local response capabilities. Such incidents are likely to require coordination activities from many states, including Michigan, even if the event took place in a distant location.

Introduction

Since 2000, the nation has been affected by disastrous events that have caused various states, including Michigan, to undertake significant actions to respond to, assist, or help accommodate the impact of events that took place well outside of their borders. Mutual aid agreements are in place between states to provide one another with supplemental resources and capabilities to respond to and recover from a disastrous event. It is also possible that certain types of events outside of U.S. territory may require coordinated response, as well.

The National Response Framework (aka Federal Response Plan) involves a recognition of, and reaction to, events of national significance. This was observed during the terrorist events of September 11, 2001—along with the federal government, all states went into a mode of heightened alert and exchanged various information and resources in a coordinated manner. More recently, Hurricanes Katrina and Rita caused such disruption in the southern states that nation-wide assistance and coordination was needed. Not only were resources deployed to the disaster areas themselves, but distant states such as Michigan also needed to accommodate large numbers of evacuees who were temporarily displaced from their homes, jobs, businesses, and even families. Some evacuees even chose to permanently change their residence to new homes in other communities across the U.S.

In some disaster scenarios, even if Michigan experiences some direct impacts, it may turn out that much greater effects in other states or nations (e.g. Canada) may require extensive additional actions to be taken by Michigan government and personnel. In recognition of these extra tasks, a Catastrophic Incident hazard is now identified, in addition to the many hazards that are known to potentially have a direct impact within Michigan.

FEMA has (in its Catastrophic Incident Annex of November 2008) defined the nature of the catastrophic disaster situation. It "will result in large numbers of casualties and/or displaced persons, possibly in the tens to hundreds of thousands…. The nature and scope of a catastrophic incident will immediately overwhelm State, tribal, and local response capabilities and require immediate Federal support…. A catastrophic incident will have significant international dimensions, including impacts on the health and welfare of border community populations, cross-border trade, transit, law enforcement coordination, and others."

Special aspects that may be part of catastrophic incidents include the possibility of occurrence without warning, the occurrence of multiple incidents over a wide-ranging area (or even without any clearly defined incident site), may involve large-scale evacuations (whether organized or self-directed), may cause widespread homelessness and displacement (either temporary or permanent), may overwhelm existing health-care systems, and may produce severe environmental impacts that exceed governmental abilities to achieve a timely recovery.

Catastrophic Incident Scenarios

There are a great many possible situations that can result in nationwide activation of mutual aid and other response and recovery mechanisms, so it is not intended that this section will provide an exhaustive list of everything that may happen. This subsection does, however, provide about ten "scenarios" designed to suggest the types of situations that may be considered a catastrophic incident. It is hoped that this will assist planners and responders in further developing their mutual aid arrangements at all levels, to accommodate a wider variety of needs, and to suggest some possible repercussions that may not have previously been considered in existing planning and exercise scenarios.

Major Hazardous Materials Incidents
An event of sufficient magnitude (like the Chernobyl nuclear power plant disaster or Bhopal hazardous materials release) may warrant a response even if located in another country. A good example for Michigan could involve a major "Chemical Valley" incident in Sarnia, Ontario. It has been reported that this one industrial area (located just across the St. Clair River from the City of Port Huron) involves 40% of Canada's chemicals, including the largest liquid natural gas storage facility in North America. Canada has national, provincial, and local regulatory frameworks that have allowed the "Chemical Valley" area to function effectively for many years, but if some sort of unlikely circumstance or deliberate terrorist activity causes a major problem in the area, its potential impacts could be great.

Energy Emergencies and "Great Blackouts"
Michigan does not need to be directly involved in a major event for it to have significant consequences that warrant the provision of State-level assistance or response. One of the most notable scenarios involves the possibility of an energy emergency. It has been reported that 28 pipelines run between the cities of Port Huron, MI and Sarnia, Ontario. These pipelines reportedly support 85% of the heating that Michigan and Ontario residents require to maintain a normal and productive lifestyle. Serious disruptions in energy supply (along with higher costs for available product) may result from a disaster that disrupts these supply lines. Such a circumstance would not need to occur specifically in Michigan in order to cause serious problems here.

The loss of electrical power for a long enough time would be expected to cause a certain proportion of affected persons to undergo serious hardships—particularly those who have special medical needs or disabilities. Shortages of certain types of goods or services may affect Michigan, even if the blackout itself is not directly experienced here. Similarly, gaps in communication, information, or service networks may have an effect well beyond the actual area that lacks electrical power.

A "Supervolcano" Event
A volcanic eruption of sufficient size could cause an incident of national significance. In 1980, the eruption of Mount St. Helens (in the State of Washington) caused about 540 million tons of volcanic ash to be scattered over an area of some 22,000 square miles. A massive eruption of a "supervolcano" would cause a much larger area of destruction and emit billions of tons of ash into the air. Several locations have been identified in the western United States where this type of event is possible, even if not especially likely in the near term. It has been calculated that volcanic ash from a "supervolcano" event could be transported through the atmosphere over a much broader area, and that significant quantities could be carried and deposited as far away as Michigan. The size of such an eruption itself would likely be considered to be a catastrophic incident and thus would probably warrant a Michigan response in providing assistance to the more heavily involved western states.

Warfare
Military action has the potential to create a catastrophic incident. The United States is potentially vulnerable to attacks on its own territory, including attacks by military nuclear weapons. Furthermore, war in other parts of the world could have significant impacts on Michigan due to economic repercussions and potentially serious drains on Federal government resources. Because of the interconnectedness of international trade, finance, and communications, harmful effects might be felt from wars fought in distant places. Michigan also is home to an ethnically diverse population and foreign wars can directly impact on the homelands and families of these citizens.

Major Terrorist Attack
Major terrorist attacks could create a catastrophic incident, particularly if those attacks use weapons of mass destruction or are targeted on critical national infrastructure. Large-scale terrorism may create economic and infrastructure damage similar to military attacks. In addition, terrorists usually choose their targets with the goal of creating as much fear and uncertainty as possible. Dealing with a major terrorist attack will require addressing the concerns of frightened and confused citizens. It is worth noting that the details and limits of a terrorist attack

are rarely understood immediately, complicating response efforts. For example, following the 9/11 attacks, confusing reports and uncertainly regarding possible additional targets caused the Federal government to take significant precautionary measures. These included shutting down the national air-travel system and evacuating senior officials. Similar dramatic steps (even if temporary) might be needed in response to future major terrorism events.

Major Earthquakes
Although a major earthquake involving the New Madrid Fault would likely have some effect on the southern portions of Michigan, it is probable that an even greater Michigan effect would stem from the massive damages, casualties, and human needs that would need to be addressed near the earthquake's epicenter (or the earthquakes' epicenters). Another possibility could involve a major earthquake along California's San Andreas Fault line, or at some other at-risk location. If the magnitude of the event is great enough, the incident may rise to the level of a catastrophic incident and thus prompt a significant response by Michigan's government, agencies, and residents.

Celestial Impact
An impact by an asteroid, comet, or meteorite has the potential to be a catastrophic incident if the object has sufficient mass and velocity to cause extensive harm. This may even be true if the impact occurs on the other side of the planet, for there may exist a relationship between celestial impacts and a rise in volcanic and earthquake activity. Approximately once per century, a major impact (over a land mass) has been observed that is of a scale comparable to a nuclear blast. The last two events were seen in Siberia, in 1908, and in the Arabian Peninsula, in 1870. The fear is that since the Earth's population is so much greater now, as is the scale of human settlement, it has become more likely that the next major impact could cause serious casualties and damage. Additional vulnerability stems from the increasing importance of electronic communications that can be affected either by a material impact, or by "space weather." (Please refer to the Celestial Impact section for more information.)

Hurricanes
Although hurricanes have little direct impact on Michigan (except for thunderstorm systems and precipitation that may stem from a distant hurricane), it has recently been seen that a sufficiently damaging event (i.e. New Orleans, Florida, New York, or other coastal states) can necessitate large-scale assistance from all states in the union. Hurricanes have the demonstrated ability to cause a catastrophic incident.

Tsunami Events
Whether it originates from a celestial impact, a seismic event, or a volcanic event, a tsunami has the potential to do severe and widespread damage. A tsunami of sufficient size/velocity has the potential to be a catastrophic incident, resulting in the type of damage and displacement seen in the 2005 Katrina/Rita Hurricane Events.

Pandemics or other Public Health Emergencies
These types of national emergencies may be purely natural in origin, or they may involve intentionally-caused bio-warfare or terrorist events, or some combination of the two. Naturally occurring pandemic influenza caused widespread precautions around the world during 2009. Although the impact of the novel influenza A (H1N1) virus in that case turned out not to be quite as bad as feared, many were still sickened throughout the country and state, and it was particularly challenging for our schools and health providers.

Some public health emergencies may be the secondary result of a damaging disaster or sabotage incident. In the case of the anthrax cases and scares of late 2001, it made sense to have a state of heightened national alert, despite the fact that most reports of "white powder" eventually turned out to be harmless. Despite the number of false reports and hoaxes, the presence of anthrax in the United States' postal system and key government/media offices was very real, and merited substantial prevention and mitigation efforts nationwide. Coming so soon after the September 11 terrorist attacks, there was initial uncertainty about whether the anthrax incidents were part of ongoing terrorist tactics.

Impact on the Public

These impacts primarily involve the diversion or sharing of Michigan resources to assist other states with major emergency events, such as the devastating impact of hurricanes upon the city of New Orleans. A couple of the most significant possibilities include a New Madrid earthquake (see the Earthquake section), the eruption of a super volcano whose ash may affect weather patterns and cause dusty debris to fall over Michigan, a large scale mass mobilization for purposes of warfare or civil defense (which may cause the dedication of various factories, resources, and infrastructure toward defense and emergency response operations), related mass tragedies involving nuclear attack or terrorism (see those sections), or a large-scale celestial impact (also covered in its own section).

Impact on Public Confidence in State Governance

Those national emergencies that arise from natural hazards, such as flooding, tend to evoke sympathy and generous helping behavior throughout the country. If there is a major shortcoming perceived by the public (usually through the media) in the government's role in such disaster, then significant discontent may arise. Hurricanes Katrina and Rita were a case involving this type of perception and discontent, raising questions about government preparedness and response, on more than one level of authority.

In many emergencies of technological origin, whether a major plane crash or a power failure, there is usually a question of the extent to which government regulation should have been able to prevent or minimize the impacts of the event. Similar issues exist with major human-related hazard events, although it is often recognized that in many such events it was not reasonably possible to anticipate exactly when and how things would go wrong. Matters of national security are often given the benefit of the doubt by citizens, although military operations are routinely treated with skepticism by a significant portion of the population. Prolonged military operations that result in casualties are more likely to raise widespread concern about whether the government is acting correctly and responsibly. However, these same cases also involve a rallying of some patriotic groups who approve of the seemingly direct nature of military action, compared to more abstract policy decisions and approaches. In a diverse democracy, it is normal that the government's authority in a particular area will be lauded by some and criticized (or even feared) by others.

Impact on Responders

National Emergency events would call for the coordination of emergency responders (and associated personnel) between states, and even from across the nation or between nations (e.g. Canada, or its Ontario province). The most direct impact of a national emergency upon responders would be dealing with the logistics of interstate mutual aid (or even its international equivalents). In an event such as the 9-11-2001 terrorist events, or the 2005 Hurricane events, numerous response personnel may have to juggle their time, resources, and efforts involving activities that assist other states or jurisdictions with disaster response and recovery, while simultaneously ensuring that their own state's (or local jurisdictions') preparedness and response needs are also adequately cared for. An additional potential impact may arise from events that occur in one's home jurisdiction after various aid has been granted to some other area—various staff, equipment, expertise, and funds may suddenly be needed "back at home" in the midst of complicated and important response or recovery operations abroad. Extra complexity would also be entailed in the tracking of expenses and the paperwork involved in reimbursement procedures, which might ordinarily be used on activities that are of clearer importance to the home jurisdiction's own emergency needs. One of the effects of national emergencies that does have an impact upon a state's own circumstances, even when not directly impacted by the national emergency event itself, is the potential need to deal with evacuees coming from an affected area, who would need food, shelter, and other types of assistance in living their lives under conditions of displacement and even duress. Such evacuees would tend to have numerous financial and material needs, since the emergency event may have caused severe material hardships for them (or at least temporarily denied them access to their homes and wealth). In addition, various disaster and emergency events tend to cause emotional, social, and psychological hardships as well as material and economic ones, since various trauma may have been experienced during the emergency events (including the loss of family and friends). The uncertainties and stresses of relocations, job loss, etc. would often require social and psychological

support structures to be sought (and often provided by the host community) in order to restore a degree of security to the evacuees conditions and lifestyle. As a part of long-term recovery, such evacuees would ideally be able to restore their lifestyles to some sort of normalcy, perhaps even including successful relocation back to their original homes and the resumption of their previous, ordinary life circumstances.

Impact on the Environment

Depending upon the type of event under consideration, environmental impacts upon Michigan may vary widely, or may not directly be felt at all. A super-volcanic eruption, even in the Western United States, could deposit large amounts of volcanic ash across the state. Although superficially similar in appearance to a snowfall event, in some ways, such material would not be collected or dissipated as easily as snow. A major earthquake, tsunami, hurricane, meteorite, nuclear, or terrorist event that causes a wave of immigration into the state (even if only on a temporary basis) may require various forms of development and land use that, under the need to provide emergency services to many people, could be environmentally damaging by the inability to speedily undertake such actions in accordance with long-term comprehensive development plans.

Recent Historical Examples of Major Catastrophic Incidents

Some examples include:

- Major warfare, such as World War II
- Great Blackouts, such as those of 1965 and 2003
- Anticipated or threatened infrastructure breakdowns (such as “Y2K”)
- Major terrorist incidents or threats, such as 9/11 and the subsequent anthrax events
- Catastrophic hurricane impacts, as seen in 2005 with hurricanes Katrina and Rita (with many displaced evacuees and a state emergency declaration in Michigan)

CIVIL DISTURBANCES

Collective behavior that results in a significant level of lawbreaking, perceived threat to public order, or disruption of essential functions and quality of life.

Hazard Description

Civil disturbances can be classified within the following four types: (1) acts or demonstrations of protest, (2) hooliganism, (3) riots, or (4) insurrection. Since most of these types of disturbance share similarities with each other, and the classifications presented here are not absolute and mutually exclusive, **it is recommended that this entire section be studied as a whole**. The descriptions that follow, while roughly organized by type of disturbance, provide information of interest in evaluating and understanding all types of civil disturbance, and therefore should not be treated as independent subsections or read in isolation from each other.

The first type, protest, usually contains some level of formal organization or shared discontent that allows goal-oriented activities to be collectively pursued. This first category includes political protests and labor disputes. Many protest actions and demonstrations are orderly, lawful, and peaceful, but some may become threatening, disruptive, and even deliberately malicious (on the part of at least some of those involved either in the protest itself or in reaction to the protest). It is only the latter type of event that should properly be classified as a civil disturbance. The destruction of property, interruption of services, interference with lawful behaviors of ordinary citizens and/or emergency responders, the use of intimidation or civil rights violations, and threats or actual acts of physical violence may all occur during civil disturbance events. Actual Michigan events have included the willful destruction of property and impeded property access during labor strikes, and heated conflicts between opposing participants at political rallies or issue-driven demonstrations. Different risks and forms of disturbance are connected with the nature and perceived importance of the cause, the degree of organization among those who are active in the protest, and the amount of group cohesion among those who are involved.

The second category of civil disturbance, hooliganism, is relatively unorganized and involves individual or collective acts of deviance inspired by the presence of crowds, in which the means (and responsibility) for ordinary levels of social control are perceived to have slackened or broken down. Certain types of events, such as sporting events, "block parties," or concerts, become widely publicized and, in addition to normal citizens who merely seek entertainment, tend to also attract certain types of persons who seek situations in which anonymity, confusion, and a degree of social disorder may allow them to behave in unlawful, victimizing, or unusually expressive ways that would normally be considered unacceptable by most ordinary people. Examples include the disorder that has followed various sporting events and college parties. Although the majority of persons present are ordinary citizens (although many may have some level of intoxication), a minority of persons begins making itself known through unlawful or extreme acts of deviance, and it is from this part of the crowd that the hazard primarily stems. This minority may include persons affected by the use of illegal drugs and alcohol, and may include criminals and persons with mental illnesses (such as antisocial personality disorder) who may either be reacting with extreme hostility to the crowding, noise and disorder, or may have deliberately sought out such crowds and disorder so as to gain opportunities to behave in ways that ordinary circumstances would not allow. Common problems include the widespread destruction of property, numerous types of assault and disorderly conduct, and criminal victimization. It should also be noted that many persons who are normally law-abiding may temporarily behave in unusually aggressive ways during these events, often prompted by an understandably defensive anxiety about the disorder and behavior exhibited by the deviant minority, but also possibly exacerbated by a level of alcoholic intoxication as well as the temptation by some to engage in appealing deviant behaviors that under normal circumstances of social control would not be selected. Many citizens remain law-abiding, but may remain in the area of a civil disturbance either because they live in the area, have activities (including social and recreational ones) that they wish to continue engaging in, have legitimate business to conduct, or because they are curious or concerned and wish to observe or witness the situation as it occurs. The majority of such law-abiding citizens will leave the area in an orderly way when given clear instructions by a legally-recognized

authority to do so. There are cases in which hooliganism may become combined with protest, and thus complicate the situation for law enforcement personnel. In some circumstances, elements of protest are added only by a small minority of participants after the disturbances have already begun, but in other circumstances, protest activity may arise out of concerns regarding the extent and nature of pre-emptive law enforcement activities that were intended to prevent a civil disturbance.

The third type, riots, may stem from motivations of protest, but lacks the organization that formal protests include. Although legitimate and peaceful protests may spontaneously form when people gather publicly with the perception that they already share certain values and beliefs, riots tend to involve violent gatherings of persons whose level of shared values and goals is not sufficiently similar to allow their collective concerns or efforts to coalesce in a relatively organized manner. Instead, there tends to be a diffuse sense of shared discontent, but relatively few norms to shape these strivings into clearly coherent action. For example, widespread discontent within a community that is sufficiently cohesive may quickly take on a set of shared leaders and clear organization, such as a march or chant that is clearly in the form of a protest or demonstration, but in an area that doesn't have the same cohesiveness and shared norms and values, a relatively chaotic form of expression may take place instead, involving assaults, intimidation, and unlawfully destructive expressions of discontent, possibly including the victimization of innocent citizens or businesses who have been selected by part of the crowd to function as scapegoats during their expression of discontent. In addition to the sentiments of discontent that may have sparked the initial activities, however, elements of hooliganism may emerge and even come to predominate, as certain persons may attempt to exploit the social disorder for their own individual ends. In other cases, elements of legitimate protest may also form within this type of civil disturbance, and pockets of organized protest may help to channel and contain the negative elements of hooliganism, looting, etc. that might otherwise threaten all area residents. The complexity of these events for law enforcement can be very great, demanding carefully calculated efforts to analyze the nature of the disturbance, and difficult decisions about how to approach and possibly involve the numerous types of persons, gatherings, groups, and behaviors that may have the potential to either mitigate or exacerbate the situation.

The fourth type of civil disturbance, insurrection, involves a deliberate collective effort to disrupt or replace the established authority of a government or its representatives, by persons within a society or under its authority. Some prison uprisings may fall into this category, although others may more properly be classified as riots or protests, depending upon the presence and extent of specific goals and organization, and the type of action used in achieving such goals. The map at the end of this section shows the locations of major correctional facilities in Michigan. An insurrection has the deliberate goal of either replacing established authorities with a new distribution of power, or with the destruction of established power structures in favor of (usually temporary) anarchy or a smaller-scale set of recognized criminal (gang), ethnic, or other group networks and power-structures. The latter circumstances tend to involve disturbances that exist on a relatively small scale, such as in a single local area or involving a prison network or "cult compound" (or any other similarly self-aware group or subculture with identified collective interests and a network that allows rapid communication and collective action). However, larger-scale insurrections are also possible, involving issues of class conflict or other widespread social inequalities, highly divisive political issues, or other important large-scale events that disrupt the social equilibrium because they illuminate areas in which cultural values are not sufficiently shared throughout the society or region that is experiencing the conflict, disruption, or strain. In many cases, this kind of large-scale social strain has developed gradually over time, and involves an entire series of compromises, concessions, and migrations that may temporarily relieve the disruptive social and value conflicts, only to re-emerge after another period of changes and population growth has caused a breakdown in previous arrangements. This description of the causes of social discontent applies to many protests and riots, as well as insurrection. In cases involving the formation or emergence of significant subcultures or counterculture, such as during the Vietnam era, or when dominant values break down or fail to be established on important key issues or mores, there is the potential for insurrection on a larger scale. The Civil War of 1861-1865 was one such instance, in which the authority of the federal government was either accepted or rejected by various states which then aligned themselves in opposition to each other. Between these two extremes (of a purely localized civil disturbance and a

national civil war) are numerous other possibilities for regional, political, class, or ethnic conflicts that may involve one or more categories of citizen in conflict with others. Examples could include prisoners versus law enforcement personnel, a countercultural group versus the establishment, or a violent political activist group in conflict with selected representatives of a contrary viewpoint. (Some such actions may overlap with those of terrorism, q.v.)

Hazard Analysis

Violent protests, disturbances, and riots have occurred throughout our nation's history. The Stamp Act Riots in the American Colonies in the 1760s, the "Boston Tea Party," and the Revolution itself involved riots and insurrection, as discontent escalated into organized international conflict. Though these events have occurred in the past, they are not considered an acceptable part of ordinary modern life.

Although destructive civil disturbances are rare, the potential is always there for an incident to occur. It is possible that risks for future disturbances may be exacerbated today by the ability of modern mass media (television, radio, the Internet, and various wireless communication devices) to instantly relay information (factual or not), in real time, to large numbers of people. That coverage may help to spread awareness of protests, discontent, riots, disorderly "parties," or other incidents to other areas or interested groups and persons, potentially exacerbating an already difficult situation. For example, media coverage of certain events has, in the past, spurred uprisings inside prisons. Communications technologies were also important in swelling the numbers of "Cedar Fest" revelers in recent East Lansing disturbances. Real-time media coverage of unfolding events is a fact of modern life that is inescapable. As a result, law enforcement officials must be skilled in monitoring all forms of media coverage to anticipate public and perpetrator actions and event progression.

Civil disturbances might be separated into several sub-categories of disturbance that could affect a community.

1. <u>Disturbances that center around a particular facility</u>: the facility could be a prison, a courthouse or other center of government, a stadium or other public meeting place, where large numbers of people may at some point gather in a disruptive fashion that is threatening to the community, its businesses, residents, or quality of life. Typically, a risk assessment would examine the history of the facility, and similar facilities in other communities. Such historical information might identify particular conditions that may cause collective behavior to get out of hand. The degree to which a community contains facilities and conditions that have been associated with civil disturbances will indicate the amount of risk that it faces from civil disturbances. The map at the end of this section shows the locations of major correctional facilities in Michigan.

2. <u>Disturbances that arise in general areas experiencing conflict and hardship</u>: This refers to neighborhoods or regions that have experienced one or more economic, social, or political stresses such as poverty, ethnic intimidation, corruption, and/or the notable presence of illegal activities. These ongoing conflicts and challenges may sometimes flare up into more widespread and blatant conflicts and unrest. The important things to recall about these sorts of civil disturbances is that it is the presence of these conflicts and problems (rather than a particular ethnic or demographic composition) that eventually generates broader disturbances. Care must be taken not to inappropriately "profile" areas based on the characteristics of their residents.

3. <u>Disturbances that interfere with normal business functions</u>: Sometimes, protests are organized in a way that is deliberately designed to disrupt the normal operations of one or more businesses, and may also happen to disrupt surrounding business operations or traffic flows nearby. Many such incidents are political, and eventually addressed through court actions or legislative proceedings. Labor negotiations may have associated employee unrest, including strikes. Protesters may object to the existence of specific facilities or businesses, or their location in a specific area, and while seeking to make such a business or its associated activities illegal, may attempt to take more direct action against its employees or patrons. Typically, the perceived harm from such businesses are either from environmental impacts or injury to persons, or social impacts concerning the image or moral standards associated with an area. In other cases, a political

demonstration may not have anything to do with the sorts of facilities or businesses in an area, but merely seeks the most crowded and inconvenient location so as to maximize the attention that it receives.

There is no specific "formula" recommended here for analyzing civil disturbance hazards, but it is probably helpful to include a historical approach that specifically addresses the social conflicts and political controversies affecting disturbance-prone areas of a community. The various costs of past events (crowd control, vandalism, arson, business disruption and closures, injuries, diverted traffic, negative economic impacts) can be estimated along with their past frequency (e.g. three times in the past hundred years) so as to produce an estimated annual cost. The history of cities with similar conditions can also be analyzed in this way, because the risk of a disturbance may be present even though there have not yet been any historic local events. This is particularly true for communities with newly-developed facilities, in rapidly growing areas, or experiencing significant social and economic changes. Their risk of civil disturbance may be increasing but there is not yet a local history of incidents that can be generalized from.

Impact on the Public

Civil disturbance impacts may include deaths and injuries, disruption of services, and short- and long-term damage to a community's tranquility and reputation (which may also affect its property values). Temporary or permanent business closures may be caused by broken windows, looting, arson, etc. Fear (and its associated security costs) may discourage visitors, shoppers, and tourists, and further cause economic impacts on the area (and associated declines in its property values). Direct property damage can be expected to cause inconvenience, at the very least, to area residents and businesses, and there is a further problem of impeded access to the area's services, and to residents' own personal property.

Impact on Public Confidence in State Government

If discontent underlies a disturbance, some persons may generalize, displace, or attribute the source of their discontent to local or state governments. Some discontent may actually be aimed toward government policies involving the environment, housing, land use, wealth distribution, taxation, military conscription, foreign affairs, labor issues, infrastructure provision, civil rights, or other issues. Although government programs often exist that attempt to address these types of concerns and to ensure that particular values (e.g. civil rights) are respected and supported throughout the jurisdiction, widespread or widely publicized disturbances or demonstrations may undermine the effectiveness of governmental programs and thus weaken public confidence in government. Other types of civil disturbance, such as wild festivities after a sporting event, may undermine public confidence in government if a pattern develops in which illegal behaviors become repetitive and widespread.

Impact on Responders

Frustration and anger may be displaced toward responders, and many citizens may not understand the nature of the motivations, rights, or responsibilities involved in either protest or policing actions. Responders may face unwarranted hostility from citizens, for many reasons, and response activities may be impeded by disruptions taking place. Response, medical facilities, communications, or transport capabilities may be overwhelmed. Psychological impacts on responders may arise from role conflicts and the nature of some of the participants involved in the disturbance (which has some differences when compared with "ordinary crime").

Impact on the Environment

Civil disturbances that stem from labor unrest (or other problems with industrial relations) may involve sabotage that causes the release of harmful substances or otherwise damages the ecosystem in an area. Civil disturbances that involve disruptive forms of collective behavior may include the lighting of fires that release toxins, especially when non-traditional manufactured items are used as fuels. Damage to property may, accidentally or deliberately, include sites that contain hazardous materials. Unruly crowds may disrupt or prevent needed maintenance activities by utility repairmen or industrial workers and thus inadvertently cause environmental problems to occur because of resulting infrastructure failures.

Significant Civil Disturbances in Michigan

As a heavily populated, politically active, well-urbanized and nationally-prominent industrial state with a long history (statehood was achieved in 1837), Michigan has seen many significant civil disturbances, including labor disputes, protests and political demonstrations, social strife, hooliganism and countercultural movements, rioting and prison uprisings. In the case of prison uprisings, the Michigan timeline contains two major points in which uprisings were observed in the modern prison system—the years 1952 and 1981. Event-related hooliganism appears to be a relatively recent historical phenomenon, appearing only after the urbanization of the state's population, the emergence of mass media, and the rise of the modern auto-oriented transportation network throughout the state (the Interstate Highway System started in the late 1950s).

Following are brief synopses of some of Michigan's major civil disturbance events:

Michigan's Significant Civil Disturbance Events

Protests

Major labor disputes, in which workers protest and seek changes in their relations with employers, have occurred in virtually every decade in Michigan. However, some have been worse than others in their overall impact on the communities in which they have occurred. Unfortunately, some disputes have turned violent at times, requiring a response by law enforcement agencies to quell the disturbances and maintain order. Numerous political protests have also occurred throughout the state's history. (Please refer also to the subsections on "Riots" for more description of how some of these protests are rooted in social and economic conditions. In cases involving violent protest, the distinction between a protest and a riot primarily involves the level of formal organization and planning behind the activities that occurred.)

Early 1800s Statewide

Native-American resistance to pressures that were compelling land cessions (the first of which took place in 1795), and widespread activity organized by Tecumseh (a Shawnee chief) led to direct military conflict. The famous Battle of Tippecanoe took place in Indiana on the morning of November 7, 1811, killing dozens and wounding several hundred of the forces on both sides. American suspicion that the British may have encouraged various Native American hostilities was one of the major reasons leading to the War of 1812, and during that conflict, certain tribes fought and killed numerous American citizens in Michigan. Overall harm to the Native American tribes was far greater in the long run. Various Native American migrations took place, often compulsory to a greater or lesser extent. A large part of the Potawatomi moved west in the 1830s. The final land cession in Michigan took place in 1842.

1874 to 1879, 1883 to 1885, 1893 to 1897 – Periods of Economic Recession, Depression, and Labor Unrest

One of the patterns evident from even the earliest of modern American industrial recession periods is that the competition for jobs can take on aggressive and illegal forms—especially when there is an over-supply of labor for lesser-skilled or unskilled jobs. Patterns of worker intimidation were reported under these conditions, in many cases organized along ethnic lines, and later leading into larger-scale patterns of violent and destructive means of assertion that came to be associated with some forms of labor organizations (varying with the industry and the time period). To the extent that legal and police powers were used to protect employers when using discriminatory hiring and firing practices, or not providing safe working conditions, or controlling their workers with exploitation and force, such workers might turn to underhanded and illegitimate means to even the odds and assert their rights to safe and reliable working conditions and wages. From these desperate and compelling circumstances of social conflict and inequality, organized crime started to develop and become entangled with legitimate parts of society's social, political, and economic institutions. In other cases, radical and socialist political ideology would eventually connect with violent activism and illegitimate funding mechanisms, some of which were international in scope.

Incidents of workers being intimidated or pressured to give up their jobs (so that their harassers could take them) are documented in Detroit during these time periods, but it is assumed that such activities were more widespread, and were not limited to just the cities. Incidents usually occurred at a small or moderate scale but employed physical violence both for offense and defense, and collectively amounted to large-scale patterns of discrimination and conflict. For example, on August 25, 1893 a group of unemployed men accosted some laborers and teamsters, and fighting led to arrests and injuries. At a meeting of Polish workers the following month, labor advocate Walter Kwiecinski saw five hundred persons and heard claims that public works jobs were primarily being given to Italians and Canadians, while he himself had assembled a list of some 800 unemployed Polish residents seeking such jobs.

April 23, 1891 Detroit

In the midst of a four-day strike, a violent riot erupted in protest against the strikebreaking efforts against the City Railway Company, and a number of streetcars were burned. (It has also been reported that some of the disruption marked a general dissatisfaction with the streetcar services).

April 18, 1894 Detroit "Connor's Creek" labor strike and uprising

During the depression of the 1890s, an excavation project for a water main, just east of the city's boundary at the time, was manned by some 300 workers, who revolted at the conditions for wage reimbursement that the city Water Board had set (estimated at only about one-third of already established wage rates). The workers demanded a higher wage, and stayed on the site throughout that day and the next, to prevent any other workers from being brought in to replace them. On the third day, men arrived from the Wayne County Sheriff's Office, but only succeeded in annoying the workers. A project foreman was attacked by a worker, and the scene quickly exploded into violent chaos when gunshots followed the attack. The mob of workers with picks and shovels surged around the armed lawmen and the project's foremen. Although the violence lasted only a few minutes (resulting in the beating of the foremen and law enforcement officers), there were about 20 serious injuries, and a total of three persons ended up dead from gunshot wounds. By the end of the day, 21 persons had been arrested. Mass meetings took place on April 22, at which many thousands of ethnic workers gathered to press for policy changes.

Spring 1911 Grand Rapids

In a move of historic solidarity, more than 6,000 workers walked out of about 50 furniture factories in Grand Rapids on April 19, 1911, protesting pay and working conditions. Most worked six 10-hour shifts for less than $2 a day. After the walkout, factory owners did their best to maintain production by bringing in other laborers. Anger built among the striking workers and tensions exploded on May 15, when a company tried to drive strikebreakers in cars to the factory through a crowd of about 1,200 strikers and supporters gathered outside the building. That evening, people poured into the streets from the surrounding neighborhood, where a riot began when the crowd grabbed rocks and pelted the factory company's cars. In the ensuing mayhem, firefighters and police were injured. Police responded by firing their pistols in the air and beating back the rioters with their billy clubs. The fighting drew more people into the streets to help the strikers, swelling the crowd to 2,000. It took firefighters with hoses and a lot more police to rescue the car and the strikebreakers. When it ended at midnight, every window in the factory had been smashed. There were injuries and arrests but no deaths. The riot was one of the few violent confrontations in what was one of the largest strikes by a non-unionized workforce.

July 1913 to 1914 Upper Peninsula

A copper miners strike in the Upper Peninsula resulted in months of vandalism, murders, threats and intimidation, harassment, and violence, as strikers and unionists clashed with strikebreakers and law enforcement personnel. This conflict pervaded the entire copper mining region, and did not merely occur at the work site locations themselves. Nearly all mines were closed down in the area, and nearly 15,000 miners stopped work. Rioting and violence was involved in the initial July clashes that prevented non-striking miners from going to work. Things calmed for a while, until some mines attempted to re-open in August. Strikebreakers (often new immigrants to the country) were terrorized away from the mines, and gun battles also took place which resulted in deaths. Court cases started, to try to reverse laws that had developed in opposition to the strike. By October, several larger mines had opened, and many former workers moved out of the area. A union-organized Christmas party in Calumet turned disastrous when someone yelled "Fire!" A long stairway led to inward-opening exit doors and in the stampede of persons leaving the building, people were pushed by the crowd and started falling down the stairs and being crushed in the crowding at the exit doors. In the end, more than 70 persons were killed, most of whom were young children. Following a disagreement about whether the victims families should accept gifts, a local union headquarters was stormed and its leaders threatened with lynching. By early 1914, the union announced that it was giving up the strike.

August 5, 1919 Muskegon

Muskegon residents protested when the Muskegon Traction & Lighting Company attempted to raise street car fares by 1 cent (from 6 cents to 7 cents) on the evening of August 5, 1919. Over 30 people, unarmed, tumultuously assembled in the streets near city hall. An argument between a few factory workers and a street car conductor escalated into a citywide rampage by a mob of nearly a thousand. They obstructed the passage of street cars, took street cars off their tracks, overturned them, and destroyed the windows and the fixtures of the cars. By dawn on August 6, the Michigan Traction & Lighting Company's car barns were destroyed and 13 street cars were also destroyed. Warning shots fired by the police only further enraged the rioters, forcing the officers to flee for their lives. No determined or organized effort was made by the police force of the city to suppress the tumult or to arrest those engaged in the incident that lasted from about 6pm until 4am. Citizens called upon the fire department to assist in suppressing the riot, but the organization refused to respond. Therefore, no arrests were made of any person engaged in the disturbance. The incident destroyed a sizable portion of the fleet, with property destruction estimated at $100,000 to $125,000, (about $1.3 to $1.5 million in 2011 dollars.) The street car service of the city was interrupted and suspended for a period of two weeks. The mayor and the common council took few steps to investigate or discipline the fire or police departments for failing to for suppress the riot and disperse the crowd. Therefore, the mayor and eight aldermen of Muskegon were found guilty of official misconduct and willful neglect of duty in connection with the street car riots.

March 6, 1930 National Protests

As the full effects of the Great Depression were being felt, discontent became organized into a nationwide series of gatherings, which included the involvement of communist groups. In Detroit, many tens of thousands participated, and violence resulted when protesters resisted police efforts to disperse them.

March 1932 Dearborn

A "Hunger March" led by 10,000 demonstrators (most of whom were laid-off autoworkers), included a battle with police that left four marchers dead and dozens injured. The Detroit portion of the march was peaceful, but as Dearborn was reached, police tear gas was reacted to with the throwing of stones and mud clumps. Dozens of persons were arrested.

1936 to 1937 Flint, Detroit, Dearborn, and other cities

A series of labor conflicts wracked the auto industry during these years. In a series of "sit down strikes" that started in Flint on December 30, 1936, industrial sites were occupied by workers who sought improvements in their wages and working conditions. Many picketers wielded sticks and other potential weapons, and many industries had their own teams of "muscle" and security men, as well as the general support of law enforcement personnel. At the time, the law gave more recognition to the right of factories to use force to protect their property than it did to unions and workers to organize and protest working conditions. On January 11, 1937, tear gas and fire hoses were used against picketers in Flint, who employed various makeshift weapons, and the conflict then escalated to the use of firearms by police. Several dozen persons were injured on both sides of the issue. In Dearborn, on May 26, 1937, union representatives were viciously attacked by company security men, while meeting with news reporters in a widely publicized event known as the "Battle of the Overpass." Many nearby persons were also attacked, beaten, and driven away, including women who wanted to hand out leaflets. Various persons suffered severe injuries and were hospitalized. The reporters themselves were harassed, and photographs of the event that soon became world-famous had almost been confiscated by company strongmen.

NOTE: Various issues involving union organization took decades of discontent, conflict, and legal and political action to be ironed out into the modern forms in which labor-industrial relations exist today. Although these issues became more stable by the second half of the 20th Century, some of their aspects are still evolving even today.

1948 Detroit

Protests by white residents of the Fenkell-Linwood area (Quincy and Baylis Streets) took place in an effort to discourage African-American residents from living in the area. Although this incident was not itself considered to be a riot (see the subsection that follows), it was indicative of the potential for such disturbances to occur in the area. Among other problems in the area, at least one other serious disturbance occurred two years later (see the February 1950 entry in the Riots subsection that follows).

1964 to 1972 Numerous Anti-War Demonstrations at multiple locations

Student-led anti-war protest demonstrations across the country, beginning with a major uprising in Berkeley, California in 1964, spread to virtually every major university campus (including several in Michigan) by the late 1960s and early 1970s. Some protest demonstrations were very large and involved violence and rioting, sometimes increasing in response to the arrival of police. In Michigan, major demonstrations occurred in East Lansing, Ann Arbor, and

other university communities. In East Lansing in May of 1972, thousands of student protesters blocked Grand River Avenue for several days, in anger over escalating U.S. activities in the Vietnam War. Eventually, Michigan State Police and local law enforcement authorities ended the blockade.

1960s and 1970s Detroit, Flint, Lansing

In the 1960s and early 1970s, strikes between the United Auto Workers Union and the major automobile manufacturing companies headquartered in the state (General Motors, Ford, Chrysler and American Motors) occasionally led to clashes with police. These strikes primarily affected Metro-Detroit, Flint and Lansing.

July 1995 to 1997 Metro Detroit

The most recent period of serious labor unrest has been the Detroit Newspaper Strike, which started in July 1995 and continued on through 1997. (The labor dispute officially ended in December 2000 when the involved unions ratified new contracts, 5 ½ years after the strike began.) The strike was marked by periods of sporadic violence and involved approximately 2,500 workers from Detroit's two daily newspapers. The strike negatively impacted many facets of the community, and at times required extensive use of law enforcement resources to supervise strike-related activities and maintain order. The most significant strike-related activity occurred on June 20-21, 1997, when a national union mass demonstration was held in support of the strikers, drawing over 100,000 people to Detroit.

Hooliganism

1970s-1990s Detroit Arson and "Devil's Night" Disturbances

On the night before Halloween during these decades, the expected number of fire calls was seen to grow to well beyond the norms for the rest of the year, and seriously challenged the ability of fire workers to respond to. Although not solely an occurrence of hooliganism, as a reputation became established for the ongoing pattern of "Devil's Night" fires and disturbances, it certainly attracted hooligans that compounded the problem, and the difficulties of dealing with it. Although Devil's Night had traditionally been associated with youthful pranks (which also prompted more serious instances of vandalism and delinquency), only a portion of the arson events can be attributed to mere hooliganism. Rather, the loss of structures were in many cases caused by deliberate criminal acts, sometimes with the intention of removing vacant properties that in their cumulative disrepair had become dangerous to enter or be around, and that in other cases were perceived as attractive locations for illegal criminal enterprises. The problems were mitigated through a combination of community partnerships, volunteer activism ("Angel's Night"), more concentrated preparation and law enforcement, and expanded demolition and clearance activities on the part of the city, as well as the gradual disappearance of the most readily targeted structures and an overall decline in city population over those decades.

1984 Detroit Sports Championship Melees

The success of Detroit's professional sports teams is sometimes unfortunately marred by violence and rioting that can gain significant national attention. After the Detroit Tigers won the 1984 World Series, the ensuing celebration turned ugly when cars were overturned and burned and nearby homes and businesses damaged. This was widely covered by the national media.

1990 Detroit Sports Championship Melees

After the Detroit Pistons won their second NBA Championship, the "celebration" following the victory resulted in eight deaths and numerous injuries. This was widely covered by the national media and tarnished Detroit's image at a time when it should have been able to peacefully revel in its sports success. Unfortunately, similar scenarios have played out in other major cities in recent years after professional sports teams have won a championship.

1980s-early 1990s East Lansing and Mt. Pleasant Civil Disturbances

Several clashes between large groups of students and police occurred in East Lansing in the late 1980s over an annual street party known as "Cedarfest." Injuries and property damage resulted from these disturbances, which also involved the use of tear gas to try to disperse rowdy and hostile crowds. Central Michigan University in Mt. Pleasant was also witness to a series of similar parties turned into riots in the 1980s and early 1990s, with the resulting clashes often involving hundreds of students and police.

1997 East Lansing Civil Disturbances

On September 6, 1997, over 500 revelers celebrating a Michigan State University football victory gathered on Gunson Street in East Lansing and set bonfires, destroyed trees and street lamps, shattered glass, and hurled bottles at police.

1998 East Lansing Civil Disturbances

On May 1, 1998, a student protest against Michigan State's decision to ban alcohol at a popular on-campus partying place for football games erupted into a riot that spilled onto the streets of East Lansing, ultimately involving over 3,000 people. The riot forced East Lansing police to use tear gas to disburse the crowd, but not before several large fires were set, traffic was blocked on Grand River Avenue, and rocks and bottles were hurled at police.

1999 East Lansing Civil Disturbances

On March 27, 1999, the largest and most serious disturbance occurred after Michigan State's loss in the NCAA Final Four basketball tournament. The melee lasted for several hours before police were able to quell it with tear gas. Total property damage exceeded $250,000. Over 130 people were arrested and charged with various crimes stemming from their participation in the riot. Nearly 120 were convicted and ordered to serve jail time, pay fines, or both. Several students were also expelled from the university. Follow up investigations by police revealed that some of these incidents were spontaneous events, while others were pre-meditated riots with the sole purpose of wanton destruction of public and private property. These types of riots continued to occur the for the following few years during the basketball tournament season, resulting in thousands of more dollars in damages and leading to several more arrests.

September 9, 2001 Kalamazoo Civil Disturbances

In the early morning hours of September 9, 2001, a riot broke out at a block party near the Western Michigan University and Kalamazoo College campuses in Kalamazoo. The crowd, which police estimated at 2,500, pelted officers with bottles and rocks, tore down street signs, broke windows, and set fires. Three police cars were heavily damaged and two police officers were injured in the melee. Twenty-one people were arrested—many charged with felonies—and nearly 50 were ticketed for underage drinking and other misdemeanors.

March 17, 2002 Kalamazoo Civil Disturbances

On the night of March 17, 2002, a spring break party around a bonfire near Western Michigan University got out of hand as people clashed with police in riot gear trying to disperse them. A car was set on fire and several other parked cars were damaged. Rioters climbed telephone poles, pulled down traffic signs and set several dumpsters on fire. About 30 officers moved in when someone threw a bottle through the windshield of a passing car. Three people were charged with unlawful assembly and a fourth was accused of assault.

2006 Saginaw Arson and "Devil's Night" Disturbances

The 42 fires reported in Saginaw's two-day period before and during Halloween were well above what would normally be expected during an ordinary two-day period. The community responded seriously and quickly to mitigate this hazard, and subsequent years had only about a quarter (or less) of this number of fires on those two days.

Riots

March 6, 1863 Detroit Faulkner Riot

False reports of the victimization of two girls led to the storming of black neighborhoods in Detroit by white mobs. Dubbed the "Faulkner Riot," extensive property damage took place, about 200 were left homeless, 2 persons were killed, and at least 20 were injured.

1885 to 1887 Detroit Parish-related Disturbances

Ethnically distinctive areas of major cities may involve issues that those from other ethnic groups may find unfamiliar or even mysterious. Such was the case in late 19th Century America, as a large number of Polish immigrants began to make a place for themselves in Detroit, after their homeland had been "partitioned" among German, Russian, and Austrian conquerors. The 1880 population of Detroit was 116,340 persons, of whom 45,645 were foreign-born. By 1890, the population was 205,876, and 81,709 of these residents were foreign-born. There were 158,157 city residents reported as having either fully foreign or "mixed" foreign parentage, in 1890. Thousands of these had Polish identity, many of whom stayed mostly within their own ethnic neighborhoods and parishes, since they hoped to be able to return to their homeland in the future (a Polish state was indeed re-established in 1918, at the end of World War I).

Riots and disturbances surrounded the suspension of Father Dominic Kolasinski from his parish, St. Albertus (at St. Aubin and Canfield Streets). The Polish area of the city's near east side was affected by antagonisms and rivalries that led to numerous gatherings, protests, disorder, and even outright violence. Father Kolasinski had been accused of mismanaging his parish's affairs, and then accused of having extramarital relations with women. His loyal followers, who tended to share a common language and area of origin in their native Poland, mistrusted and defied the decrees of the area's German Bishop, who suspended Father Kolasinski and appointed replacement clergy to take over the parish. Antagonisms toward Father Kolasinski's accusers, and even toward the replacement clergy and the Bishop himself, caused numerous gatherings and protests over the course of many months.

On December 1, 1885, a crowd swarmed around the church after ejecting a replacement priest, followed by a 20 minute melee with police. A crowd protested around the home and business of one of Father Kolasinski's accusers. On the next day, an even larger crowd pelted police-accompanied replacement priests, and about a thousand persons surrounded an accuser's home and store on Hastings Street. During the following weeks, various crowds assembled to block the replacement priest from taking up duties at the parish, and threats of violence toward Kolasinski's accusers increased. On December 22, 1885, about 50 "roughs" engaged in demonstrations and threats against the new priest. Finally, on December 24-25, there was a standoff between different factions (of about 50 persons each) gathered to support or protest the reinstatement of Father Kolasinski, and although this confrontation was quieted by police, gatherings recurred in the early morning hours, with hundreds of additional persons arriving per hour around the church, hoping for an early Christmas Mass. By the dawn hours, a crowd of several thousand had assembled, and then marched to confront the Bishop at his downtown residence on Washington Street. The Bishop left discreetly to celebrate Mass at a different church, causing crowds to find him and then be turned away. The crowds dispersed by midday but about 400 recongregated at St. Aubin and Willis, surrounding the store and residence of one of Kolasinski's accusers. After several hours of shouting and threats, a resident emerged with a handgun, killing one person and wounding another, before police stormed the house and arrested all three men inside. The next day, about 2000 Polish residents gathered at St. Albertus and then surrounded the store and home where they smashed all windows until its owner fired shots in the air and more than 100 police were able to divert and control the crowd. Subsequent months throughout 1886 saw occasional disturbances of smaller magnitude: a March 5 gathering of up to 500 shouting persons at Fredro Hall (at Russell and Leland Streets), an April 9 clash between Polish factions at Fredro Hall, and an August 16 anti-Bishop demonstration in which a crowd near the church broke windows on a nearby convent and orphanage. On March 20, 1887, more than 3000 persons gathered for an anticipated re-opening of St. Albertus, which resulted not only in disappointment but to continued clashes between Kolasinski's defenders and opponents, in which several serious injuries of policemen and activists resulted. A girl was wounded by a police gunshot, and 50 officers eventually managed to clear the streets. Numerous arrests followed over subsequent days. On May 19, 1887, more than a thousand persons gathered to expel a new priest, but were themselves dispelled by about 100 organized men. By 1889, following the resignation of the German Bishop, his replacement by a new Irish one, and the departure of one of Kolasinski's accusers, these sorts of disturbances had calmed quite a bit, although a great deal of alarm and misunderstanding had spread throughout the city and led to a cycle of stereotyping and segregation of "the Polish quarter" and its residents. A supporter of Kolasinski claimed that there were at least "5,000 of us, besides women and children," who would go without a church while waiting determinedly for the priest to be allowed to return. By 1889, Kolasinski had returned and started to lead new services for his thousands of supporters (estimated as numbering ten thousand or more), also starting the construction of an alternate parish three blocks to the west of St. Albertus.

1914-1918 World War I Ethnic Hostilities

Ethnic hostilities increased as World War I started and progressed (American involvement in the war began in 1917). The loyalty of various Germans was questioned, as well as persons of other ethnicities corresponding to the hostile Axis powers in Europe, and various pressures and hostilities resulted in the vandalism of homes and businesses.

February 28, 1942 Detroit "Sojourner Truth" Housing Clashes

A riot took place when white residents protested the right of 200 African-American defense workers to move into a new housing project (named after Sojourner Truth) in the northeast part of the city. An angry picket line was formed, and conflicts escalated when one of the new residents tried to cross the line in a car. More than a thousand persons were in the area, participating in the conflict in some manner. More than 40 persons were injured and 220 were arrested.

June 20-21, 1943 Detroit Major Riot

A series of small racially-oriented skirmishes in Detroit escalated into a major riot, as about 100,000 persons massed near downtown Detroit (not all of whom were actively involved in violence, however). The riot quickly overwhelmed city and state police, so Federal troops in armored cars were brought in at Governor Harry Kelly's request to help restore order. The riot was quelled after more than 36 hours, but not before it claimed 34 lives and caused over 700 injuries. More than 1,800 arrests were made.

February, 1950 Detroit Ethnic Hostilities

Disturbances in the Fenkell-Linwood area (Princeton Street) involved white protesters stoning a house and vandalizing a car belonging to a new African-American resident, followed by at least one antagonistic meeting (150 residents at a neighborhood association) that expressed a mixture of fears, bigotry, and

protests at changing residential patterns and policies in the city. (Please refer to the General Comments about Urban Civil Disturbances subsection that follows in this document.)

Aug. 30 - Sept. 5, 1966 Benton Harbor Riot

After a fatal shooting that had racial significance, street violence erupted in the city. The rioting included stones being thrown at cars. A man was arrested for the shooting, and things eventually quieted after the National Guard was called in, on the order of Governor George Romney.

July 23 to 29, 1967 Detroit Riots

One of the most infamous riots in the United States occurred in Detroit from July 23-29, 1967. This uprising resulted in the greatest loss of life and the largest destruction of property of any of the national riots of the 1960s. Looting, burning, and sniping reached a scale unknown to in a U.S. city in the twentieth century, exceeded only by the 1863 New York City Draft Riot. The violence erupted when police raided an illegal after-hours drinking club (a "blind pig"), arresting numerous patrons and the bartender. Shortly thereafter, a crowd that had gathered began to loot nearby stores. Within an hour, the looting had spread to a 16 block area, with many stores having been plundered and set afire. Police estimate that over 5,000 persons were actively involved in the rioting, which quickly engulfed large sections of the city - as much as six to seven miles out from the initial flash point. Over 150 fires consumed a 15 block area and burned uncontrolled when firefighters were forced to withdraw after being pelted by objects.

In response to the rioting, then-Governor Romney declared a state of public emergency, mobilized nearly 8,000 National Guardsmen and several hundred Michigan State Police troopers to assist in restoring order, and requested supplemental Federal military assistance. Nearly 5,000 Army paratroopers were dispatched to Detroit to assist the National Guard and state and local police units. Over 13,000 military troops, guardsmen, and police worked to quell the disturbance. Over 7,000 people had been arrested for their participation in the incident, 43 people had been killed, and over 1,000 had been injured. Five thousand had been left homeless. Over $50 million in damage had been incurred, due to the fires and looting.

The 1967 Detroit riot was part of a series of riots that occurred in cities across the country in the mid-1960s. In 1967 alone, over 160 riots occurred in U.S. cities and towns, many in communities with less than 25,000 in population. Outside of the Detroit riot, the other mid-60s riots that gained most of the national attention were the August, 1965 riot that occurred in the Watts section of Los Angeles (which resulted in 34 deaths, 1,000 injuries, 600 damaged buildings, 4,000 arrests, and $35 million in losses) and the July, 1967 Newark, New Jersey, riot, which caused 26 deaths, 1,500 injuries, and 1,400 arrests. More than 300 fires were reported in the latter disorder, and property damage was estimated at more than $15 million. Rioting continued in 1968, following the assassination of Martin Luther King, Jr. Disturbances occurred in over 130 cities, with the final tolls standing at 46 deaths, 7,000 injuries, more than 20,000 arrests, and nearly $100 million in damage (mostly from the more than 2,600 fires set). Over 80,000 military troops were used to quell those incidents.

July, 1975 Detroit Riot

Disorder followed the shooting of a black youth (who died the next day) by the white owner of a bar near Livernois and Fenkell. Crowds numbering several hundred gathered and began to damage area businesses, causing tens of thousands of dollars worth of property damage. Fighting broke out, focused on racial antagonisms. An uninvolved motorist trying to drive through the area ended up being pulled from his car and died three days later from the injuries he sustained. Mayor Coleman Young, who at the time had only been recently elected, helped to calm the disturbance by bringing in hundreds of law enforcement personnel and also personally walking the area for the following two nights. The bar owner was charged with second-degree murder, and the bar itself had been trashed by the crowds. About 100 persons were arrested.

June 16-17, 2003 Benton Harbor Riot

The city of Benton Harbor erupted into riots on June 16-17, 2003, after a motorcyclist being chased by police crashed into an abandoned house and died. Two nights of violence brought hundreds of police to the area to calm the citizens who felt exasperated with community conditions and circumstances. Rioters roamed a six to eight block area, setting fires and attacking passers-by, police officers, and firefighters. One person was shot in the shoulder and others were beaten and stabbed. In all, about 15 people were injured. It was estimated that about 23 homes were damaged or destroyed by fire. A total of about 10 people were arrested.

Insurrection

Early 1800s Statewide Native American Struggles

Native-American resistance to pressures that were compelling land cessions (the first of which took place in 1795), and widespread activity organized by Tecumseh (a Shawnee chief), led to direct military conflict. The famous Battle of Tippecanoe took place in Indiana on the morning of November 7, 1811, killing dozens and wounding several hundred of the forces on both sides. American suspicion that the British may have encouraged various Native American hostilities was one of the major reasons leading to the War of 1812, and during that conflict, certain tribes fought and killed numerous American citizens in Michigan. Overall harm to the Native American tribes was far greater in the long run. Various Native American migrations took place, often compulsory to a greater or lesser extent. A large part of the Potawatomi moved west in the 1830s. The final land cession in Michigan took place in 1842.

1952 Jackson County Prison Uprising

Although violence is a fact of life in Michigan's prisons, large-scale, deadly prison uprisings are relatively rare. However, there have been two such incidents in the Michigan prison system over the past 50 years that have caused significant injury, loss of life, property destruction, and response support from other state agencies and the involved local government. The first of those incidents occurred from April 20-24, 1952, at the Southern Michigan Prison in Jackson. That five-day siege resulted in the death of one inmate and serious injury to nine others. More than a dozen guards were held hostage throughout the uprising. Eventually, all were released, though several had been beaten or were otherwise wounded. Officials estimated that approximately one-half of the prison's 6,500 inmates had participated in some way in the rioting. Numerous prison buildings had been severely damaged or burned to the ground. When the dust settled, the official damage estimate was put at $2.5 million. The damage was not fully repaired for several months. Throughout the uprising, the Michigan State Police had provided critical assistance in containing and eventually controlling the riot. The last Michigan State Police trooper left the prison on Labor Day, over four months after the uprising began. Sometime after that, a new Department of Corrections riot squad was formed to handle any such incidents in the future. It is interesting to note that this incident at Southern Michigan Prison was the worst in a string of 30 major prison riots that occurred across the country in 1952 and 1953.

1981 Jackson, Marquette, and Ionia Counties Prison Uprising

The second major prison uprising in Michigan occurred over the Memorial Day weekend in 1981 at the State Prison of Southern Michigan in Jackson, Marquette Branch Prison in Marquette, and the Michigan Reformatory in Ionia. The uprisings, which occurred on May 22 at Jackson and Ionia, and again on May 26 at Jackson and Marquette, were thought to be related. Although all three facilities were damaged, the State Prison of Southern Michigan incurred the worst damage. The disturbances began when officials from the Michigan Corrections Organization at the State Prison of Southern Michigan attempted to take administrative control of the prison and lock down prisoners over the Memorial Day weekend. Rioting broke out at the facility, which then spread to

the Michigan Reformatory in Ionia later in the day. The situation temporarily settled over the weekend, but rioting began again on May 26 at the State Prison of Southern Michigan, which then spread to Marquette Branch Prison. Both disturbances were quelled later in the evening, but only after major physical damage had been inflicted on the facilities.

The final damage figures for the two days of rioting were significant. The May 22 disturbances at the State Prison of Southern Michigan and the Michigan Reformatory resulted in 67 inmates and 27 staff members being injured, many requiring hospitalization. The May 26 disturbances saw an additional 44 staff members injured, along with 42 inmates. Fortunately, no lives were lost in either disturbance. The physical damage to the three facilities totaled $5 million, with another $4.1 million in riot-related costs incurred. Damages at the State Prison of Southern Michigan included fire and smoke damage to eight cell blocks, destruction of eight modular units, and damage to the academic vocational building, the inmate store, and the food service facility. The master key system also had to be replaced. At the Michigan Reformatory, two cell blocks were damaged, in addition to the prison chapel, the food service building, and the school. The master key system also had to be replaced at this facility as well. At the Marquette Branch Prison, two vocational education buildings were destroyed, and the industries building, service building, and six cell blocks were damaged.

It took many months for the damage at the three facilities to be totally repaired and services brought back to normal. In the end, legal and disciplinary actions were taken against 19 corrections personnel and numerous inmates for their roles in the two disturbances.

August 13, 1995 Lenawee County Prison Uprising

At the Gus Harrison Correctional Facility, three housing units were taken over by prisoners. Several correctional staff were assaulted as they attempted to secure prisoners during a power outage. Several prisoners were also assaulted by the rioters, as well. Fortunately, no lives were lost as the housing units were eventually retaken by correctional gun squads. During the incident, the facility was assisted by the Michigan State Police, Lenawee County Sheriff's Department, and the City of Adrian Police Department. A great portion of the housing units sustained heavy damage during the disturbance.

General Comments about Urban Civil Disturbances

Various racial and ethnic bigotries have been expressed at numerous times and locations throughout Michigan, sometimes exacerbated by major news events (which can be local, state, or national). For example, anti-German sentiments were frequently expressed during World War I. Some of these ethnic and racial antagonisms were institutionalized and enforceable by laws, contracts, or other arrangements. One example of this would be the "restrictive covenants" that prevented the sale of designated properties to those in specified minority groups. The use of restrictive covenants became unconstitutional as a result of a court decision (Shelley vs. Kramer) in 1948, but similar de facto patterns of residential pressures and segregation would still be evident for many decades afterward.

During periods of turmoil, social change, and immigration, the challenges of these large-scale social patterns often correspond with the symptoms of social conflict—in the attitudes, behavior, and policies of individuals, groups, organizations, and institutions. The number of civil rights protection programs and options has increased over time, and the Michigan Department of Civil Rights was formed in 1965, but it is useful to be aware of the possibility that widely publicized (and sometimes poorly understood or misrepresented) events may cause surges in conflicts and problems. Stereotyping, scapegoating, and discrimination can lead not only to individual crimes, but also to the disruption of neighborhood residents and the escalation of mistrust, fears, and protests into riotous incidents. It is also possible for these tensions and incidents to endure and to form an ongoing pattern of social conflict (see the section on Terrorism and Major Criminal Incidents).

Further complicating the situation, particularly in urban areas, is that certain types of "illegitimate opportunity structures" (criminal organizations) have been known to give preferential treatment to those from particular family or ethnic backgrounds. Within the complexity and dynamics that are present in modern large cities, it has been very common for individuals to mistake or confuse their individual experiences of crime, poverty, etc. with larger-scale patterns of ethnicity, race, and social class, and to draw unwarranted conclusions about "all" persons who are perceived to be members of a particular class or group.

In actuality, social science has shown that within every large descriptive category of persons (age, race, gender, nationality, social class, etc.) there is a great deal of diversity. This diversity becomes apparent as an individual has more experience and interaction with a wide array of persons from a given background (e.g. ancestry or national origin), social situation (e.g. poverty), or socially defined category (e.g. ethnic identity), or with particular physical characteristics (e.g. sex). There usually turns out to be just as much diversity within any such large categories of persons as there is between them (to the extent that it is even valid to try to describe or define "them" collectively as a group). There is no quick shortcut to fairly and validly judge a person's character or motivations, based upon such large-scale classifications as gender, race, or social class—one must instead actually observe and get to know each person as an individual in order to start to make such assessments. (Gang-related

clothing or the exhibition of countercultural symbols may be perceived as individual choices, rather than confused with a broader ethnic or other category, but even in such cases, it is often very difficult for a stranger to be able to judge the degree of authenticity and the actual meaning of such symbols for the persons who use them. On the other hand, an individual's decision to adopt a cautious or wary attitude in an unfamiliar setting or when meeting new persons is not quite the same as exhibiting deliberate prejudice, bigotry, or discrimination.)

National Situation

Nationally, over the past 50 years, a significant civil disturbance has occurred somewhere in the country in virtually every decade. Violent rioting has been particularly troublesome, with major events having occurred in Los Angeles, Newark, and Detroit in the summers of 1967-68, in Miami's Overtown and Liberty City areas in 1980 and 1989, in Los Angeles in 1992, in St. Petersburg, Florida in 1996, in Seattle in 1999, in Cincinnati in 2001, and in Benton Harbor in 1966 and 2003. The toll in terms of injury, loss of life, and property damage from these events has been staggering. Damage from the 1992 Los Angeles riot alone was in excess of $1 billion. Perhaps even more tragic has been the lingering, negative impact and loss of investment in these ravaged communities. Many of the riot areas still have not fully recovered from the damage, destruction, and negative image brought on by these events.

Programs and Initiatives

Civil disturbances are often difficult for local communities to handle. Officials must walk a fine line between the constitutional right of individuals and groups to assemble and air grievances, and the overall needs of the community to provide essential services, ensure the personal safety of citizens, prevent property damage, and facilitate normal commerce. Fortunately, most demonstrations and large public gatherings are held in a peaceful, responsible manner. However, there never seems to be a shortage of groups whose primary objective is to disrupt normal activities and even cause injury and property damage.

Handling events that could result in civil disturbance is a difficult operation, at best. Normally, law enforcement personnel are outnumbered several times over, and they are often ill equipped and under-trained to handle a large, unruly crowd. Many police departments offer some type of disturbance training, but because the events happen so infrequently, and turnover is relatively high in law enforcement positions, constant re-training is necessary. Unfortunately, that training costs money, and many departments are already hard-pressed to meet basic training needs. Nevertheless, proper training of law enforcement personnel, adequate resources, and incident anticipation and planning are the keys to successful incident management. Mutual aid agreements tend to be vital to the timely handling of civil disturbance events.

Another important element in response to civil disturbances is the proper visual documentation of the incident from start to finish. To that end, many police departments have begun to videotape incidents that could result in a civil disturbance. Such documentation can be used at a later time to identify criminal acts and perpetrators, review actions, and make determinations as to an incident's cause.

In most civil disturbances, local law enforcement resources, augmented where necessary by the Michigan State Police, are sufficient to manage and end the incident. If, however, local resources are not adequate, the Michigan National Guard can be activated to provide for the immediate preservation of public peace and safety. A Governor's declaration of emergency is necessary to activate the Michigan National Guard.

College Campus Anti-Rioting Law

In the wake of the riot that occurred at Michigan State University in 1999, a new state law (2000 PA 51) aimed at curbing rioting on or near (within 2,500 feet of) Michigan's public colleges and universities took effect on June 1, 2000. This Act, which amended the State Code of Criminal Procedure, allows judges to ban campus rioters and others convicted of riot-related offenses, unlawful assembly, and civil disorder from all public college and university campuses in Michigan for up to two years for a felony conviction, or one year for a misdemeanor. (Note: Although the Act is intended to serve as a deterrent to the type of unlawful behavior exhibited at Michigan

State University and other college campuses in recent years, civil libertarians have expressed concern that the law, as written, could potentially be interpreted in such a manner as to punish persons for simple, non-violent acts of civil disobedience.)

Crowd Control

In some cases, crowd control techniques are critical to the avoidance of injuries and death. For example, on December 3, 1979, in Cincinnati, Ohio, inadequacies of event planning and crowd control led to the trampling deaths of 11 attendees at a rock concert. About 10 others were injured at this event, even though the crowd itself was not riotous or violent. Much was learned from this incident, however, and a useful and insightful analysis of this event was made available at http:www.crowdsafe.com/taskrpt/toc1.html for general study.

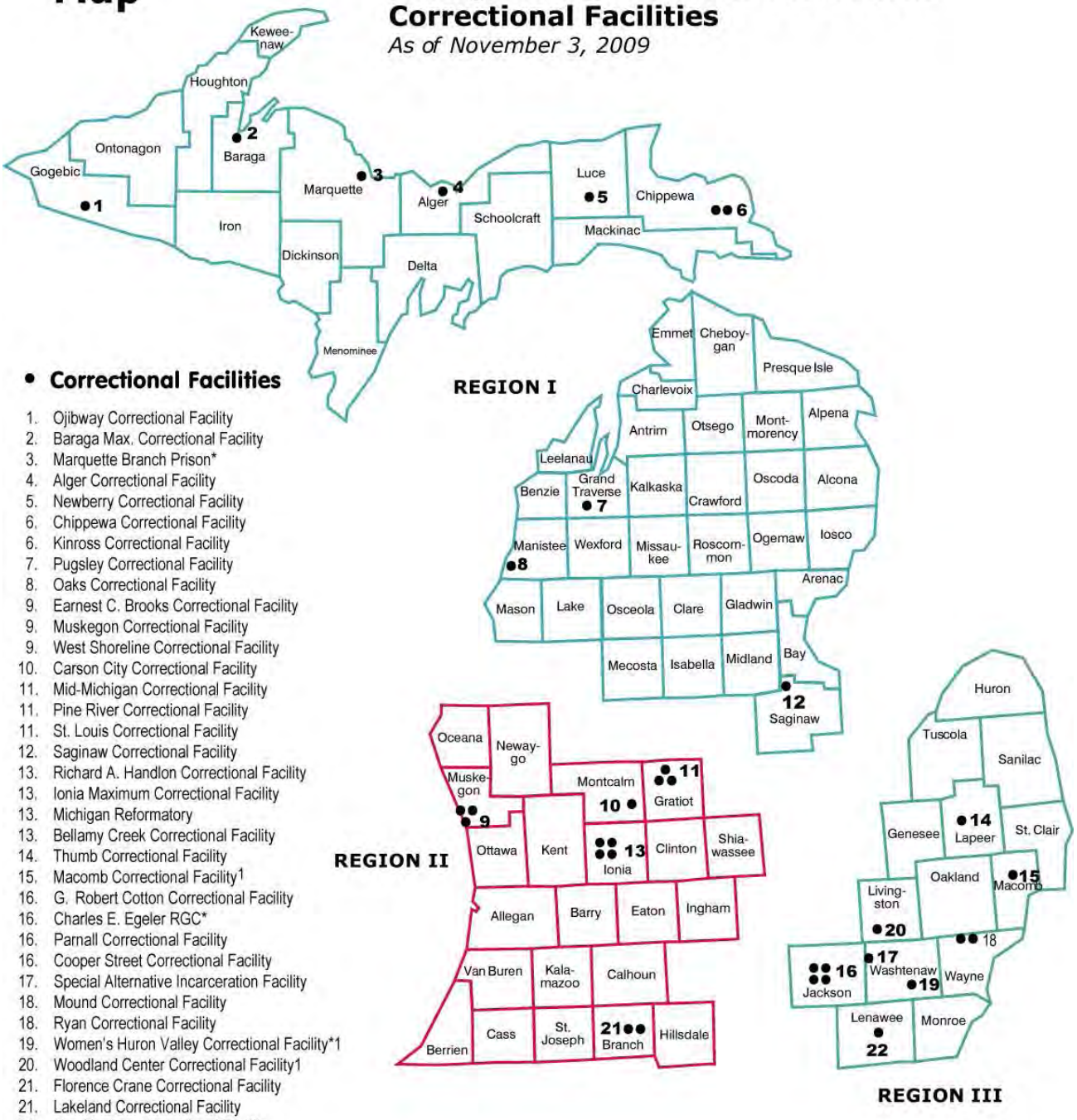
Prisons

Prison uprisings are first contained by Michigan Department of Corrections facility squads, composed of trained Correctional Custody personnel. Department Emergency Response Teams (ERT) then assign their members to resolve the situation. ERT members are specially trained personnel who respond to security needs or emergency situations which arise during daily institutional operations. ERT also responds to situations which threaten the safety or security of any correctional institution, or which pose a threat to the community. Additional units may be brought in from other nearby facilities, if necessary, to quell the disturbance. If those resources are not sufficient to manage and end the uprising, specially trained officers from the Michigan State Police can be activated to assist Department of Corrections personnel. The Michigan State Police may also be mobilized to provide perimeter security around the facility, and to augment resource needs. In extreme cases, Michigan National Guard military personnel can be activated to assist with the restoration of order within the facility.

Map

Michigan Department of Corrections Correctional Facilities

As of November 3, 2009



- **Correctional Facilities**

1. Ojibway Correctional Facility
2. Baraga Max. Correctional Facility
3. Marquette Branch Prison*
4. Alger Correctional Facility
5. Newberry Correctional Facility
6. Chippewa Correctional Facility
6. Kinross Correctional Facility
7. Pugsley Correctional Facility
8. Oaks Correctional Facility
9. Earnest C. Brooks Correctional Facility
9. Muskegon Correctional Facility
9. West Shoreline Correctional Facility
10. Carson City Correctional Facility
11. Mid-Michigan Correctional Facility
11. Pine River Correctional Facility
11. St. Louis Correctional Facility
12. Saginaw Correctional Facility
13. Richard A. Handlon Correctional Facility
13. Ionia Maximum Correctional Facility
13. Michigan Reformatory
13. Bellamy Creek Correctional Facility
14. Thumb Correctional Facility
15. Macomb Correctional Facility[1]
16. G. Robert Cotton Correctional Facility
16. Charles E. Egeler RGC*
16. Parnall Correctional Facility
16. Cooper Street Correctional Facility
17. Special Alternative Incarceration Facility
18. Mound Correctional Facility
18. Ryan Correctional Facility
19. Women's Huron Valley Correctional Facility*[1]
20. Woodland Center Correctional Facility[1]
21. Florence Crane Correctional Facility
21. Lakeland Correctional Facility
22. Gus Harrison Correctional Facility

*Includes reception centers

[1]Inpatient psychiatric units operated by the Michigan Dept. of Community Health

Source: Correctional Facilities Administration

NUCLEAR ATTACK

A hostile action taken against the United States which involves nuclear weapons and results in destruction of property and/or loss of life

Hazard Description

Nuclear weapons are explosive devices that manipulate atoms to release enormous amounts of energy. Compared to normal chemical explosives such as TNT or gunpowder, nuclear weapons are far more powerful and create harmful effects not seen with conventional bombs. A single nuclear weapon is able to devastate an area several miles across and inflict thousands of casualties. Although nuclear attack is an unlikely threat, the severe damage that would be caused by even one weapon requires the danger to be taken seriously.

The threat of nuclear attack has primarily been associated with the Cold War between the United States and the Soviet Union in the last half of the 20th Century. Although the Cold War is over, there remains a threat of nuclear attack. More nations have developed nuclear weapons and there is also the possibility that terrorists could use a nuclear weapon against the United States.

Understanding Nuclear Weapons

The following information about nuclear weapons is important for understanding the threat of nuclear attack: (1) types of nuclear weapons, (2) measures of weapon power, (3) forms of attack, and (4) types of delivery systems.

Nuclear weapons have been built in a wide variety of types for several different purposes. The first weapons relied on nuclear **fission**, or the splitting of heavy atoms to release energy and create an explosion. Later, new weapons were invented that used a combination of fission and **fusion**, which involves the creation of heavier atoms from lighter ones. Fusion bombs are also referred to as **hydrogen bombs** or **H-bombs**. For emergency planning purposes, the important differences are that (1) fusion bombs are more difficult to build and (2) that they can be much more powerful. Otherwise, all types of nuclear weapons create the same types of effects.

The power of nuclear weapons is measured by comparing the energy released by the weapon to the energy released by large amounts of conventional high explosive. The strengths of smaller weapons are measured in **kilotons** (or thousands of tons) of TNT explosive. A twenty-kiloton bomb produces as much energy as twenty thousand tons of TNT exploded all at once. The strength of larger weapons is measured in **megatons**, or millions of tons of TNT. A two-megaton bomb produces as much energy as two million tons of high explosive.

Smaller nuclear weapons are generally designed to be used against military targets on the battlefield. These are called **tactical** nuclear weapons. Larger devices designed to attack cities, infrastructure, and military bases are called **strategic** nuclear weapons.

Bombs can be set off at varying heights above the target. If the bomb is set off high in the air, its effects are spread out over a wider area and generally more damage is done. This is called an **air burst**. A bomb that is set off at or near the Earth's surface level wastes much of its energy against the ground. This is called a **ground burst**. Ground bursts have some specific military uses and terrorists may use ground bursts because they are unable to lift their weapons high enough to create an air burst.

Like any weapon, a nuclear device must be carried to its target by a **delivery system**. The first nuclear weapons were bombs dropped out of aircraft. Later, tactical weapons were made small enough to fire out of cannons or carry in large backpacks. **Intercontinental ballistic missiles** (**ICBMs**) are rockets that can carry one or more nuclear weapons across thousands of miles in less than an hour. Terrorists may lack sophisticated missiles, but they could create effective delivery systems by transporting a nuclear weapon in the back of a truck, aboard a cargo plane, or within a shipping container.

Effects of Nuclear Weapons

The effects of nuclear weapons are more complicated than those of conventional explosives. Nuclear devices cause damage through six major effects: (1) thermal pulse, (2) blast, (3) prompt radiation, (4) electromagnetic effects, (5) mass fire, and (6) residual radiation.

THERMAL PULSE is an intense flash of light and heat released within the first few seconds of a nuclear explosion. The damage from thermal pulse is almost instantaneous and covers a wide area. People and animals exposed to the pulse can be badly burned. Flammable objects such as buildings, vehicles, and trees may be set on fire. The flash is strongest close to the bomb and becomes weaker with distance. Even people located far away from the explosion may still be blinded by the intense light of the pulse.

BLAST is a powerful wave of force that moves out from the center of the explosion through the air and the ground. The farther the blast travels, the weaker it becomes. Very close to the bomb, the blast will destroy even the most strongly built buildings and will kill everyone not hidden deep underground. Farther away, buildings may survive, but with severe damage, and people will be injured by being picked up and smashed against objects. At still greater ranges, buildings will be less damaged and injuries will largely result from shattered glass and thrown debris. At all distances, a powerful wind follows the initial blast wave and adds to the destruction. The blast from a ground burst will dig a large crater into the ground, but this cratering will not occur with an air burst.

PROMPT RADIATION is the harmful blast of high energy radiation given off at the same time as the thermal pulse. Prompt radiation includes gamma rays and neutron radiation. This radiation is capable of killing or injuring living beings by damaging tissues and organs. Prompt radiation is quickly absorbed by the atmosphere and does not impact as wide an area as other nuclear weapons effects. In most instances, a person close enough to receive a harmful dose of prompt radiation is also close enough to be immediately killed by the explosion's thermal pulse or blast. However in unusual cases, some people who survive the immediate effects of the bomb may sicken or die days later, from radiation poisoning.

ELECTROMAGNETIC EFFECTS occur immediately after a nuclear explosion and may damage communications equipment, computers, and electronics. Radios, cell phones, and power lines are especially vulnerable. In most cases, the effects are limited to an area near to the explosion. Some equipment may recover after a period of time, while other devices will need to be replaced. One special type of nuclear attack might cause more widespread electromagnetic effects: a very large nuclear weapon carried high into the atmosphere by a missile is capable of damaging communications and electronics over a very large area.

MASS FIRE results from the ignition of thousands of individual fires by a bomb's thermal pulse, combined with widespread destruction from its blast. Over a period of hours, small fires merge and feed on damaged buildings and debris. Controlling these fires would be very difficult, due to damaged water mains, destroyed fire-fighting equipment, and blocked roads. The result is an extremely intense fire that can spread quickly and reach very high temperatures. Mass fire may significantly expand the area devastated by a bomb, destroying areas that might otherwise be only lightly damaged by other types of effects.

RESIDUAL RADIATION is unlike prompt radiation in that it lasts well after the nuclear explosion has ended. The ground immediately underneath the center of the explosion will be dangerously radioactive for several days due to "induced radiation." There will also be some radioactive dust and debris that will drift downwind of the explosion. This radioactive dust is called "fallout." Fallout will be a minor problem in the case of an air burst explosion, but will be very intense in the case of a ground burst attack. Regardless of the type of attack, the danger from fallout will tend to be greatest close to the site of the attack. The cloud of fallout will weaken the longer it lasts and the farther it travels.

Note that the effects of a nuclear attack will depend on the size of the weapon. A larger bomb will cause damage over a wider area. The importance of different types of damage will also vary with the weapon. Large strategic

nuclear weapons will create most of their damage though thermal pulse and mass fires, while with small tactical bombs the blast effect and prompt radiation will be relatively more important.

The Nuclear Attack Threat

Nuclear attack against the United States would originate either as a strike by an enemy military or as a terrorist attack. Fortunately, nuclear devices are very difficult to build and this limits the availability of the weapons. A nuclear weapon more closely resembles a precisely built scientific tool then a simple, rugged bomb. Careful engineering and extremely rare materials are needed to make a working nuclear weapon.

At the end of World War II only the United States possessed nuclear weapons, but over time more nations have developed the necessary technology. At least eight countries now possess nuclear devices, while several more have secret nuclear weapons programs and may therefore be building bombs. While some of these "nuclear powers" are allies of the United States, others remain potential enemies. While unlikely, it is possible that an international crisis in areas such as the Persian Gulf, the Taiwan Straits, or the Korean Peninsula could escalate into an exchange of nuclear weapons. American cities are not invulnerable to attack.

There also remains a risk from accidental, mistaken, or unauthorized launch of nuclear weapons. Even the most sophisticated technology may malfunction and even the best-trained personnel may make tragic mistakes. Once a missile has been launched there is no way call it back, and a nuclear warhead fired in error will do just as much damage as one launched in anger.

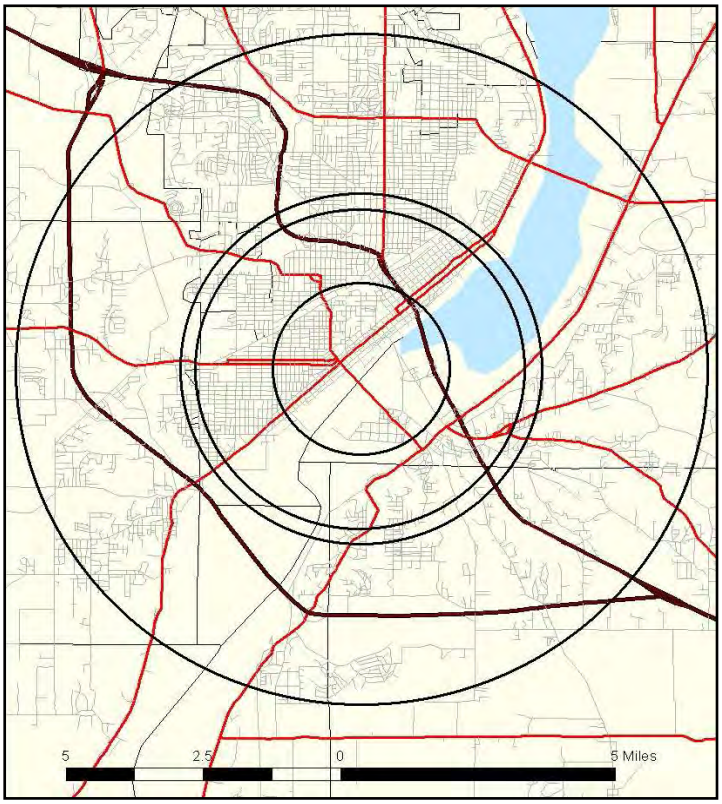
A strike by a nuclear power could consist of a single weapon or thousands, depending on the strength and intentions of the attacker. The most likely form of military attack would be the launch of intercontinental ballistic missiles fired from thousands of miles away. Although the United States now has a limited ability to shoot down incoming missiles, there are fewer than 30 interceptor missiles, of doubtful reliability. A very small attack or an accidental launch might possibly be stopped, but a larger attack would certainly strike the United States.

A nuclear power would have the ability to attack several locations at the same time. Multiple attacks across the United States would overwhelm national assets, forcing individual states or regions to rely on local resources. These attacks would probably be targeted on large cities and military bases and would use strategic nuclear weapons—each with a power of 100 kilotons or more. Cities would usually be attacked with air bursts, and military bases by the use of ground bursts.

The following map illustrates the effects of a typical military nuclear missile warhead. This example shows the effects of a 750 kiloton air-burst detonation at an altitude of 8,000 feet on a clear day above a mid-sized American city. Such an attack would be representative of an attack on Michigan cities such as Grand Rapids, Lansing, Flint, or Ann Arbor. The rings in the illustration show distances from the center of the nuclear explosion.

<u>Outer Ring: 6.3 miles across</u>

At this distance, the exposed skin of persons outdoors will suffer immediate 3rd degree burns (8 kcal/cm^2). With medical services destroyed or overwhelmed, almost all severely burned victims will die. Within this ring, mass fires can be expected to develop within hours. Eventually, most of this area will be destroyed by fire.



Second Ring: 3.3 miles across
At this distance, the blast wave will totally destroy light frame structures, such as most homes (5psi). Sturdier buildings will be severely damaged, with their interiors destroyed. Winds of 160mph would then follow the blast wave.

Third Ring: 3.0 miles across
At this distance, exposed persons will be affected by intense prompt radiation (5Gy). Between 50% and 80% of victims will eventually die from this exposure, unless first killed by blast or thermal effects.

Inner Ring: 1.6 miles across
At this distance, the blast wave will totally destroy even reinforced concrete buildings (20psi). Winds of 230 mph will follow the blast wave. Essentially everyone within this ring will be killed immediately.

Lighter damage will extend well beyond the area depicted in this map, mostly due to the effects of the thermal pulse.

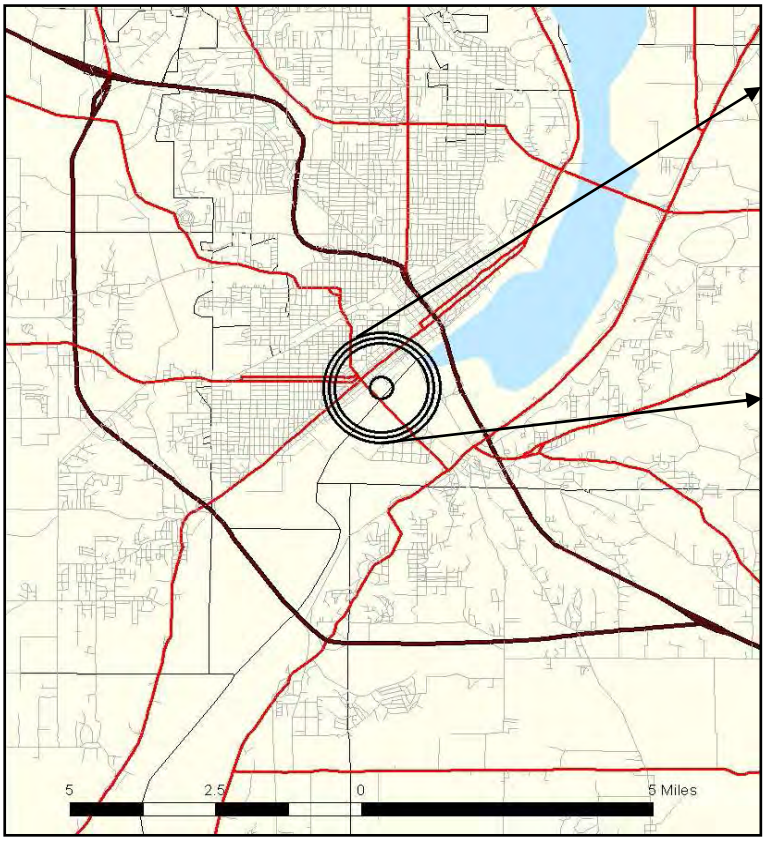
Nuclear Terrorism

As far as is known, no terrorist organization has ever managed to gain access to nuclear weapons. However, the great destructive potential of these devices make them very desirable for terrorist groups that wish to cause massive and indiscriminate casualties. It is known that several terrorist groups have actively pursued nuclear weapons capability.

Terrorists could acquire nuclear weapons as gifts from friendly governments, by stealing them from military stockpiles, or by building a crude device on their own. Each of these approaches is considered unlikely, but not impossible. A determined and well-financed terrorist group such as Al Qaeda may eventually be able to acquire a working nuclear weapon.

A nuclear attack by a terrorist organization would likely involve only a single weapon. An attack by only a single weapon would still be a major disaster, but resources could gradually be sent from the entire United States to aid the devastated area.

Because powerful strategic bombs are more difficult to steal or build, it is likely that a terrorist device would be of the less powerful tactical type. A rough estimate for the strength of this kind of nuclear weapon would be 25 kilotons or less. Even such a ‘small’ device would be approximately as powerful as the bombs that destroyed the Japanese cites of Hiroshima and Nagasaki at the end of World War II.



A terrorist nuclear weapon would be unlikely to arrive aboard a missile. It is much more probable that the bomb would be smuggled to the target, hidden inside the back of a truck or within a cargo container. Even a bulky improvised nuclear weapon could easily be carried in this way. The bomb could be detonated from inside its hiding place, creating a nuclear ground burst. There is a lesser possibility that terrorists could use a cargo plane to deliver a nuclear weapon as an air burst.

This map illustrates the effects of a possible terrorist nuclear bomb. This example shows the effects of a 25 kiloton nuclear weapon detonated at ground level on a clear day in a mid-sized American city. Such an attack would be representative of an attack on Michigan cities such as Grand Rapids, Lansing, Flint, or Ann Arbor. The rings in the illustration show distances from the center of the nuclear explosion.

Outer Ring: 1.0 miles across
At this distance, exposed skin will suffer immediate 3rd degree burns (8 kcal/cm2). With medical services destroyed or overwhelmed, most severely burned victims will die. Within this ring, mass fires can be expected to develop within hours. Eventually, most of this area will be destroyed by fire.

Second Ring: 0.9 miles across
At this distance, the blast wave will totally destroy light frame structures, including most homes (5psi). Sturdier buildings will be severely damaged, with their interiors destroyed. Winds of 160mph would then follow the blast wave.

Third Ring: 0.8 miles across
At this distance, exposed persons will be affected by intense prompt radiation (5Gy). Between 50% and 80% of victims will eventually die from this exposure, unless first killed by blast or thermal effects.

Inner Ring: 0.2 miles across
At this distance, the blast wave will totally destroy even reinforced concrete buildings (20psi). Winds of 230 mph will follow the blast wave. Essentially everyone within this ring will be killed immediately.

Lighter damage will occur out to a distance of approximately two miles, or twice the diameter of the outer ring on the map. This damage will be caused by a combination of blast and thermal pulse effects.

The arrows in the diagram represent the area covered by a moving cloud of radioactive fallout. This cloud will drift downwind from the site of the explosion, but the size and direction of the area affected by the fallout will depend considerably on wind and weather conditions. For example, in clear weather with winds blowing at 15 miles per hour, lethal levels of radiation will be encountered several miles downwind from the site of the explosion and harmful levels will occur for up to six miles downwind. Fatalities are expected in persons

continuously exposed for four days in the contaminated area. People finding shelter or evacuated immediately will suffer substantially less harmful effects.

Note the significant differences between the two examples. The terrorist bomb directly impacts a much smaller area, but it creates a dangerous cloud of radioactive fallout. The lethal thermal pulse from the air burst missile explosion covers an area much greater than the area of heavy blast damage, while in the case of the terrorist bomb those two effects are more equal. In the case of the missile explosion, the area of effect for prompt radiation is much smaller than that for blast and thermal effects, but in the case of the terrorist bomb, lethal radiation extends almost as far as the other effects.

Global Consequences of Nuclear Attack

A final consideration for the nuclear attack hazard is the impact of a nuclear attack outside of Michigan's borders. An attack elsewhere in the United States or elsewhere in the world would have serious negative economic consequences. Such an attack would also result in a global call for emergency response resources, including those in Michigan. Finally, a large scale nuclear war involving many nuclear weapons could have damaging effects on climate worldwide. A nuclear attack would have serious consequences for Michigan, regardless of where that attack occurred.

Impacts of Nuclear Attack

Impact on the Public

A nuclear attack would cause catastrophic damage over a wide area. Attacks on populated areas would inflict massive loss of life, destruction of property, environmental damage, infrastructure failure, and public health impacts. In the case of a ground burst weapon, some areas would remain uninhabitable for an extended period of time. A nuclear war, even if occurring far from the United States, would have serious economic and environmental consequences, resulting in additional harm to the public. Although unlikely to occur, nuclear attack potentially poses a very great threat in terms of fatalities, property damage, and size of impact area.

Impact on Public Confidence in State Governance

Public confidence in state government following a nuclear attack is difficult to predict. It is likely that public reaction would depend on the perceived effectiveness of government response to the disaster. Given the extensive damage caused by nuclear weapons, and the limited available resources, it is very likely that government services would be overwhelmed. An especially serious problem would be insufficient medical resources for the treatment of injured victims. It is conceivable that the unmet needs of survivors could result in a significant loss of confidence in state government. On the other hand, anger at the perpetrators of the attack and feeling of patriotic solidarity might increase popular support of government, at least in the short term.

Impact on Responders

A nuclear attack would pose extensive risks and challenges for responders. In any attack on a populated area, many responders would be immediately killed or injured in firehouses, police stations, hospitals, etc. affected by the explosion. Surviving responders would face serious and unfamiliar challenges, including widespread infrastructure failure, high levels of radiation, mass urban fires, and the disruption of command and communications systems. Responders would also face an unprecedented level of need from thousands of injured or dying citizens. In the short term, emergency resources would unavoidably fall far short of requirements. Help could only be provided to a limited percentage of the total number of victims. Extensive casualties would be expected among responders. In the long term, responders and emergency managers would face massive challenges in sheltering, evacuation, medical care, and public order.

Impact on the Environment

A nuclear attack would cause significant environmental damage. In addition to the immediate destruction from blast and thermal effects, continuing damage would be expected due to toxic smoke clouds from mass urban fires, hazardous materials released from damaged storage facilities, and waste from wrecked water treatment systems.

Radioactive contamination would occur, with the extent depending on the specific details of the attack. At worst, large areas would be poisoned by fallout, and a crater at the site of an explosion could remain heavily contaminated for years. Use of numerous nuclear weapons might cause environmental damage on a regional or global scale, far beyond the effects created by a single weapon or small number of weapons. Such damage could occur during an extensive nuclear war. Specific effects would depend on the size and number of weapons used, as well as their specific targets. Global environmental impacts might include a drop in global temperature, reductions in food production, damage to the Earth's protective ozone layer, and an increase in background radiation levels.

Additional Nuclear Attack Guidance Information

During the Cold War, the nuclear attack hazard was not customarily analyzed at the local level. The large numbers of weapons available to the United States and Soviet Union threatened destruction on an enormous scale, and few plans could attempt to adequately address the hazard. Even communities not directly attacked would have been profoundly or fatally impacted by the effects of a superpower exchange.

Today, the threat of nuclear attack is very different, and local planning may again be appropriate for this hazard. The possibility of attack still exists, but the principal threat is the use of an individual nuclear weapon or a small number of weapons. Cold War planning scenarios may need to be updated to reflect the fact that the nature of the threat has changed. Not only are there far fewer nuclear weapons than in past decades, but the individual weapons are, for the most part, far less powerful.

When considering the hazard of nuclear attack by a foreign power, local vulnerabilities would be assessed in terms of proximity to possible high-priority targets. These might include military bases, large power plants, oil refineries, and major population centers. Targets identified in Cold War plans may no longer be relevant, as closed military bases and shut-down power plants are no longer likely targets. Since there is no way to accurately assess the probability of nuclear war, most mitigation strategies would be prompted by, and originate from, federal initiatives and defense priorities. The "risk" part of a local hazard analysis on this topic would therefore probably be missing, due to lack of information, but the "vulnerability" portion can still be assessed in terms of the presence of potential targets.

Also worthy of consideration is the possibility that one or more nuclear weapons might be used in an attack by a terrorist organization, especially in light of the ongoing threat posed by international terrorist groups. The section of this plan dealing with Terrorism and Similar Criminal Activities should be freely referred to, particularly in regards to potential terrorist targets. When planning for a terrorist nuclear attack, consider that the effects of a terrorist weapon are likely to be very different than those caused by a nuclear missile attack.

For any nuclear attack planning, the presence of fallout shelters, or makeshift substitute shelters, might be a key factor of analysis. When considering mitigation and response strategies, the ability to shelter or evacuate people would clearly be important. The ability to maintain government functions and social services would be similarly important. Protection of critical computer and communications systems from the effects of electromagnetic pulse would also be worth considering. The presence of redundancies (backup systems) in an area's infrastructure and critical services would be another means to assess local vulnerability to a nuclear attack.

Summary

Nuclear attack is an unlikely hazard, but even a single weapon could cause death and destruction on a massive scale. Nuclear weapons inflict damage over a wide area and through a variety of effects, including thermal pulse, blast, fire, and radiation. Despite the end of the Cold War, nuclear attack by foreign nations remains a real possibility, and this danger has been joined by the threat of terrorist nuclear attack. It makes sense to continue to prepare for the nuclear attack hazard as part of an overall emergency management strategy.

PUBLIC HEALTH EMERGENCIES

A widespread and/or severe epidemic, incident of contamination, or other situation that presents a danger to or otherwise negatively impacts the general health and well-being of the public.

Hazard Description

Public health emergencies can take many forms—**disease** epidemics, large-scale incidents of food or water **contamination**, extended periods without adequate water and sewer **services**, harmful exposure to chemical, radiological or biological agents, and large-scale infestations of disease-carrying insects or rodents, to name just a few. Public health emergencies can occur as primary events by themselves, or they may be secondary events to another disaster or emergency such as a flood, tornado, or hazardous material incident. The common characteristic of most public health emergencies is that they adversely impact, or have the potential to adversely impact, a large number of people. Public health emergencies can be statewide, regional, or localized in scope and magnitude.

Perhaps the greatest emerging public health threat would be the intentional release of a radiological, chemical, or biological agent with the potential to adversely impact a large number of people. Such a release would most likely be an act of sabotage aimed at the government or at a specific organization or segment of the population. Fortunately, Michigan has not yet experienced such a release aimed at mass destruction. However, Michigan has experienced hoaxes and it may only be a matter of time before an actual incident of that nature and magnitude does occur. If it does, the public health implications—under the right set of circumstances—could be staggering.

Hazard Analysis

Michigan has had several large-scale public health emergencies in recent history, but fortunately nothing that caused widespread severe injury or death. The 1973 PBB contamination incident is unprecedented in U.S. history, but the long-term implications of contamination may be less than was feared. Similarly, the northern Michigan water and sewer infrastructure disaster of 1994 is also unprecedented in scope, magnitude, and public health and safety implications for the affected communities. These events, though unusual, have heightened awareness of the broad nature of threats that can result in a public health emergency. Such emergencies no longer simply involve the spread of disease, but rather can arise out of a variety of situations and circumstances.

In 2001, Michigan health officials were introduced to the emerging health threats posed by foot-and-mouth disease and the West Nile encephalitis virus. Although foot-and-mouth disease is a highly contagious disease that only affects animals, a widespread outbreak such as that which occurred in parts of the United Kingdom in the spring of 2001 could have significant public health implications for humans as well, due to the potentially large numbers of dead animal carcasses that would have to be disposed of to prevent disease outbreaks. The Michigan Department of Agriculture and Rural Development, in conjunction with numerous other federal, state and local agencies and the agriculture industry, continues to monitor the foot-and-mouth disease situation and take the necessary steps to prevent the introduction and spread of the disease in the United States.

The West Nile encephalitis virus, which arrived in Michigan in August 2001, presents an equally challenging scenario for public health officials. Transmitted to humans by the bite of an infected mosquito, the West Nile virus is commonly found in Africa, West and Central Asia, and the Middle East. Health officials do not know how the virus was introduced to the United States. However, in 1999 and 2000, it caused an outbreak of human encephalitis in and around New York City that created a national stir and raised fears across the country that it would cause a full-blown public health emergency. The virus eventually spread to Michigan in 2001. It peaked in Michigan in 2002 with 644 reported cases, including 51 deaths. There has been a decline in reported cases every year since then.

Although no area in Michigan (or elsewhere) is immune to public health emergencies, areas with high population concentrations will always be more vulnerable to the threat. In addition, the more vulnerable members of society—the elderly, children, impoverished individuals, and persons in poor health—are also more at risk than the general population.

Michigan is fortunate in that it has an excellent public health system that constantly monitors the threats that could lead to a widespread or significant public health emergency. However, even the best monitoring and surveillance programs cannot always prevent such incidents from occurring. When they do occur, Michigan's public health agencies have shown the ability to effectively muster the resources necessary to identify and isolate the problem, and mitigate its effects on the population. In addition, if the problem is such that a multi-agency and multi-jurisdictional response is required, the emergency management system in Michigan can be utilized to enhance coordination and effectiveness of the response and recovery effort.

Impact on the Public

The primary types of public health impacts involve the threat or presence of either disease, contamination, or sanitation problems. Disease epidemics or pandemics have the potential to cause widespread debilitation or loss of life, associated medical expenditures, and decreases in productivity and quality of life. Contamination can at least temporarily lower property values, as well. Sanitation problems require effort and expense to resolve. Contamination and sanitation issues increase the probability and variety of diseases that may affect the population. Facilities may be shut down, as a means of preventing disease transmission or of containing contamination, and thus cause a loss of the services being provided to the public (by schools, for example). Medical resources may become overwhelmed and unable to deal with any additional needs. As traditional medical services become increasingly difficult to access (or if their quality declines due to overwork or understaffing) then increasing numbers may turn to less responsible and effective alternative means of treatment (or may forego treatment entirely).

Impact on Public Confidence in State Governance

The PBB incident of the mid-1970s caused part of the population to perceive a "cover up" by the state, or suspicions of faulty research involving the amount and nature of PBB risks. Although it took time for the cause and nature of the incident to be understood, and the detection of long-term health risks from PBB eventually became clearer, the public and the mass media's understanding of the nature of scientific research tends to be prone to misjudgments, hasty conclusions, and an abundance of speculation.

Food-borne illnesses, including the contamination of products during manufacture, is another type of public-health emergency that is likely to be associated in the public mind with the effectiveness of government policies and regulatory agencies. Widespread illness that is associated with public infrastructure (e.g. water, sewer, electrical) or with conditions that are overseen by government inspectors (e.g. air conditioning and ventilation systems) are more likely to cause a loss of public confidence in government when it occurs. Maintenance-related and environmental issues that may affect public health in an area (such as urban blight and insect/rodent infestations, contaminated brownfield sites, scrap tire piles, industrial or nuclear accidents) are also ones for which some level(s) of government will be held accountable by the media and the public. Post-disaster conditions that allow the spread of illness (or the breakdown of public health services) will also have a great potential to cause dissatisfaction with and loss of confidence in government.

There are also cases (e.g. a cluster of lethal meningitis infections on a large university campus) in which the public is unfamiliar with epidemiological methods and data, and believes that a problem exists despite government assurances that there is not yet sufficient evidence to reach that conclusion. The result would be that, unless offsetting information is proactively provided to the public, various persons will feel that abstract analysis techniques (or bureaucracy) are preventing government workers from seeing conditions that certain citizens consider to be "obvious." This mismatch in understanding and perception often results in citizen criticism of "government."

Impact on Responders

The primary types of emergency public health concerns involve the threat or presence of either disease, contamination, or sanitation problems. Certain types of contamination issues are similar to hazardous materials (q.v.) in their impact on responders, in that special measures, expertise, and precautions may be required when dealing with an incident. A similar approach may be taken with sanitation issues, in which special crews may need to be called in to deal with the problem, and the measurement and monitoring of the problem may require specialized equipment and expertise. On the other hand, issues of contagious disease tend to call for different response and precaution procedures, since there are many human-related transmission vectors that can seem more diffuse and unclear. Unless special training and equipment is obtained and employed, responders may be found to have an increased risk of succumbing to the contagious illness being responded to. (Even with the use of equipment and training, responders may still be more at risk, due to increased exposures to bacterial and viral threats.)

Impact on the Environment

A public health emergency tends to primarily affect people, but in a severe, large-scale event, decontamination centers, quarantine buildings, or additional medical facilities might need to be developed quickly, disregarding land use laws. This type of development may result in the loss of an area's natural wildlife habitat and could also impact the environment by causing nearby properties to flood.

Significant Public Health Emergencies

Following are brief synopses of some of the more significant public health emergencies that have occurred in Michigan and other parts of the United States in recent years:

1973 Chemical Contamination (Polybrominated Biphenyl Contamination)

One of Michigan's most serious statewide public health emergencies occurred in 1973 when a chemical company inadvertently sent bags of a fire retardant containing polybrominated biphenyl (PBB), a highly toxic chemical, along with a shipment of livestock feed supplement to Michigan Farm Bureau Services. After being mixed with the livestock feed, the contaminated mixture was distributed statewide for use by farmers in feeding livestock herds. The result was an environmental and public health disaster of unprecedented magnitude in Michigan. Thousands of cattle and other animals died from the poisoning and serious questions were raised regarding the long-term effects of this contamination on all Michigan residents.

1977 Oakland County Foodborne Pathogenic Contamination (Botulism Outbreak)

In 1977, the worst outbreak of botulism in U.S. history was linked to home-canned jalapeno peppers served by an Oakland County restaurant. (Botulism is caused by a bacterium that grows from spores in an atmosphere without oxygen. Improperly canned foods are a primary source of the botulism bacterium. Botulism attacks the neuromuscular system and is one of the most dreaded of food poisoning agents, with a high mortality rate.) The restaurant used 200 jars of home canned peppers because a crop failure the preceding winter had created a shortage of commercially prepared peppers. Fifty-nine (59) restaurant patrons reportedly fell ill from the botulism poisoning, though no one died. Many of those affected required intensive care level treatment and horse serum botulism antitoxin. (Note: The supply of horse serum botulism antitoxin is limited, and it must be transported from regional depots to a hospital that has need of it. Because the amount of toxin required to paralyze a person is so low, the potential for a very large botulism outbreak always exists.)

Spring 1997 Michigan Foodborne Pathogenic Contamination (Hepatitis A Outbreak)

In the spring of 1997, almost 300 cases of hepatitis A occurred in at least four Michigan school districts. A rapid epidemiological investigation by local, state and federal epidemiologists linked this outbreak to frozen strawberries distributed through the national school lunch program. Tracing of the implicated strawberries identified 13 different lots sent to several states in addition to Michigan. Several hundred Michigan schools were potentially affected. A massive program was instituted to evaluate risk at schools that received the frozen strawberries, to inform parents about immune globulin prophylaxis, and to provide it to recently exposed children. The prompt and insightful epidemiological investigation and rapid, well-organized response of the Michigan local health department system helped to prevent the occurrence of additional illnesses and to reduce community anxiety.

Aug. 1998 – Feb. 1999 Multi-state outbreak Foodborne Pathogenic Contamination (Listeriosis Outbreak)

2002 Nationwide outbreaks Foodborne Pathogenic Contamination (Listeriosis Outbreak)

A multi-state outbreak of Listeriosis, from August 1998 to February 1999, had its origin at a Bil Mar Foods meat plant in Zeeland. (Listeriosis is caused by the foodborne bacterium Listeria monocytogenes—commonly called Listeria—that can cause serious illness and death to pregnant women, newborns, older adults, and persons with weakened immune systems.) Health officials identified the vehicle for transmission of the Listeria bacterium as hot dogs and deli meats produced at the plant under numerous brand names. The exact source of the contamination was not determined. A total of 21 deaths and 100 illnesses nationwide had been linked to the contaminated meats. In December, 1998, 35 million pounds of hot dogs and deli meats were voluntarily recalled by the manufacturer—the largest meat recall in U.S. history. Once the recall was instituted, the number of illnesses caused by the outbreak decreased dramatically. The Zeeland plant was allowed to resume meat production in March, 1999, after more stringent food safety procedures were implemented. In 2002, at least 40 persons were sickened and 10 were killed in a nationwide listeria outbreak linked to the meat company Pilgrim's Pride Corp. The company then recalled 27.4 million pounds of meat, after tests at a Pennsylvania plant revealed strains of Listeria monocytogenes that matched the outbreak strain.

November 2008 Holland, MI Norovirus Outbreak

About 420 Hope College students, faculty, and staff reported coming down with an illness from a noro-like virus in November 2008. Symptoms included diarrhea, nausea, and vomiting for 24 to 48 hours. The outbreak prompted the school and county health officials to close the campus and cancel activities starting November 7th, with students who stayed on campus restricted from gathering. Campus security and Holland police were asked to break up any

parties or other student gatherings both on and off campus. The campus reopened four days later on November 11th and students were given a bag with plastic gloves, disposable wipes and bleach-based cleaning spray for sanitizing their rooms. Hand sanitizer dispensers were placed in about 40 locations on the Hope College campus to aid in the attempt to stop the spread of the norovirus outbreak.

Spring 2010 South East Michigan Foodborne Pathogenic Contamination (Campylobacter)

Thirteen patients fell ill around the same time, with fever and diarrhea later confirmed to be caused by bacteria in raw milk, a food-borne contaminant called campylobacter illness. The suspect milk was distributed to members of a farm cooperative in Vandalia, and not sold in grocery stores.

There have been no significant waterborne E-coli outbreaks in Michigan in recent years, but outbreaks in other parts of the country and in Canada provide examples of what could happen in Michigan under certain circumstances:

1998 Atlanta, Georgia Waterborne Pathogenic Contamination (E. coli Outbreak)

In Atlanta, June 1998, a more deadly strain of E. coli contamination struck at least 26 children who had been playing in a pool at a water park. Four of the children became critically ill with kidney failure, and required hospitalization. The children were thought to have contracted E. coli from a child with a leaky diaper. Tests conducted by health officials revealed that the chlorine levels in the pool were below the level needed to kill the E. coli bacteria.

1998 Alpine, Wyoming Waterborne Pathogenic Contamination (E. coli Outbreak)

In June 1998, an E. coli outbreak struck the community of Alpine, sickening many of the town's 470 residents along with numerous tourists who had passed through the town. Subsequent investigation by health officials revealed the source of the contamination to be the town's water supply, which had somehow become tainted with E. coli bacteria. It was the largest waterborne outbreak of that particular strain of E. coli in U.S. history.

1999 Washington County, NY Waterborne Pathogenic Contamination (E. coli Outbreak)

In September 1999, an E. coli outbreak traced to the Washington County Fair in upstate New York caused two deaths and nearly 800 persons to fall ill. Hundreds of people sought medical treatment at hospitals, and dozens were hospitalized with the illness. Health officials called the E. coli outbreak the worst in New York history, and possibly one of the worst in U.S. history. Subsequent investigations have determined that the likely cause of the outbreak was due to contamination of the fair's drinking water supply—possibly when rainwater washed over cow feces from a cattle barn on the fairgrounds and ran into an underground aquifer tapped by the fair's wells.

2000 Walkerton, Ontario, Canada Waterborne Pathogenic Contamination (E. coli Outbreak)

In May 2000, one of the worst ever E-coli outbreaks in North America occurred in the Canadian farm town of Walkerton, Ontario, located approximately 125 miles northwest of Toronto. The town's water supply became contaminated with E. coli bacteria—possibly after a heavy rainfall washed manure from surrounding farms into one of the town's drinking water wells. Ordinarily, the chlorinator on the well would destroy the harmful effects of E-coli. However, the chlorinator on that particular well had not worked for several weeks, allowing the E-coli to contaminate the entire water supply. The tainted water outbreak killed at least seven residents and sickened 2,300. An estimated 200 residents, many of them children, may have sustained permanent organ damage. Walkerton's water was finally declared safe to drink in December 2000, eight months after the E-coli outbreak occurred.

In November 2000, Michigan's first significant foodborne contamination outbreak in recent years occurred in Cadillac (see description below). Recent E. Coli outbreaks in other parts of the country provide additional examples of what could happen in Michigan under certain circumstances:

1993 State of Washington Foodborne Pathogenic Contamination (E-coli Outbreaks)

In 1993, an E-coli outbreak tied to undercooked hamburgers served at Jack in the Box Restaurants in western Washington killed four children and sickened more than 600 others. This highly publicized outbreak was one of the worst in U.S. history and eventually led to a multi-million dollar legal settlement with the infected restaurant patrons.

1999 Petersburg and Orland Park, IL Foodborne Pathogenic Contamination (E-coli Outbreak)

A September 1999 party, held in a cow pasture in St. Petersburg, Illinois and attended by 1,800 people from 15 Illinois counties and six other states (including Michigan), resulted in an E-coli outbreak that sickened over 200 (with 20 requiring hospitalization). Health officials indicated that those who got sick most likely either ate or drank something contaminated by E. coli bacteria, but were unable to pinpoint exactly what the source was.

During the weekend of June 5-6, 1999, more than 4,000 people became ill after eating potato salad prepared by a deli in Orland Park, near Chicago. The deli had distributed the potato salad to over 530 graduation parties being held in the area. No deaths occurred as a result of this incident, but it was determined to be the largest known outbreak in the United States of the enterotoxigenic strain of E. coli.

2000 Cadillac, MI Foodborne Pathogenic Contamination (Salmonella Outbreak)

In early November 2000, a salmonella poisoning outbreak in Cadillac killed one person and sickened 17 others. Health officials were able to trace the likely source of the poisoning back to a caterer who provided food to four events on November 4. The suspected food item was served at the two events where people became ill, but not at the other two events.

2002 Clinton Township, MI Foodborne Pathogenic Contamination (Salmonella Outbreak)

In March 2002, a salmonella poisoning outbreak in Clinton Township hospitalized at least 10 people. The source of the poisoning was traced backed to pastries at a local bakery. As many as 60 people may have eaten the pastries in one of Macomb County's worst outbreaks of salmonella poisoning. Many of the customers were sick in bed for several days after consuming the pastries.

2008 Multiple States Foodborne Pathogenic Contamination (Salmonella Outbreak)

In November 2008, Michigan joined a rapidly expanding investigation of a nationwide outbreak of Salmonella Typhimurium, which ultimately exceeded 700 cases from 46 U.S. States and from Canada. A total of 38 confirmed cases with onset dates between October 2008 and February 2009 were identified in Michigan from 15 widely dispersed counties in the lower peninsula of the State. Of these, there were 12 reported hospitalizations. Two unusual features of both the Michigan and nationwide outbreak were noted very early in the investigation—the predominantly young distribution of the cases and the high frequency of exposure in institutional settings such as elementary schools, colleges, long term care facilities, and correctional centers.

Spring 2009 East Lansing, MI Foodborne Pathogenic Contamination (E-coli Outbreaks)

In spring 2009, Michigan State University faced a food poisoning outbreak that closed a campus dining hall. Over 50 people were stricken with a stomach illness. About 28 students reported symptoms that included diarrhea, vomiting, nausea, and stomach pain, and were treated at a local hospital. Approximately 30 other students were treated at the student health center. During the fall semester at MSU, dozens of cases of E. coli, all containing the

same genetic fingerprint, were reported and linked to contaminated lettuce from large commercial bags sold by Aunt Mid's. Twenty-one people were hospitalized, with one developing HUS, or hemolytic uremic syndrome, a type of kidney failure linked to food poisoning.

Spring 2011 Germany Foodborne Pathogenic Contamination (E-coli Outbreaks)

An E. coli strain infected thousands in Germany in the spring of 2011. At least 39 deaths, 810 cases of hemolytic syndrome, and 2,684 other cases had been reported to health agencies. It was so deadly because it combined the powers of two other types of E.coli, enabling it both to stick fast to the inside of the gut and to release a deadly toxin. The E. coli strain responsible, O104:H4, appeared to produce the same toxin, called a Shiga-like toxin, typical of enterohemorrhagic E. coli. Further, the bacteria had the ability to clump together, like a stack of bricks, and adhere to cells that line the intestines. This clumping property is characteristic of enteroaggregative E. coli, a pathogen linked to diarrhea outbreaks in developing countries, especially in children.

(Note: Federal health officials estimate that 76 million illnesses, 325,000 hospitalizations, and 5,000 deaths occur in the United States each year due to foodborne diseases. Food safety is complicated by the fact that Americans eat out more often and eat more processed foods, both of which involve more potential exposure to food handling errors. In addition, the number of persons who are more vulnerable to foodborne diseases (those with weakened immune systems, the elderly) continues to increase over time.

Spring 1994 Northern Michigan Loss of Water and Sewer Service

A breakdown of critical water and sewer infrastructure can (if not immediately abated) result in a public health emergency for the affected area. That is exactly what happened in the early spring of 1994 in northern Michigan, when over 3,200 water and sewer lines broke or became frozen due to unusually deep subterranean frost depths. The emergency conditions were present in some locations for up to 5 months. As a result, many communities had to provide shelter for those residents without water and/or sewer service for an extended period of time. In addition, boil-water advisories were issued in many communities, due to the potential for water contamination from lack of adequate system pressure. Fire safety hazards were also prevalent, due to the lack of adequate system pressure, as well as the fact that many homeowners were using improper equipment to thaw out frozen water and sewer lines (sometimes starting fires in the process).

Because of the public health and safety risks associated with this unusual event, as well as the millions of dollars in physical damage caused to this vital infrastructure, Michigan was granted a Presidential Disaster Declaration in May, 1994. That declaration allowed for the immediate repair, restoration and/or replacement of the damaged water and sewer infrastructure. By the middle of summer, most of the repair work had been completed, thus bringing to a close one of Michigan's (and the nation's) most unusual public health emergencies.

Communicable Disease Epidemic (Influenza Pandemics)

There have been several communicable disease outbreaks or epidemics, or the potential for such threats, which can be classified as public health emergencies. One of the principal dangers of communicable disease outbreaks is that they can rapidly overwhelm the local health care system.

Influenza is an example of a potential public health emergency of very large proportions. No one knows when the influenza virus might "shift" its structure to produce a virus to which no one will be immune. Influenza can exact a terrible toll on communities. During a typical influenza season, approximately 1,188 deaths in Michigan are expected. However, during the next influenza pandemic (a worldwide epidemic), as many as 10 to 100 times that many might die, without an adequate and well-organized public/community health care system to combat the disease. As hard as the world public health community is trying to conduct influenza surveillance in order to provide the most advance notice possible, if pandemic influenza were to strike it would likely do so very early in the season and spread so rapidly that preparation would need to be done on an emergency basis.

In the northern hemisphere, the normal flu season starts in November and ends in May. Flu viruses are amenable to chilly weather, and therefore predominate around the winter season in temperate climates. (Contagion may also be assisted by persons spending more time in indoor areas with less ventilation from outside.)

Background On Influenza Pandemics

The world's worst influenza pandemic—the "Spanish flu" of 1918-19—resulted in 500,000 to 675,000 deaths in the United States and 20 to 40 million worldwide. More than 25 million Americans—nearly one quarter of the population at the time—fell ill. Scientists speculate that the virus that caused that pandemic may have percolated for several years within humans, or possibly pigs, until it grew strong enough to kill millions worldwide. The virus spread rapidly—moving around the world in a matter of a few months—in a time period in which there was much less movement of people than there is today. The virus reached Michigan in the fall of 1918. Over 8,000 of the 2.8 million state residents fell ill and half of those eventually succumbed to the disease. In retrospect, the spread of the illness was felt to be exacerbated by behavior of important officials who had misguided concerns that the effects of "panic" might be more harmful than the disease itself—a notion that proved disastrous. The pandemic had an unusual aspect, however, in that many of those who died were persons who had been young and

healthy, whereas the normal pattern for influenza deaths is to take a higher toll among those who are elderly or have compromised immune systems.

(Note: As a sheer numerical comparison, the 1918-19 influenza pandemic worldwide death tolls came close to equaling the death tolls of the medieval Black [Bubonic] Plague that struck in the 6th, 14th, and 17th centuries. The number of U.S. deaths from the pandemic exceeded the number of U.S. soldiers killed on the battlefield in World Wars I and II, the Korean War, and the Vietnam War combined.)

Two other major influenza pandemics occurred during the 20th century—the 1957-58 "Asian flu" that killed 70,000 in the United States, and the 1968-69 "Hong-Kong flu" that resulted in 34,000 U.S. deaths—each spreading with the same rapidness as the 1918-19 pandemic. The possibility is always there that another pandemic could occur at any time. The speed and frequency of modern global travel could greatly exacerbate the spread and potential impacts of future pandemics, forcing public health officials to race against the clock to prevent the death tolls experienced in past pandemics.

Influenza viruses are designated with letters and numbers. Three main groups exist (A, B, and C), and Influenza A contains those viruses that have the capacity to cause human pandemics. Within that main classification are more specific letter-number designations that specify two types of proteins on the outer part of the virus—hemagglutinin (H) and neuraminidase (N). There are 16 known types of H and 9 known varieties of N, and combinations of these protein types distinguish various strains of the Influenza A virus from each other. As of 2009, only three combinations—H1N1, H2N2, and H3N2—have been involved in viruses confirmed to spread directly from person to person. However, it is possible for other virus strains, such as those found in birds or swine, to change and become capable of infecting other species. In 1976, a swine flu outbreak occurred among humans stationed at the Fort Dix military facility in New Jersey, and was addressed with a mass vaccination program, although the vaccine itself was found to have a small (1 in 100,000) risk of causing the serious Guillain-Barré syndrome.

In 2005, an outbreak of influenza A (H5N1), also known as "avian flu" or "bird flu," was reported in several countries throughout Asia. First identified in 1997 Hong Kong, cases of avian influenza A (H5N1) in birds were later confirmed in Cambodia, China, Hong Kong, Indonesia, Japan, Laos, Pakistan, South Korea, Thailand, and Vietnam. Human cases of avian influenza were reported in Thailand and Vietnam. In an investigation, it was not determined that the avian flu was spread from person to person. The outbreak of avian influenza prompted the killing of more than 25 million birds in Asia. This strain of avian influenza A (H5N1) was not found in the United States. However, in February 2004, different strains of avian flu were detected among several flocks of birds in the U.S., and state officials ordered the destruction of hundreds of thousands of birds. The avian influenza strain found in Delaware was H7N2, in Pennsylvania the strain was H2N2, and the H5N2 strain was found in Texas. The strain found in Texas was determined to be "highly pathogenic" to birds. However, the strain of avian influenza in Texas was not the same as the strain in Asia.

The World Health Organization (WHO) announced a substantial risk of an influenza epidemic in the near future. One of the primary concerns is that the virus could quickly spread across the World. In response, many countries have begun planning in anticipation of an outbreak. During the spring of 2009, a new influenza virus was identified. Studies showed that this new virus was different from what had normally circulated throughout the world. Humans are expecially vulnerable because their immune systems had not been previously exposed to this virus, therefore allowing limited immune response. H1N1 (also called "swine flu," in this case) has exhibited atypical presentation in human populations. Over 90% of detected cases are in persons under 65 years of age. In comparison to other flu viruses, hospitalizations and deaths associated with H1N1 are dramatically higher in children and young adults. Also of concern, the virus has demonstrated the ability to develop resistance to anti-viral medications. Thousands of cases of influenza-like illness were reported in Michigan during the last week of October 2009 alone. However, according to an Associated Press wire report (of September 29, 2010) regarding

CDC recent studies, that strain of the "swine flu" no longer represented a major threat in the United States because most citizens came to show signs of immunity.

Contagious Disease Outbreaks

Some diseases, such as influenza, are contagious or infectious, and can be transmitted by any of a variety of mechanisms, including droplets from coughs and sneezes, insect bites, contaminated water or food, or other vectors. Epidemiology is the study of the distribution and determinants of disease in human populations and the application of this study to control health problems. The following table explains a few epidemiology terms that may be helpful in understanding the spread of disease.

Epidemiology Terms	
Epidemic	The occurrence of more cases of a disease than would be expected in a community or region during a given time period.
Pandemic	An epidemic that becomes very widespread and affects a whole region, a continent, or the world.
Endemic	Present in a community at all times but in relatively low frequency. Something that is endemic is typically restricted to, or peculiar to, a locality or region.
Zoonosis	An infectious disease that may be transmitted from (wild and domestic) animals to humans.

The following table is a list of epidemics that have occurred in the United States.

Significant Epidemics in the United States

Year	Epidemic	Location	Year	Epidemic	Location
1657	Measles	Boston, Massachusetts	**1831-1832**	Asiatic cholera	United States (brought by English immigrants)
1687	Measles	Boston, Massachusetts	**1832**	Cholera	New York City and other major cities
1690	Yellow fever	New York, New York	**1833**	Cholera	Columbus, Ohio
1713	Measles	Boston, Massachusetts	**1834**	Cholera	New York City
1729	Measles	Boston, Massachusetts	**1837**	Typhus	Philadelphia, Pennsylvania
1738	Smallpox	South Carolina	**1841**	Yellow fever	United States (especially severe in the south)
1739-1740	Measles	Boston, Massachusetts	**1847**	Yellow fever	New Orleans
1747	Measles	Connecticut, New York, Pennsylvania, South Carolina	**1848-1849**	Cholera	North America
1759	Unknown type	North America	**1849**	Cholera	New York
1761	Influenza	North America and West Indies	**1850**	Yellow fever	United States
1772	Measles	North America	**1850-1851**	Influenza	North America
1775	Unknown type	North America, particularly in the Northeast	**1851**	Cholera	Illinois, Missouri, and the Great Plains
1783	Bilious disorder	Dover, Delaware	**1852**	Yellow fever	United States
1788	Measles	Philadelphia, Pennsylvania and New York	**1855**	Yellow fever	United States
1793	Influenza and "putrid fever"	Vermont	**1860-1861**	Smallpox	Pennsylvania
1793	Influenza	Virginia	**1865-1873**	Smallpox	Philidelphia, New York City, Boston, New Orleans
1793	Yellow fever	Philadelphia , Pennsylvania	**1865-1873**	Cholera	Baltimore, Memphis, Washington, DC
1793	Unknown type	Harrisburg, Pennsylvania	**1865-1873**	Recurring epidemics of typhus, typhoid, scarlet fever, and yellow fever	United States
1793	Unknown type	Middletown, Pennsylvania	**1873-1875**	Influenza	North America and Europe
1794	Yellow fever	Philadelphia , Pennsylvania	**1949**	Polio	United States
1796-1797	Yellow fever	Philadelphia , Pennsylvania	**1952**	Polio	United States
1803	Yellow fever	New York	**1980-present**	AIDS	Worldwide
1820-1823	Fever	United States, spreading from the Schuylkill River			

Source: Wikipedia online encyclopedia

There have been a number of significant pandemics in human history, generally zoonoses that stemmed from the domestication of animals, such as influenza and tuberculosis. The following table lists pandemics that have occurred throughout the history of the world, supplemented by a list of diseases that may soon reach pandemic proportions.

Significant World Pandemics

Year	Pandemic	Description
165-180, 251-266	Antonine Plague	The Antonine Plague may possibly have been smallpox brought back from the Near East. It killed a quarter of those infected and up to five million in all. At the height of a second outbreak (251-266) 5,000 people a day were said to be dying in Rome.
541	Plague of Justinian	The Plague of Justinian was the first recorded outbreak of the bubonic plague. It started in Egypt and reached Constantinople the following spring, killing (according to the Byzantine chronicler Procopius) 10,000 a day at its height and perhaps 40 percent of the city's inhabitants. It went on to destroy up to a quarter of the human population of the eastern Mediterranean.
1300s	Bubonic Plague ("Black Death")	Eight hundred years after its last outbreak, the bubonic plague returned to Europe. Starting in Asia, the disease reached Mediterranean and western Europe in 1348 and killed twenty million Europeans in six years, a quarter of the total population (and up to half the population in the worst-affected urban areas).
1816 - 1826 1829 – 1851 1852 – 1860 1963 – 1875 1899 – 1923 1961 - 1966	Cholera	The first pandemic (1816-1826). Previously restricted to the Indian subcontinent, the pandemic began in Bengal, then spread across India by 1820. It extended as far as China and the Caspian Sea before receding. The second pandemic (1829-1851) reached Europe, London in 1832, Ontario and New York in the same year, and the Pacific coast of North America by 1834. The third pandemic (1852-1860) mainly affected Russia, with over a million deaths. The fourth pandemic (1863-1875) spread mostly in Europe and Africa. The fifth pandemic (1899-1923) had little effect in Europe because of advances in public health, but Russia was badly affected again. The sixth pandemic began in Indonesia in 1961, called El Tor after the strain, and reached Bangladesh in 1963, India in 1964, and the USSR in 1966.
1918 - 1919	Spanish Flu	The Spanish Flu began in August 1918 in three disparate locations: Brest, France; Boston, Massachusetts; and Freetown, Sierra Leone. An unusually severe and deadly strain of influenza spread worldwide. The disease spread across the world, killing 25 million in the course of six months; some estimates put the total of those killed worldwide at over twice that number. An estimated 17 million died in India, 500,000+ in the United States and 200,000 in the UK. It vanished within 18 months.
1957-1958	Asian Flu	Influenza A (H2N2) caused about 70,000 deaths in the United States. First identified in China in late February, 1957, the Asian flu spread to the United States by June 1957.
1959-Present	AIDS	The World Health Organization estimates that millions now die from AIDS each year, worldwide.
1960s	Cholera	El Tor was identified again in an outbreak in 1937 but the pandemic did not arise until 1961 in Sulawesi. El Tor spread through Asia (Bangladesh in 1963, India in 1964) and then into the Middle East, Africa, and Europe. From North Africa it spread into Italy by 1973. In the late 1970s there were small outbreaks in Japan and in the South Pacific.
1968-1969	Hong Kong Flu	Influenza A (H3N2) caused about 34,000 deaths in the United States. This virus was first detected in Hong Kong in early 1968 and spread to the United States later that year. Influenza A (H3N2) viruses still circulate today.
2002-2003	SARS	After the People's Republic of China suppressed news of the outbreak both internally and abroad, the disease spread rapidly, reaching neighboring Vietnam in late February 2003, and then other countries via international travelers. The last case in this outbreak occurred in June 2003. There were a total of 8,069 cases of disease and 775 deaths.

Possible Future Pandemics
(diseases that may possibly attain pandemic proportions)

Disease	Description
Lassa fever	The infection is endemic in West African countries, causing many deaths. Outbreaks of the disease have been observed in Nigeria, Liberia, Sierra Leone, Guinea, and Central African Republic.
Rift Valley fever	Rift Valley fever is a viral zoonosis causing fever. It is spread by the bite of infected mosquitoes. Approximately 1% of human sufferers die of the disease. Among livestock the fatality level is significantly higher.
Ebola virus	Ebola hemorrhagic fever is a very rare, but severe, mostly fatal infectious disease occurring in humans and other primates, caused by the Ebola virus. It was first discovered in 1976. Epidemics with 50 to 80% mortality have occurred in the Democratic Republic of the Congo, Gabon, Uganda and Sudan.
Marburg virus	The Marburg virus is the causative agent of Marburg hemorrhagic fever. Both the disease and virus are related to Ebola and originate in the same part of Africa (Uganda and Eastern Congo). The zoonosis is of unknown origin, but some scientists believe it may be hosted by bats.
Bolivian haemorrhagic fever	The Bolivian haemorrhagic fever, also known as black typhus, is a hemorrhagic fever and zoonotic infectious disease occurring in Bolivia. First identified in 1959, black typhus is caused by the machupo virus.
Avian flu	In November 2004 the director for the western region of the World Health Organization said that an influenza pandemic was inevitable and called for urgent plans to combat the virus. The Centers for Disease Control (CDC) claims that a flu pandemic could kill more than 200,000 people in the United States.

Source: Wikipedia online encyclopedia

Other Public Health Events and Conditions of Significance

Spring 1993 Milwaukee, WI Waterborne Pathogenic Contamination (Cryptosporidium Outbreak)

One of the more infamous public health emergencies to occur in this country happened not in Michigan, but rather in nearby Milwaukee, Wisconsin, in the spring of 1993. Public health officials there were alerted to a widespread health problem when, on April 5, thousands of city residents suddenly became ill with a gastrointestinal disorder. There was increased absenteeism from schools and businesses, and groceries and pharmacies ran out of anti-diarrheal medications. Follow-up investigation identified the largest waterborne disease outbreak in U.S. history, caused by the pathogen cryptosporidium. More than 400,000 Milwaukee residents were infected with the parasite, over 4,000 of whom required hospitalization.

Cryptosporidium is present in approximately 97% of the surface water and 39% of drinking water supplies in the United States. Normally, the human body can effectively fight off the illness. Even so, more than 900,000 people in the U.S. become ill each year from waterborne parasites like cryptosporidium, and up to 900 die as a result. For persons in immuno-compromised health situations (e.g. persons with AIDS), infection with cryptosporidium can be life-threatening. Over 100 persons with compromised immune systems in the Milwaukee area are believed to have died prematurely after being infected with cryptosporidium from the water supply. Although a definitive cause has never been established for the Milwaukee outbreak, officials believe that possible sources might have included runoff from upstream cattle farms, local slaughterhouses, or possibly even human sewage.

In addition to the lives lost, the financial price tag for this incident was very high as well. Engineering studies indicated the need for nearly $90 million in improvements to Milwaukee's water supply and treatment system, to prevent such an outbreak in the future. These studies were significant because their recommendations could easily apply to hundreds of utilities across the country, including those in Michigan. Milwaukee's outbreak pointed out the inadequacies in watershed protection programs, public health surveillance, and drinking water standards. As a result of this incident, the city has made drastic changes in its water treatment processes, as well as its monitoring and public information efforts for cryptosporidium.

Various dates and locations West Nile Virus

The West Nile virus is a mosquito-borne virus that can cause encephalitis (inflammation of the brain) and meningitis (inflammation of the lining of the brain and spinal cord). Outbreaks of the disease caused by the West Nile virus have occurred in Egypt, Asia, Israel, South Africa, and some parts of Europe and Australia. The virus was first seen in the U.S. in the fall of 1999 in New York City, and has since spread across the U.S. to the Pacific Ocean, into several Canadian Provinces, and possibly into Mexico. The virus was first detected in Michigan in 2001 and has been detected in Michigan each year since then. The virus peaked in Michigan in 2002, when 644 human cases were reported, including 51 deaths. In 2003, human cases in the state dropped to 19, with no fatalities. In 2004, 16 human cases, none fatal, were reported in Michigan. The West Nile virus lives in birds and other animals, and mosquitoes can transfer it from the animals to humans. Seniors, infants, and people with weakened immune systems are most vulnerable to West Nile and most likely to become seriously ill from it. Experts urge residents to monitor the birds in their yards, especially when one dies.

Sept. 2002 Farmington, MI Legionnaires Disease
August 2002 Vermont Legionnaires Disease

In September of 2002, four people were killed and 30 others became ill from an airborne bacteria in vapor emitted from an air conditioning cooling unit at a grocery store in Farmington. It was also reported that at least 16 people were sickened by the disease in Vermont around the same time. Legionnaires disease is spread when people inhale mist carrying the bacteria. People infected with the bacteria may develop pneumonia-like symptoms and high fevers within two weeks of exposure. The disease can be fatal, especially to the elderly, people with weakened immune systems, and children.

May, 2003 Byron Center, MI Food Tampering

In one of the nation's largest reported cases of food tampering, a former supermarket employee admitted to poisoning about 250 pounds of the store's ground beef with insecticide, sickening at least 92 people who ate the meat. The employee had a dispute with a co-worker and had put the insecticide in the meat in an attempt to get him in trouble. The insecticide he used had a high concentration of nicotine as its active ingredient, and swallowing it could be fatal. The disgruntled employee poured the insecticide on the ground beef as he prepared it and packaged the poisoned meat.

2003 Washington Foodborne Pathogenic Contamination (Mad Cow Disease)
2004 Texas Foodborne Pathogenic Contamination (Mad Cow Disease)

Mad Cow Disease is the name commonly used for Bovine Spongiform Encephalopathy (BSE), a slowly progressive, degenerative, fatal disease affecting the central nervous system of adult cattle. In humans, a rare and deadly form called variant Creutzfeldt-Jacob disease has been linked to eating infected tissue from cows. Mad Cow disease in Britain in the 1980s and 1990s had been blamed for the deaths of 150 people. Fortunately, there has never been a documented case of the human illness from the eating of contaminated beef in the United States. Since 1990, the U.S. Department of Agriculture (USDA) has conducted aggressive surveillance of the highest risk cattle going to slaughter and 10,000 to 20,000 animals per year have been tested. The only documented case of the brain-destroying disease in U.S.-born and raised livestock was discovered in 2004, in Texas, just days before Independence Day, one of the major grilling weekends of the year. The only other case of the disease in the United States turned up in 2003 in Washington state, in a dairy cow that had come from Canada. As soon as the BSE cases were identified, both the USDA and FDA had activated their BSE Emergency Response Plans and the USDA immediately recalled the meat. Meat that did enter the food supply was quickly traced and removed from the marketplace.

Various dates and locations VRSA and VISA

Staphylococcus aureus is a bacteria commonly found on the skin and in the nose of healthy people. It can occasionally get into the body, with the potential to cause serious, life-threatening blood infections or pneumonia. Staph aureus infects about 400,000 U.S. hospital patients a year, killing about one-quarter of them. VISA (Vancomycin-Intermediate Staphylococcus Aureus) or VRSA (Vancomycin-Resistant Staphylococcus Aureus) are specific types of antimicrobial-resistant staph bacteria. While most staph bacteria are susceptible to the antimicrobial agent vancomycin, some have developed resistance. VISA and VRSA can no longer be successfully treated with vancomycin.

Various dates and locations Radon (See Michigan map at the end of the section)

Radon is a colorless, odorless, radioactive gas that is created naturally by the breakdown of uranium and radium. Radon gas is continuously released from rocks and soil containing these two elements. Uranium and radium may be found in almost all soil and rock, but are most often associated with those containing granite, shale, and phosphate. The Surgeon General has declared radon exposure to be the second leading cause of lung cancer deaths in the United States, after smoking. Exposure to natural radon is estimated to be responsible for 7,000 to 30,000 lung cancer deaths each year in the United States. As with other forms of cancer, lung cancer resulting from exposure to radon may develop over many years before it is diagnosed.

Various dates and locations Fecal-Oral Contamination (Viral, e.g. Norovirus)

Gastroenteritis caused by viruses is becoming a greater public health threat. These viruses are easily transmittable, are not treatable by antibiotics or anti-virals, and can survive on surfaces for long periods of time. Hospitalization and death can be likely if persons suffering from infection-caused dehydration are not promptly treated. Outbreaks can be difficult to contain if proper hygiene practices are not implemented.

Since September 2008, 172 norovirus outbreaks have been reported to the MDCH, with a total of 5,065 persons reported ill. One hundred and six of the reported outbreaks occurred at healthcare facilities, hospitals, nursing homes, and long-term care facilities. Thirteen outbreaks were related to restaurants or catering facilities, and 30 outbreaks occurred at universities, schools, and day-care centers.

1970s to Present Dioxin and PCBs

The Saginaw watershed—including the Tittabawassee River (and floodplain) downstream of the City of Midland, the Saginaw River, and Saginaw Bay—is contaminated with dioxin and polychlorinated biphenyls (PCBs) as a result of industrial processes. These contaminants can cause health effects in humans, and may be carcinogenic. Multiple state and federal agencies have been and continue to be involved with assessing the effects of exposure in humans and animals, and studying environmental clean-up issues. In 2005, news media reported that an environmental firm had discovered a pool of PCBs under some sewer lines in St. Clair Shores, with concentrations that were "200,000 times above safe levels." It was reported that more than $7 million had been spent since 2002 in canal clean-up near Lake St. Clair.

Programs and Initiatives

Michigan Department of Community Health

The Michigan Department of Community Health and local and district health departments across the state have a number of programs and initiatives in place to protect the health, safety and well being of Michigan's residents. These programs and initiatives have been very successful in preventing, or limiting the scope and magnitude of, the types of public health emergencies described above. However, because the types of threats to public health are always changing, and because the population is becoming larger and more mobile, the possibility always exists for a local, regional, or statewide public health emergency to occur.

The Director of the Department of Community Health, and local public health officers, have the authority (under the Michigan Public Health Code—1978 PA 368, as amended) to take those steps determined necessary and prudent to prevent epidemics and the spread of hazardous communicable diseases, or to effectively mitigate other conditions or practices that constitute a menace to public health. The Director and local public health officers can issue written orders to implement the required preventive steps and/or responses, and those orders can be enforced through the imposition of civil and criminal penalties for failure to comply. State and local health departments have detailed, written emergency operations plans that address public health emergencies.

The World Health Organization

The World Health Organization (WHO) has established six levels of pandemic "phases," based upon observable phenomena, and allowing the easy incorporation of new recommendations and approaches into existing national preparedness and response plans. Phases 1 to 3 concern preparedness activities, including capacity development and response planning, while Phases 4 to 6 indicate a need for response and mitigation efforts. After a first pandemic wave has occurred, particular "periods" are defined, to facilitate post pandemic recovery activities.

Inter-Pandemic Period (phases 1 and 2):

Phase 1: No new influenza virus subtypes have been detected in humans. An influenza virus subtype that has caused human infection may be present in animals. Although present in animals, the risk of human disease is considered to be low.

Phase 2: No new influenza virus subtypes have been detected in humans. However, a circulating animal influenza virus subtype poses a substantial risk of human disease.

Pandemic Alert Period (phase 3, 4, and 5):

Phase 3: Human infection(s) with a new subtype has caused sporadic cases or small clusters of disease in people, but has not resulted in human-to-human transmission sufficient to sustain community-level outbreaks. Limited human-to-human transmission may occur under some circumstances, or may affect close contacts.

Phase 4: Small clusters include limited human-to-human transmission, but the spread is highly localized, suggesting that the virus is not well adapted to humans. The ability to cause sustained disease outbreaks in a community marks a significant upward shift in the risk for a pandemic. Phase 4 indicates a significant increase in the risk of a pandemic but does not necessarily mean that a pandemic is a forgone conclusion.

Phase 5: Large outbreak clusters occur, but human-to-human spread is still localized, suggesting that the virus is becoming better adapted to humans, but may not yet be fully transmissible. (substantial pandemic risk)

Pandemic Period (phase 6):

Phase 6: Pandemic phase, with increased and sustained transmission in the general population.

During the post-peak period, pandemic disease levels in most countries with adequate surveillance will have dropped below peak observed levels. The post-peak period signifies that pandemic activity appears to be decreasing. However, it is uncertain whether additional waves will occur, and countries therefore need to be prepared for a second wave. Previous pandemics have been characterized by waves of activity spread over months. Once the level of disease activity drops, a critical communications task will be to balance this information with the possibility of another wave. Pandemic waves can be separated by months, and an immediate "at-ease" signal may be premature. In the post-pandemic period, influenza disease activity will have returned to levels normally seen for seasonal influenza. It is expected that the pandemic virus will behave as a seasonal influenza A virus. At this stage, it is important to maintain surveillance, and to update pandemic preparedness and response plans accordingly. An intensive phase of recovery and evaluation may be required.

U.S. Centers for Disease Control and Prevention

At the national level, the U.S. Centers for Disease Control and Prevention (CDC), a branch of the Department of Health and Human Services, has the responsibility and authority to investigate public health emergencies to determine their cause, probable extent of impact, and appropriate mitigation measures. The CDC can also assist state and local public health officials in establishing health surveillance and monitoring systems/programs, and in disseminating information on prevention and treatment to the general public. The CDC announced dedicated funding for bioterrorism response, and Michigan has been strengthening its surveillance and intervention infrastructures with these funds. Since 2001, the CDC has also provided dedicated funding for public health emergency preparedness programs. In 2002, the MDCH Office of Public Health Preparedness was established to oversee these cooperative agreements. In the 2009 Influenza A (H1N1) event, CDC coordinated with numerous health departments across the country, tracked influenza cases, and provided information about outbreak trends. Tests were also performed, to verify whether flu cases were indeed of the correct type.

Disease Information Website

The State of Michigan maintains a website titled "Emerging Disease Issues" at www.michigan.gov/emergingdiseases that provides a wealth of information on infectious diseases that may be transmitted among humans or between animals and humans. The website features information provided by several Michigan state agencies (e.g., Community Health, Agriculture and Rural Development, and Natural Resources), state universities, federal agencies, local health departments, and various national and international health organizations and professional disciplines. At the time of this writing, the website addressed the following diseases in depth: Bovine Tuberculosis, West Nile Virus, Chronic Wasting Disease, Rabies, Lyme Disease, Avian Influenza, Foodborne Illness, and a wide array of U.S. and foreign animal diseases. The Department of Community Health also maintains a website for chemical-related public health issues at
http:www.michigan.gov/mdch/0,1607,7-132-2945_5105---,00.html
It includes data and links to other websites regarding the human health effects of many hazardous substances, including dioxin, heavy metals, pesticides and others.

Michigan Pandemic Influenza Plan

In October 2009, the Michigan Department of Community Health updated the "Michigan Pandemic Influenza Plan," to provide response guidelines for an influenza pandemic affecting Michigan. Although the plan cannot eliminate the disease, it will aid in reducing the impact by enabling state and local agencies to anticipate, prepare for, and respond efficiently and effectively to the disease. The plan, which is divided into pre-pandemic, pandemic, and post-pandemic phases, details necessary activities at the state and local level related to:

- command and management,
- crisis communications,
- surveillance,

- laboratory testing,
- community containment,
- infection control in health care facilities,
- vaccines and antivirals/medical management,
- data management,
- border/travel issues
- recovery

The Michigan Pandemic Influenza Plan is available for review and downloading at www.michigan.gov/flu.

U.S. Health and Human Services Pandemic Influenza Plan

Like the State of Michigan, the federal government also has developed a plan to address the threat of pandemic influenza. The "HHS Pandemic Influenza Plan," released in November 2005 and updated three times in 2006, is the federal government's blueprint for pandemic influenza preparation and response. It provides guidance to national, state, and local policy makers and health departments, to aid all involved in achieving a state of readiness and quick response. The HHS Pandemic Influenza Plan includes an overview of the threat of pandemic influenza, a description of the plan's relationship to other federal plans, and an outline of the key roles and responsibilities during a pandemic. The plan is available for review and downloading at www.hhs.gov/pandemicflu/plan/.

Michigan Health Alert Network

The "Michigan Health Alert Network" (MIHAN) is a secure, statewide web-based disease alert system serving over 4,000 health care providers and other critical responders at local health departments, hospitals, clinics, and several state governmental agencies. The Michigan Department of Community Health (MDCH) has implemented the MIHAN to enhance the State's emergency public health communications system and serve as a platform for health alerts, prevention guidelines, national disease surveillance, and electronic laboratory reporting. It is used by the MDCH Office of Public Health Preparedness to support and strengthen preparedness and response for bio-terrorism, public health, and medical emergencies, at the local, state, and federal levels. The MIHAN provides role-based alerting and permissions, secure web-based communication, and bi-directional alerting with message confirmation by telephone, e-mail, and text pager, plus broadcast facsimile capabilities. The MIHAN serves as a foundation for the integration of public health and emergency response partners throughout Michigan, plus tribal health centers, border states, Canada, and federal agencies, including the U.S. Centers for Disease Control and Prevention (CDC).

Food Law (2000 PA 92)

The Food Law of 2000 was enacted to modernize, standardize, and consolidate Michigan's food laws, while adopting the U.S. Food and Drug Administration's (FDA) 1999 Food Code as a uniform regulatory standard for retail food establishments such as restaurants, other food service facilities, groceries, and convenience stores. The law helps to protect Michigan consumers from serious foodborne illnesses such as E. coli, salmonella, listeriosis, botulism, and hepatitis.

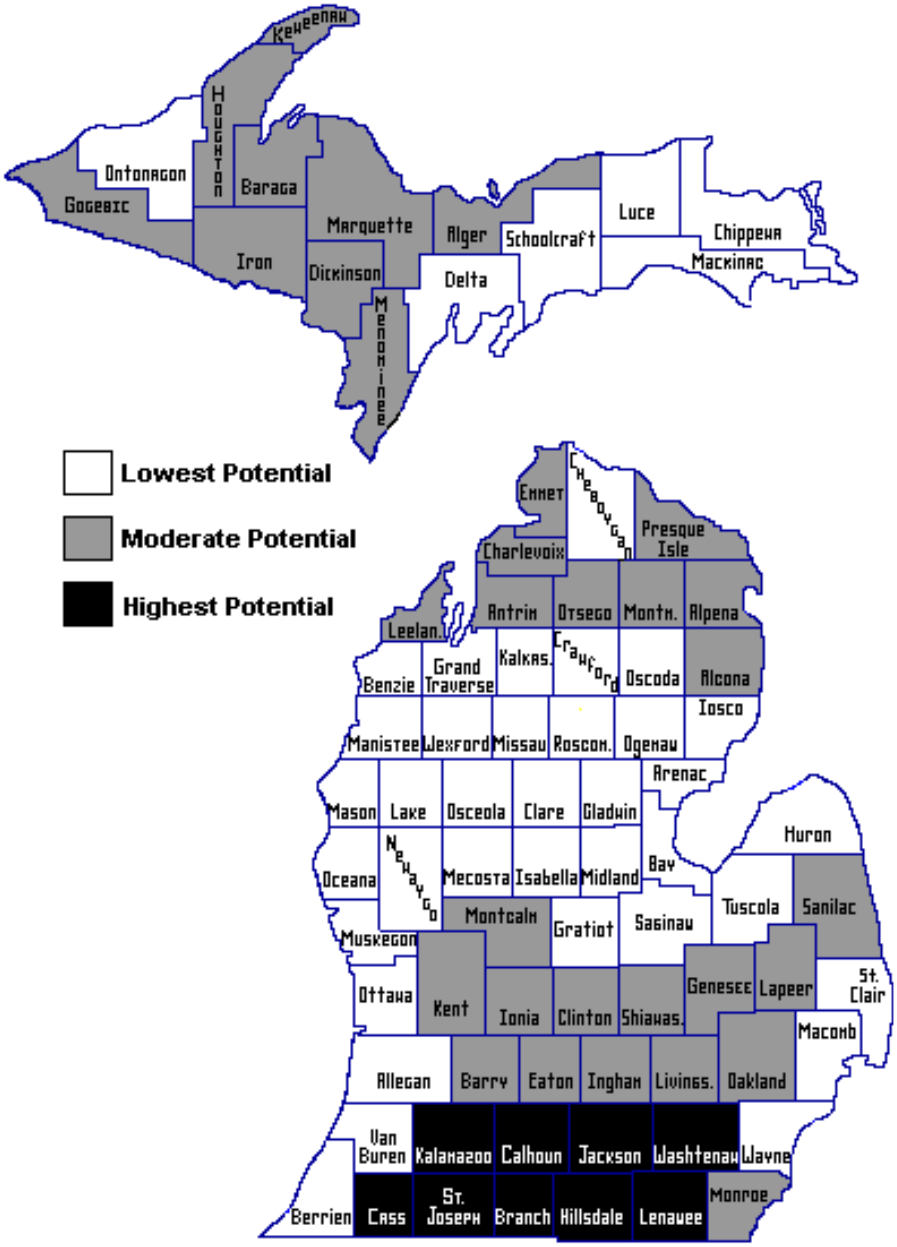
U.S. Food and Drug Administration Food Code

The U.S. Food and Drug Administration (FDA) Food Code is the national regulatory standard for retail food establishments. The FDA Food Code is neither Federal law nor Federal regulation, but represents the FDA's best advice for a uniform system of regulation to ensure that food at retail establishments is safe and properly protected and presented. It may be adopted and used by agencies at all levels of government that have responsibility for managing food safety risks at the retail level. The Food Code provides practical, science-based advice and manageable provisions for mitigating risk factors known to contribute to foodborne illnesses. Michigan initially adopted the 1999 FDA Food Code with the Michigan Unified Food Law of 2000 (2000 PA 92). The FDA Food Code is revised every two years.

(Note: For information on specific programs and initiatives aimed at mitigating water and sewer system failures, please refer to the Infrastructure Failures section.)

Radon Zones in Michigan

This map was developed by the U.S. Environmental Protection Agency (EPA) using five factors to determine radon potential: indoor radon measurements, geology, aerial radioactivity, soil permeability, and foundation type.



Source: Adapted from an Environmental Protection Agency map

Note: Consult the EPA Map of Radon Zones document (EPA-402-R-93-071) for additional background information on this map. That document also contains information on radon potential variation <u>within</u> counties. The EPA also recommends that this map be supplemented with any available local data in order to further understand and predict the radon potential of a specific area.

TERRORISM AND SIMILAR CRIMINAL ACTIVITIES

Terrorism: "…activities that involve violent…or life-threatening acts…that are a violation of the criminal laws of the United States or of any State and…appear to be intended (i) to intimidate or coerce a civilian population; (ii) to influence the policy of a government by intimidation or coercion; or (iii) to affect the conduct of a government by mass destruction, assassination, or kidnapping" Federal criminal code. 18 U.S.C. §2331

Hazard Description

Terrorism is the use of violence by individuals or groups to achieve political goals by creating fear. The political motives of terrorism distinguish it from ordinary crime. Terrorism is carried out for a cause; not for financial gain, personal revenge, or a desire for fame.

Terrorism is a long-established strategy that is practiced by many groups in many nations. The United States is threatened not only by international terrorists such as Al Qaeda, but also by home-grown domestic terrorist groups including racist, ecological, anti-abortion, and anti-government terrorists.

A wide range of techniques can be used by terrorists, including bombings, shootings, arson, and hijacking. Regardless of the specific tactics used, terrorists seek the greatest possible media exposure. The goal of terrorists is to frighten as many people as possible, not necessarily to cause the greatest damage possible. Media coverage allows terrorists to affect a much larger population than those who are directly attacked.

Non-terrorist criminal activity may resemble terrorism, but lacks a political objective. Emergency management is typically not concerned with routine, individual crimes, but does need to prepare for crimes that impact large portions of the population. Such attacks may require resources not available to local law enforcement agencies. Crimes of this sort include mass shootings, random sniper attacks, sabotage of infrastructure, and cyber-attacks. The types of criminal attacks considered in this section are those that resemble terrorism or that may cause widespread immediate disruption to society.

Terrorism in the United States

Terrorists intend to use fear as a weapon to achieve their goals. This approach allows a small, weak group to potentially influence the actions of an entire nation or government. Terrorists lack the power to achieve their ultimate aims through the direct use of force, but by staging relatively small attacks in a spectacular fashion, they hope to have a major political impact. Their goals are effectively summarized by the proverb "Kill one, frighten 10,000." Terrorism can be an effective strategy for a weak group to use when fighting a strong opponent.

Terrorism has been used for thousands of years, but modern terrorism developed in the 19th Century. The United States has suffered from terrorist attacks for more than a century: U.S. President William McKinley was assassinated by an anarchist terrorist in 1901, the Los Angeles Times building was destroyed in 1910, and Wall Street was bombed in 1920. Racial and religiously-motivated terrorism continued throughout the 20th century. A new wave of terrorism was instigated in the 1960s by left-wing radicals. This was followed by right-wing extremist terrorism in the 1980s and 1990s. All of these attacks were conducted by American domestic terrorists against other Americans.

The United States has also been the target of terrorists from other countries. Conflict in the Middle East led to many attacks on American targets overseas, primarily by Palestinian nationalist terrorists, as well as groups supported by Libya and Iran. Hijackings, kidnappings, and bombings of Americans occurred throughout the 1970s and 1980s, and into the 1990s. By the mid-Nineties the danger had shifted toward attacks by violent Islamic extremist groups such as al-Qaeda. Al-Qaeda successfully moved their terrorist campaign inside of the United States homeland with the World Trade Center bombing in 1993 and the devastating 9/11 attacks in 2001.

Types of Terrorists

Terrorists fall into five major categories, based upon the political cause that motivates their actions. These categories are: nationalist, religious extremists, left wing terrorists, right wing terrorists, and single-issue terrorists.

Nationalist terrorists act in support of a cultural or ethnic group. Typically they are fighting on behalf of national populations that wish to have an independent government, but are currently ruled by another country. Nationalist terrorists tend to direct their attacks against the "occupying power" that they wish to drive away, but may also attack other nations that support their enemies. Nationalist terrorists claim to speak for their entire national group, but usually only represent a small minority of extremists. Examples of nationalist terror groups include the Provisional Irish Republican Army (Northern Ireland), the Popular Front for the Liberation of Palestine (Palestine), and the Armed Forces of National Liberation (Puerto Rico).

Religious extremist terrorists are violent adherents of a specific religion. They may be violent extremists within a large, generally peaceful faith such as Islam or Christianity, or members of a small "cult" religion in which the entire group is extremist. These terrorists tend to be especially committed because they believe their violent actions are supported by their deity and because they may expect to be rewarded after death. Religious terrorists see themselves as fighting in a battle of ultimate good against pure evil, in which any action is justified. Examples of religious extremist terrorists include al Qaeda (International), Hezbollah (Lebanon), and the Aum Shinrikyo cult (Japan).

Left wing terrorists attempt to force society to change to match their goals and values. They tend to target the government, powerful institutions, and symbols of authority. Socialist and Communist terrorists of this type were a threat in the late 1960s and 1970s, but have weakened in recent decades. Examples of left-wing terrorist groups include the Weathermen (United States), the Red Army Faction (Western Europe), and Shining Path (Peru).

Right wing terrorists see themselves as fighting for traditional values against an invading group and/or against a tyrannical government. In the United States these terrorists are associated with anti-immigration, white supremacy, anti-government, and Christian Identity movements. Only the most extreme elements of these movements have become terrorists, but they have carried out a substantial portion of the recent attacks in the United States. Right wing groups tend to target members of hated ethnic or religious minorities, or government employees. In recent years, right wing terrorists have usually operated as violent individuals termed "lone wolves" and not in organized groups. Examples of right wing terrorist groups in the United States include "The Covenant, The Sword, and the Arm of the Lord" and "The Order." Examples of right-wing "lone wolf" terrorists include Timothy McVeigh (of the 1995 Oklahoma City bombing) and James von Brunn (of the 2009 National Holocaust Museum shooting in Washington, D.C.).

Single-issue terrorists are not committed to an all-encompassing belief system, but rather are intensely concerned with one particular cause. Frequently these issues are of interest to many members of society, but only small numbers of individuals convert this interest into terrorist action. Common causes for single issue terrorists in the United States include animal-rights, environmentalism, and opposition to abortion. These terrorists carry out the majority of terrorist attacks within the United States, but tend to target property or individuals rather than attempting to cause massive casualties. Examples of American single issue terrorist groups include the Animal Liberation Front and the Earth Liberation Front, but many single issue terrorists operate as independent lone wolves or in small informal groups.

Terrorists and terrorist groups tend to fall into one of these five categories, but there are examples of terrorists who fit more than one of these categories. For example, nationalist terror groups have often promoted radical left-wing political views while religious extremist terrorists frequently have extreme right-wing views.

The most effective terrorists tend to operate in groups of like-minded individuals. Such groups range from a few committed amateurs to sophisticated international paramilitary organizations. Even in the larger organizations, terrorist groups are structured into small "cells" with a handful of members each. This structure, combined with the intense personal commitment of many terrorists, makes these groups difficult to discover, infiltrate, and disrupt.

Non-terrorist Criminals

Terrorism is a crime, but not all criminals are terrorists. Most crimes impact only a small number of victims and are appropriately handled by local law enforcement. Rarely, a criminal event will impact a large number of people. Examples include mass-shootings at schools or workplaces, infrastructure sabotage, and cyber-attacks. Such major criminal events may resemble terrorist attacks, but there are important differences between terrorists and other criminals.

The principal difference between terrorism and other types of crime is motivation. Terrorists are motivated by a political cause, not by personal gain. Terrorism is not only defined by what an attacker does, but why he or she does it. This is an important distinction because it explains other characteristic differences between terrorism and non-terrorist crimes.

Non-terrorist criminals may be driven by a wide variety of purposes. These motivations are highly idiosyncratic and difficult to categorize or predict. Most criminals avoid major crimes with widespread impact because the chance of monetary gain is low and the risk of punishment is high. Occasionally a criminal will be willing to take that risk. Major criminal events have been conducted for reasons of personal revenge, monetary gain, desire for fame, and due to mental illness.

There are other important differences between terrorists and criminals, although these are generalizations that do not hold true in all cases. Terrorists tend to prioritize their mission over their personal safety and will often risk capture or death to achieve their goals. Criminals usually seek freedom to enjoy the rewards of their crimes and so plan to escape undetected after their attacks. American criminals, especially those who conduct large-scale attacks, tend to operate as individuals or small groups. The most effective terrorists belong to organizations or networks that coordinate multiple members and share extensive resources.

Criminal and Terrorist Weapons and Techniques

There are a wide variety of harmful weapons and tactics available to terrorists and criminals. The specific effects of a terrorist or criminal attack, as well as the emergency response required, are determined largely by the tools used.

Explosives are by far the most common terrorist tool and have also been used by particularly violent criminals. Bombs have many advantages for an attacker, including flexibility, availability, and ease of use. Explosives can be delivered in many ways, including massive car bombs, hidden suicide vests, assassination devices, and letter bombs sent through the mail. Bombs are effective at both destroying property and harming people. Explosive attacks also produce dramatic images of destruction guaranteed to receive the media coverage that terrorists seek out.

A wide variety of explosive materials are available. Military explosives are the most powerful, but are difficult for most terrorists and criminals to get. Commercial explosives are widely available for legitimate use by mines, farms, and businesses. With over 2.5 million tons used each year in the United States, commercial explosives are powerful and easy to acquire. Alternatively, terrorists and criminals may choose to make their own explosives. Effective bombs can be built from commonly available materials such as farm fertilizer, diesel fuel, and hydrogen peroxide.

Explosives are also relatively easy to use. This allows even untrained bombers to launch damaging attacks. Common terrorist tactics include anti-personnel bombs, packed with metal objects to increase injuries, and suicide bombs that can be set off at the most harmful possible time and place. For non-suicidal attackers, bombs can be left in place to explode long after the bomber has made an escape. One common explosives technique of particular importance to emergency responders is the secondary device. This tactic uses a pair of bombs, the first of which draws rescuers and bystanders to the scene and a second, hidden bomb is targeted to then kill these emergency responders.

Explosive attacks can be countered by careful law enforcement work to identify and disrupt possible attacks before they occur. Alert and properly educated citizens can provide important assistance by observing and reporting signs of a possible attack, such as an unwarranted purchase of explosive materials, or the presence of a suspicious package in a public place. Some high-risk areas such as airports can be equipped with explosives screening devices. Particularly high-risk facilities, such as government buildings, may be physically hardened to limit the damage from attack by explosives. If a bomb or potential bomb is detected, specially trained law enforcement bomb squads should be contacted to dispose of it.

Case: Bath School Disaster (1927)

On May 18, 1927, the Bath Consolidated School in Bath, Michigan, was the target of an attack with explosives. The bomber was probably motivated by personal revenge against the local school district (stemming from a taxation issue), and so this event is classified as criminal, rather than as a terrorist attack. Although many of the explosives failed to detonate, the bombs in the school killed dozens of students and teachers. The bomber also destroyed his home and farm with explosives. Immediately after the school attack, the bomber approached the rescue operations scene and detonated an explosive device carried in his vehicle, killing himself, local officials, and several bystanders. The final death toll was 45, with 58 additional persons injured. The Bath Disaster remains the second most deadly U.S. bombing attack, after the Oklahoma City Bombing, as well as the most lethal attack on an American school. This case also provides early examples of such tactics now in common use by terrorists, including a secondary device, suicide bombing, and car bomb.

Case: Oklahoma City Federal Building Bombing (1995)

On April 19, 1995, the Alfred P. Murrah Federal Building in Oklahoma City, Oklahoma, was attacked by a large truck bomb. The attack killed 168, injured more than 680, destroyed the building, and caused widespread destruction over a sixteen-block area. Although initially suspected of being carried out by international terrorists, the attackers were in fact anti-government domestic terrorists, one of whom had extensive Michigan connections. This attack is an example of right wing anti-government terrorism. It also demonstrates the extensive destruction that can be caused to large buildings which lack adequate target hardening and security measures.

Case: Bali Bombing (2005)

On October 12, 2002 terrorists bombed the tourist district of Kuta on the Indonesian Island of Bali. The targets were several nightclubs frequented by Western tourists. An initial backpack suicide bomb was directed against patrons inside a dance club. Shortly thereafter, a large car bomb detonated on a busy street near the first attack, killing survivors of the initial bomb and would-be rescuers. The second bomb weighed over a ton and devastated several blocks of buildings. In total, 202 persons were killed, with a further 209 injured. The attack was carried out by Jemaah Islamiyah, an Indonesian extremist Islamist organization. This case is an example of the versatility of terrorist explosives, used at Bali as both a small suicide weapon and a massive remotely detonated car bomb. It is also an example of a large secondary device, intended to kill those responding to the initial bomb.

Case: Northwest Airlines Flight 253 Bombing Attempt (2009)

On Christmas Day 2009, Umar Farouk Abdulmutallab attempted to destroy Northwest Airlines Flight 253, approaching Detroit Metropolitan Airport. The weapon used was an explosive device provided by the “al-Qaeda in the Arabian Peninsula” terrorist group and hidden in his underwear. The device was small and easy to conceal, but was capable of damaging or destroying the airliner. The explosive failed to detonate properly and instead

ignited and burned Mr. Abdulmutallab, who was then subdued by the plane's passengers and crew. This attack demonstrates the potential effectiveness of even small bombs when used against vulnerable targets such as aircraft. It also demonstrates that international terrorism may be directed at targets in Michigan.

Suggested cases for readers' further study: (1) 1993 WTC bombing (demonstrates the importance of terrorist planning), (2) London transit bombing (demonstrates the use of small improvised devices), (3) Airline insurance bombing (demonstrates a criminal attack against an airliner), (4) Madrid train bombings (demonstrates political benefits for terrorists).

Incendiaries are similar to explosives and share many characteristics. Incendiaries are used to start fires rather than to destroy through explosion. Generally they are targeted at structures and property rather than directly against people. This makes incendiaries appealing to groups such as animal rights terrorists that seek to minimize casualties. The devices can be as simple as a can of gasoline ignited on a porch, or as sophisticated as a military thermite bomb. The use of fuel-laden jetliners as suicide missiles in the 9/11 attacks can be considered a massive application of improvised incendiary devices.

Countermeasures against incendiary attack are very similar to those against explosive attacks. Effective law enforcement, good intelligence on potential attackers, surveillance of critical sites, and hardening of particularly vulnerable targets can all be helpful. Note that the construction of simple incendiary devices can be very difficult to prevent since there are no legal restrictions on incendiary materials such as gasoline and matches. Prompt fire detection and effective firefighting can limit the damage once an attack occurs.

Case: Michigan State University Agriculture Building Arson (1999)
On December 31, 1999, environmental terrorists affiliated with the Earth Liberation Front (ELF) set fire to the Agriculture Biotechnology Support Project, located in a classroom and office building at Michigan State University. The university was targeted because of its work on genetically modified crops. The fire was set when there were few people in the building. Damages to the building and research equipment totaled approximately $1 million. Four domestic terrorists from Michigan and Ohio were later tried and convicted in federal court for carrying out this attack. This attack, a similar attack against Michigan State in 1992, and an attempted attack against the Michigan Technological University Forestry Center in 2001 are all typical of attacks by environmental terrorist groups. These attacks generally are designed to cause property damage but few deaths and injuries. These attacks also demonstrate the vulnerability of universities and research centers to terrorist attack.

Case: 9/11 Airliner Attacks (2001)
On the morning of September 11, 2001, terrorists hijacked four commercial airliners originating from Boston Logan Airport, Newark International Airport, and Washington Dulles International Airport and then deliberately crashed the aircraft into the World Trade Center in New York City, and the Pentagon in Arlington, Virginia (with a fourth crashing in rural Pennsylvania), killing approximately 3,000 persons and causing billions of dollars in property damage. This coordinated attack was the deadliest act of terrorism in history. The attack would have been even worse had the fourth aircraft hit its intended target, which was presumed to be the White House in Washington, D.C. Instead, passengers attacked the hijackers, probably causing them to crash the aircraft into the open field in Pennsylvania.

Although these attacks began as hijackings, they may be classified as incendiary terrorism because most of the damage was caused by large fires started by the crashing airliners and their spilled jet fuel. It was these fires that caused the collapse of the three largest buildings at New York's World Trade Center, and of portions of the Pentagon building.

These attacks caused major disruption to airline travel, including a temporary ban on all civilian flights in the United States. Significant and expensive changes were made to improve security at airports and aboard aircraft. Substantial damage was caused to the overall U.S. economy, due to the direct and indirect costs of the attacks.

With the 9/11 attacks as justification, the United States and its allies launched major military campaigns in Afghanistan, Iraq, and Pakistan that have cost tens of thousands of lives and trillions of dollars. This one terrorist operation, conducted by 19 men armed with knives, continues to have global repercussions years after the event.

The 9/11 attacks demonstrate the ability of terrorists to seek out vulnerabilities and to creatively exploit them. The attacks were incredibly effective because the terrorist tactics were unexpected, and terrorists will continue to attempt to surprise their targets with new weapons and techniques. These attacks also illustrate that a major terrorist attack can have repercussions that extend well beyond the immediate scene of the attack.

Suggested case for readers' further study: Alphabet bomber (example of multiple incendiary attacks as part of an individual's terror campaign).

Shooting attacks are a popular tactic for both terrorists and criminals. Firearms can be used to target a specific individual or to attack many people in a crowded place. Small arms such as pistols, rifles, and shotguns are easily available in the United States, including semi-automatic weapons with large capacity magazines. Shootings at schools and workplaces are among the most common types of major criminal attack.

An important drawback to the use of firearms, particularly in a mass shooting, is that the attacker is not likely to escape. Therefore shootings are usually carried out by suicide attackers, those expecting to be arrested, or criminals who are acting impulsively and without thought to consequences.

Countermeasures against shooting attacks are difficult, since attackers usually choose unprotected public areas. Protection against attacks has to be balanced against the public's need to use their schools, shopping malls, government buildings, and workplaces. Appropriate security measures and effective lock-down training can limit casualties in high-risk buildings such as schools. Rapid response by well-trained law enforcement officers and emergency medical personnel is also very important.

Case: Columbine School Shooting (1999)
On April 20, 1999, two students staged an attack at Columbine High School near Denver, Colorado. Although the criminals attempted to use explosives, all of the casualties were inflicted with small arms. Using a variety of handguns and shotguns, the criminals killed 13 teachers and students and wounded 24 others. By targeting crowds of students during lunch, the attackers were able to inflict all of the casualties within 23 minutes. The criminals expected to die during the attack and took their own lives at the end of their assault. This attack demonstrates the vulnerability of facilities, such as schools, where large numbers of victims can be founds in close proximity. It also illustrates the short duration of most mass shooting attacks and the need for a very rapid law enforcement response.

Case: Mumbai Attacks (2008)
On November 26, 2008, terrorists attacked the Indian city of Mumbai. The primary weapons employed were rifles and handguns, though small explosives were also used. Ten terrorists attacked six targets across Mumbai's downtown area, including hotels, a railway station, a hospital, a restaurant, and a Jewish community center. There were also shootings on the city streets and several diversionary attacks. In total, more than 160 persons were killed and more than 290 injured. Sixteen of the dead and many of the injured were law enforcement officers. The attack was conducted by Lashkar-e-Taiba, a Pakistani extremist Islamist group. The attackers intended to die during their mission, though one man was taken alive. This case demonstrates the large number of casualties that can be inflicted by firearms in a crowded urban environment. It also demonstrates the significant challenge for law enforcement when suddenly confronted with a number of heavily-armed and suicidal gunmen, and the substantial police casualties which may result.

Case: Fort Hood Shooting (2009)
On November 5, 2009, a single gunman launched a shooting attack at the Fort Hood military post, located near Killeen, Texas. The attacker was Major Nidal Malik Hasan, a U.S. Army psychologist. Using a single handgun, Hasan killed 13 military personnel and wounded 29 others before being subdued. Hasan is accused of terrorism; acting for political reasons related to his extremist Islamist beliefs. It is believed that he was radicalized though the Internet and specifically through contact with Anwar al-Awlaki, a member of the terrorist group "Al Qaeda in the Arabian Peninsula." This case demonstrates the potential lethality of a highly trained and well-equipped gunman. Maj. Hasan made far more effective use of his weapon than other mass shooters, which can be attributed to his high level of training and preparation. It also demonstrates the danger posed by "lone wolf" attackers (self-radicalized and acting outside of the direct control of an established terrorist organization). Finally, it is an alleged example of an American citizen acting on behalf of a cause typically identified with international terrorists. As an American and a member of the military, Maj. Hasan does not fit the expected terrorist profile, which may have enabled him to avoid detection as a deadly threat.

Suggested cases for readers' further study: (1) Virginia Tech shooting (an example of heavy casualties caused by a single gunman, and of a university target), (2) D.C. Beltway Sniper (example of random attacks, the effectiveness of a small team, long-range shooting, and widespread public fear), (3) Beslan School attack (an example of massive casualties, terrorist targeting of young children, difficult rescue operations, and a large suicide team with military weapons).

Chemical weapons attacks involve the use of poisonous materials, usually toxic gases. This is a potentially dangerous type of weapon, but is difficult to use effectively. Poison gas tends to disperse quickly and unpredictably, which reduces casualties even when used on an unsuspecting target. Chemical weapons attacks are very similar in effect to the accidental release of hazardous materials.

As with explosives, there are many possible types of chemical weapons. Military gases such as nerve gases can be deadly, but are difficult to acquire or manufacture. Commercial gases such as chlorine and hydrogen cyanide are produced in massive quantities and easier to find, but they are less effective. One possible terrorist tactic is to attack chemical storage facilities in order to harm the surrounding communities.

Chemical attacks have been rare in practice. Despite their theoretical effectiveness, few terrorists or criminals have attempted to use chemical weapons and most of their attacks have failed.

Case: Tokyo Sarin Attack (1995)
On March 20, 1995, Japanese domestic terrorists launched a poison gas attack on the Tokyo subway system. The perpetrators were members of Aum Shinrikyo, a religious cult with extensive financial and scientific resources. The terrorists manufactured their own supply of the military nerve gas Sarin. This attack demonstrates that while it is difficult to create mass casualties with terrorist chemical weapons, it is comparatively easy to cause mass panic.

Although the nerve gases used in Tokyo were highly lethal, and the attackers intended to cause many casualties, the terrorists had difficulty in spreading the gas effectively. Twelve people died in the attack, approximately fifty were severely injured, and more than a thousand suffered more limited health effects. The attacks did cause considerable alarm, and medical facilities were overwhelmed by uninjured but frightened citizens. One lesson learned from this attack was the importance of preparing first responders and emergency room personnel to deal with chemically contaminated victims.

Suggested case for readers' additional study: Afghan girls' school attacks (an example of non-fatal uses of toxic gas, recent attacks, and schools as targets).

Biological weapons use disease organisms to cause illness and death. This type of attack is sometimes referred to as "germ warfare." Some biological weapon organisms, such as anthrax, will sicken victims that come in contact with weapon materials, but the victims cannot easily spread their disease to others. This type of attack resembles the use of a chemical weapon. Other germ warfare organisms, such as smallpox and plague, can pass from one victim to another, allowing an initially small attack to eventually infect a large number of victims.

Biological weapons may be attractive to terrorists and criminals because some varieties are relatively easy to produce. A widespread disease outbreak could potentially sicken many people and cause widespread panic. In addition, biological terrorism can be targeted against crops or livestock if the attacker wishes to causes significant economic damage instead of human casualties.

Biological weapons also possess drawbacks for potential attackers. The effects are hard to control and a disease released against a terrorist's enemies might very well spread to infect the attacker's friends and allies. Another problem is that the most deadly germ warfare agents, such as smallpox and breathable anthrax, are quite difficult to manufacture. In addition, standard infectious disease control techniques, such as patient isolation, antiseptics, hand washing, and antibiotics, can be very effective countermeasures against biological attacks, just as they are against natural disease outbreaks.

One major consideration for potential biological attacks is that germ warfare is often not recognized as an attack. Victims often do not show symptoms for several days and unlike a bomb explosion or mass-shooting, biological attacks are often mistaken for naturally occurring diseases. This may be an advantage for certain criminals who want their attacks to go unrecognized, but may be a major drawback for a terrorist who wants to use a biological attack to achieve political goals.

Case: Rajneeshee Salmonella Attack (1984)
During September and October 1984, followers of the fringe religious leader Bhagwan Shree Rajneesh deliberately attacked residents of The Dalles, Oregon, with the salmonella organism. Salmonella was spread by means of contaminated glasses of water and by spraying the organism on restaurant salad bars. A total of 751 people were sickened and 45 were hospitalized. None of the victims died.

The attack was an attempt to reduce voter turnout in a local election, allowing the Rajneeshee religious community to gain control of the Wasco County Circuit Court. The perpetrators did not intend for their attack to be recognized. They hoped that it would be mistaken for an accidental outbreak of food poisoning. Only after the group was investigated for other crimes was the outbreak recognized as a deliberate biological attack.

This attack is a creative example of the criminal use of biological agents. It demonstrates the difficulty in identifying a biological event as a deliberate attack.

Case: Amerithrax Anthrax Attack (2001)
In October 2001, several letters contaminated with anthrax were mailed to locations in Florida, New York, and Washington, DC. The intended targets were politicians and members of the media, but most of the victims were accidentally exposed. Twenty-two victims suffered a confirmed anthrax infection and five died. Several structures, including government office buildings and postal facilities, were contaminated by anthrax and required expensive decontamination before they could be reoccupied. Fortunately, anthrax does not spread easily from person to person and the disease outbreak was quickly contained.

The content of the contaminated letters had initially suggested that Islamic terrorists were responsible for the attack. Following shortly after the 9/11 terrorist disaster, the Amerithrax attack was the subject of considerable media coverage and caused great national concern. Public fear was heightened by a large number of "copycat" incidents which followed over the next several months, though fortunately all of these proved to be mere hoaxes.

Eventually federal investigations determined that the attack was conducted by a domestic criminal posing as a foreign terrorist. In 2008, a U.S. government anthrax researcher was identified as the likely source of the attacks. An indictment was sought by the United States Attorney's Office, but the suspect committed suicide before his arrest. The likely motive was personal and professional gain, as the attacks increased funding for the researcher's anthrax vaccine project.

This incident is an example of a criminal use of biological weapons. It demonstrates that it can sometimes be difficult to determine whether an attack is criminal or terrorist in nature. It also shows that attackers are not all foreigners or members of the radical political fringe; in this case the criminal was a highly trusted government employee.

Radiological weapons, sometimes called Radiological Dispersal Devices (RDDs) or "dirty bombs," are weapons designed to spread hazardous radiological materials. These devices do not create a nuclear explosion. The most standard design for a radiological bomb surrounds conventional explosives, such as dynamite or gunpowder, with radioactive materials in the form of powder or scraps of metal. Such a bomb would do the same damage as a normal (non-radiological) explosive and in addition would spread radioactive materials around the area near the explosion.

No radiological weapon has even been used in an actual attack. However, based on U.S. government tests of dirty bomb designs, the health effects of this type of weapon would likely be quite limited. It is difficult to create enough contamination to make victims seriously ill and even more difficult to cause deaths through radiation. It is likely that more people would be killed by the normal explosives in a dirty bomb than would be seriously hurt by the effects of radiation. However, cleaning up an area once it has been contaminated by radioactive materials would be extremely difficult and expensive. In addition, radioactive threats tend to cause a great deal of fear in the general public. This makes radiological weapons potentially very useful for terrorists: they create little actual destruction, but considerable terror and disruption.

Radiological weapons are considered a serious threat because the components for a dirty bomb have legitimate civilian uses and can easily be stolen by terrorists or criminals. Hospitals, food processing plants, and research centers all possess radioactive materials that would be of use in making a weapon. There is a proven black market in radioactive materials, particularly involving sources stolen from Eastern European countries. Plans for radiological weapons have been discovered in the hands of several potential terrorists, including U.S. domestic terrorists.

Case: Goiânia accident (1987)

No actual radiological weapon has ever been used in a criminal or terrorist attack. However, one radiological hazardous material incident demonstrates the possible health effects of a major successful attack. On September 13, 1987, medical equipment was stolen from an abandoned hospital in Goiânia, Brazil. The thieves were seeking metal for salvage and were unaware that they had taken a powerful radioactive source. The protective casing for the equipment's caesium chloride source was cracked open with a hammer and the deadly material dispersed through homes and businesses. The victims, some of whom were children, and none of whom were aware of the danger, handled the radioactive caesium and in some cases painted it on their bodies or ate it.

The danger was not recognized for more than two weeks, when doctors identified the radioactive material. When the incident was made public, local medical facilities were then overwhelmed by approximately 130,000 persons seeking medical care. Eventually, 249 victims were found to be contaminated, four of whom died. Extensive clean-up work required widespread radioactive monitoring, demolition of a number of buildings, excavation of contaminated soil, and disposal of large amounts of radioactive waste.

The Goiânia accident represents nearly a worst case example of radioactive contamination. The material involved was especially dangerous and the danger was undetected for several weeks. Victims had ongoing close contact

with the radioactive material, including ingestion. A dirty bomb attack would likely be detected immediately, and a much timelier and more effective response conducted. Despite the seriousness of this incident, there were only four deaths, although cleanup was difficult and expensive. Public fear of radiation led to large numbers of unexposed but concerned persons demanding medical treatment.

Nuclear weapons are potentially the deadliest terrorist tools. Unlike the radiological "dirty bombs" described above, nuclear weapons create very large explosions capable of creating widespread damage and many casualties over a large area. The great destructive potential of these devices make them very desirable for terrorist groups that wish to cause massive and indiscriminate casualties. Fortunately, nuclear weapons are difficult to build, especially because they require the use of rare and carefully guarded materials. Although several terrorist groups have actively sought to acquire nuclear weapons, no terrorist organization is known to have succeeded in doing so.

The importance of the terrorist nuclear threat is not that such an attack is likely, but that it is possible, and that the damage caused by such an attack would be immense. Nuclear weapons cause damage by releasing enormous amounts of heat, by creating powerful explosive shock waves, by releasing damaging radiation, by disrupting electronic devices, and in some cases, by creating radioactive dust, called fallout, that drifts downwind from nuclear explosions. Nuclear weapons vary greatly in their power and effects: the weapons most likely to be used by terrorists are very dangerous, but are still far less powerful than the strategic nuclear weapons possessed by nations such as the United States, Russia, and China.

For more detail on nuclear weapons and their effects, see the Nuclear Attack section of this document.

Case: Bombings of Hiroshima and Nagasaki (1945)
Although the nuclear attacks against Japan at the end of World War II were military strikes rather than terrorism or criminal activity, these cases are included because these are the only examples of nuclear weapons used against populated areas. The attacks, each using one nuclear bomb, destroyed the centers of the cities of Hiroshima and Nagasaki, though not their outskirts. At Hiroshima, 4.7 square miles of the city were destroyed and approximately 100,000 residents were killed. At Nagasaki, 1.8 square miles were destroyed and approximately 60,000 died. In both cases, the greatest cause of damage and destruction was intense heat and fire. The weapons used against the cities of Hiroshima and Nagasaki were weak by modern military standards, but were approximately the strength of the most likely types of terrorist nuclear weapons. These attacks provide a very rough guide as to the damage and casualties to be expected from a terrorist nuclear attack against a medium-sized city.

Sabotage is the destruction of property or the disruption of operations in an attempt to harm a business, government, or other entity. Attackers who use sabotage are called saboteurs. Sabotage often overlaps with, and can be difficult to distinguish from, other terrorist or criminal tactics. For example, explosives can be used to destroy vehicles or infrastructure, or chemical poisons can be used to contaminate food and medicine. The principal identifying characteristic of sabotage is that the attack is unusually not intended to harm large numbers of people, but rather to cause economic harm or embarrassment to the target. Where deaths or injuries do occur, they are usually incidental, rather than the purpose of the attack. Past sabotage tactics have included the toppling of electrical power pylons, the burning of vehicles, destruction of railroads and bridges, and contamination of food and medicine.

Many single-issue terrorists, including ecological extremists and anti-abortion radicals, have used sabotage widely. These groups have usually preferred to destroy property rather than to kill people. Most other terrorists tend to avoid sabotage as they seek the media coverage that results from numerous casualties. Sabotage by non-terrorist criminals is difficult to characterize, as it ranges from planned campaigns by organized labor groups, to one-time extortion plots, to attacks by mentally disturbed individuals.

Case: Byron Center Meat Tampering (2003)
In January 2003, a disgruntled employee intentionally contaminated 250 pounds of ground beef sold at a local supermarket in Byron Center (Kent County), Michigan. The meat was poisoned with insecticide containing harmful amounts of nicotine. The attacker was seeking revenge on his supervisor, whom he hoped would be blamed for the illnesses. Although the ground beef contained potentially lethal doses of toxin, there were no fatalities resulting from the attack. Investigation did identify 92 individuals sickened by the poison. The attacker was convicted and sentenced to seven years in prison. This incident demonstrates the willingness of some saboteurs to endanger the lives of numerous bystanders in pursuit of their goals. In this case, the attacker had no specific interest in harming the poisoning victims, except to use them to embarrass a personal enemy.

Case: Pontiac School Bus Bombings (1971)
On August 30, 1971, ten Pontiac school buses were bombed and destroyed in response to a controversial, court-ordered busing plan to integrate Pontiac schools. Authorities believe that several individuals slipped through a hole cut in the wire fence that surrounded the Pontiac bus depot, and placed dynamite under the buses. The explosion and fire destroyed the buses and focused national attention on Pontiac and the school busing issue. Subsequent attempts to overturn the Pontiac busing plan failed, and eventually 70 other school districts across the country were ordered to implement similar busing plans to achieve racial integration in schools. The Pontiac bombers, later apprehended and convicted of the attack, were identified as members of the Ku Klux Klan.

Suggested case for readers' further study: Tylenol cyanide poisonings (an example of a major impact on industry, and an unknown perpetrator with an undetermined motive).

Cyber-attack is a new category of terrorist and criminal threat. Cyber-attacks involve the use of computers, electronic devices, and/or the Internet to attack computer systems. Examples of some types of cyber-attacks include computer viruses, which damage many infected computers, denial-of-service attacks, which shut down a targeted website, and hacking attacks, which damage sensitive information. These attacks may be used as part of extortion schemes, to undermine public confidence in the target's security, as a form of technological vandalism, or as military sabotage.

Early cyber-attacks were primarily conducted by amateur computer "hackers" operating individually or in small teams. More recently, well organized groups of profit-driven professional cyber-attackers have developed. These teams of cyber-saboteurs can operate globally, attacking targets anywhere in the world through the Internet. Their customers include organized crime, national governments, and possibly terrorist organizations. These professional cyber-attackers can be very effective because they control large networks of "zombie" computers called "botnets." These are computers taken over without their owners' knowledge and controlled remotely, often for criminal purposes.

Another possible source of cyber-attacks are "hacktivists," computer criminals motivated by a political cause rather than by a profit motive. Several global networks of hacktivists have been created, including "Anonymous" and "Lutzsec." These loosely organized groups include members in multiple countries who coordinate their efforts online. There are also a number of nationalist hacktivist organizations, some of which may be sponsored by national intelligence services. Hacktivists groups are difficult to disrupt, both because of the challenge in determining the real identity of group members, and because they may be located in countries which refuse to cooperate with international law enforcement. Hacktivists have generally confined their cyber attacks to vandalism of websites, denial of service attacks, and theft of personal information. There is however, the potential for extremist members of these politically-motivated groups to shift their activities to more destructive cyber-terrorism.

National governments are also developing sophisticated cyber-attack capabilities, both to support espionage programs and to damage the computer networks of enemies. Cyber-attacks backed by extensive national military and intelligence resources could be especially destructive and difficult to counter. One new cyber-attack

capability which appears to have been deployed by government-sponsored programmers is the ability to cripple or destroy industrial machinery by taking over the software that controls the machines. Cyber-attacks on these "industrial control systems" could be used to damage critical infrastructure such as electrical grids, water treatment systems, and fuel pipelines as well as to attack industrial targets. National cyber-attack capabilities are also expected to include efforts to disrupt secure national networks such as those used for banking and by law enforcement. A cyber war between nations with sophisticated cyber-attack capabilities could be very damaging, even to innocent bystanders in the conflict.

An analysis of cyber-attacks usually requires special resources to identify and report details about ongoing or past significant incidents that involve attacks upon or exploitation of computer networks or communications system. The Michigan Intelligence Operations Center especially tracks any such operations that impact the U.S. homeland or national security interests.

Here are some examples of information that may be noted and reported about cyber-attacks:

- What type of activity occurred?
    - Data exfiltration
        - If data was exfiltrated, how much and what type?
        - To what IP address?
    - Malicious file infiltration
    - Malware detection
    - Botnet activity
    - Spear Phishing
- What attack vector was used?
- What vulnerability did the threat actors exploit/attempt to exploit?
    - Known vulnerability for which a patch exists (include Common Vulnerabilities and Exposures [CVE] number if known)
- Upon gaining access, what did the threat actors do?
    - Scan for vulnerabilities and attempt to move laterally across the network
    - Host malware on a system
    - Compromise Active Directory server / Domain controller
    - Create additional accounts
    - Exfiltrate username and password hashes
    - Exfiltrate specific types of documents (either by name/subject or file type)
    - Exfiltrate whatever files and information they could get access to
- IP addresses involved in malicious activity?
    - The number of times the IP was involved in an event on that given day
    - The country associated with the IPs
- What malicious websites or domains were involved?
    - Indicate what IP address the domain resolved to at the time of the incident
    - Domain/IP registration information if available, including country of origin
    - Other domains hosted by malicious IPs
- When did the activity occur?
    - In addition to the date, include the period of time (the hours) from when the activity was detected to when it stopped
    - Each day the IP was involved, if across multiple days
- Phishing and Spear Phishing
    - E-mail header information
        - Sending IP
        - Mail relays involved
        - True email address (if message was spoofed)

    - Subject line
    - Attachments (more information in the next bullet section for malicious attachments)
    - Hyperlinks in the email, including the actual destination for any spoofed links
    - Text from the body
    - For spear phished individuals, include how the malicious actor attempted to bait their target
- What malicious code/software was detected or what indicators were associated with malicious files?
    - File name
    - File size
    - Hash values (e.g. MD5, SHA-1, ssdeep)
    - Timestamps
    - Additional malware information
- What botnet(s) were associated with the incident?

Case: July 2009 Cyber-Attacks (2009)

On the 4th of July, 2009, a series of cyber-attacks were directed against computer systems in the United States and in South Korea. Targets included the websites of the U.S. State Department, the U.S. Department of Defense, the White House, numerous South Korea government agencies, a large bank, and a major South Korean media company. The attacks were designed to shut down the targeted websites by overloading them with traffic. This was accomplished with a "botnet" of computers infected by a computer virus. Thousands of computers were hijacked and used in these attacks without their owners' knowledge. The cyber-attack software was also designed to damage the computers in the botnet several days after the start of the attack. Some experts believe that the attack was sponsored by the government of North Korea, perhaps with the help of criminal networks operating outside of that country. As with many cyber-attacks, it has been impossible to definitively prove who was responsible for the attacks. This case demonstrates the significant economic and governmental disruption which can be caused by even primitive cyber-attacks. It also demonstrates that the geographic locations of the cyber-attackers and of their targets are largely irrelevant. Attacks can be launched from anywhere, to anywhere, through the use of the Internet.

Case: Stuxnet (2010-Present)

First discovered in June of 2010, Stuxnet is a highly sophisticated cyber-attack program. This "computer worm" software has been designed to infect industrial control systems created by the Siemens Corporation. On most computers, the Stuxnet worm stays hidden and does no damage. However, if the Siemens control software is connected to certain types of motors, the worm conducts a cyber-attack on the infected system. The targeted motor is ordered to rapidly change speeds, which will destroy certain types of connected industrial equipment. Meanwhile the safety mechanisms on the equipment are disabled, and monitors will show motor performance as completely normal, even as the equipment is being destroyed. It is believed that Stuxnet was designed specifically to damage uranium processing equipment operated by the government of Iran. Substantial harm was apparently inflicted on its processing facility at Natanz. The creators of Stuxnet are unidentified, but given the sophistication of the software, and the care with which only Iranian government systems were targeted, it is considered likely that at least one national intelligence service was involved in creating the worm. Several governments have expressed an interest in damaging Iran's nuclear industry in order to stall the creation of Iranian nuclear weapons. The case provides an example of the sophisticated cyber-attack tools which may be deployed by national governments. It also provides the first example of cyber-attack software capable of causing physical damage, not merely theft or destruction of data.

Possible Terrorist/Criminal Targets

Terrorists typically select targets that will generate the maximum possible media coverage, but the specific types of targets selected by terrorists and criminals depend entirely on the goals of the attackers. For nationalist, left-wing, and right-wing terrorists, the preferred targets are usually buildings or people with strong symbolic meaning for their enemies. These terrorists may attack government buildings, strike public monuments, or assassinate well-known leaders. Single-issue terrorists tend to target facilities or individuals directly associated with their specific

cause. For example, anti-abortion terrorists might target abortion clinics, anti-Jewish terrorists might target synagogues, and animal rights terrorists may target animal research centers. Finally, religious extremist terrorists tend to emphasize killing or injuring large numbers of victims in a spectacular manner. These terrorists might be expected to target schools, airports, mass-transportation systems, sporting events, places of worship, or entire cities.

Most terrorists will usually seek out targets that are poorly defended by law enforcement, security screening, or other protective measures. Such "soft" targets offer the opportunity to do the maximum possible damage. Even terrorists who do not intend to survive their attack want to accomplish their mission, and well-protected targets can make that difficult to achieve. Terrorists rarely feel the need to strike only one specific target, so they will examine multiple targets until they find one that is vulnerable.

Targets for non-terrorist criminals are difficult to identify because criminals may have a wide range of motivations, including financial gain, personal revenge, a desire for fame, or mental illness. Criminals are generally more likely to choose targets that they are personally connected with, as when criminal employees target their workplace or criminal students target their own school building.

Impacts of Terrorism and Similar Criminal Activities

Impact on the Public

The specific impact of terrorism or similar criminal activities would depend on the nature of the terrorist targets and the type of weapons used against those targets. Given the wide range of possibilities, it is difficult to generalize about damage or casualties. In a worst case scenario, a terrorist or criminal attack could cause significant damage to people, property, and to the economy. Infrastructure, such as transportation, computer networks, or communications might be damaged or overwhelmed by a fearful population. Worst case scenarios, however, are unusual. Most attacks will do little damage and only a very few will cause mass casualties. One likely impact of terrorism on the public would be an increase in fear, uncertainty, and inconvenience. Terrorism is, after all, intended to cause terror. In some cases, innocent citizens may suffer misguided retaliation if they are identified with an ethnic group or political movement held responsible for terrorism. Public impact may also be increased by the effect of government anti-terrorism programs, as demonstrated by the inconvenience created by increased airport security measures.

Impact on Public Confidence in State Governance

Public reaction to terrorist attacks would vary depending on the effectiveness of the attack and the type of target. It is possible that state government would be held accountable for failing to stop a terrorist plot, though counter-terrorism is generally considered to be a federal government responsibility. Governments may also be pressured to create new legal restrictions and law enforcement measures in response to a terrorist attack. Such measures would be expected to create public opposition from citizens who feel their rights violated by counter-terrorism efforts. Finding the correct balance between civil liberties and public security is likely to remain a difficult challenge.

Impact on Responders

Responders may face difficult and unexpected challenges following a terrorist or criminal attack, especially if the attack involves mass casualties or uses chemical, biological, radiological, nuclear, or cyber attack. Terrorists, and criminals who conduct terrorist-like violent attacks, may behave very differently from other types of criminals with which responders are familiar. Terrorist weapons may pose a direct hazard to the life and safety of responders, especially in the case of secondary devices specifically targeted on those responders.

Impact on the Environment

Terrorist and violent criminal attacks are very rarely targeted specifically on the environment, but environmental damage is possible as an indirect consequence of an attack. This would be especially true in the case of chemical, radiological, biological, or nuclear weapons which could contaminate a significant area for an extended period of time. Damage to infrastructure may also cause environmental problems, as in the case of an oil pipeline sabotaged with explosives or a metropolitan water treatment system disabled by cyber-attack. Please refer to the sections on dam failures, energy emergencies, fires, hazardous materials, infrastructure failure, nuclear attack, oil and natural gas pipeline and well accidents, public health emergencies, and transportation accidents for more examples of the type of impacts that may result from terrorism or major criminal incidents.

Programs and Initiatives

(Note: Refer to the Weapons of Mass Destruction Attack Procedures section of the Michigan Emergency Management Plan for a comprehensive list of federal and state response assets that can be mobilized for incidents of sabotage / terrorism involving weapons of mass destruction.)

Homeland Security Act of 2002

The Homeland Security Act of 2002, Public Law 107-296, established the Department of Homeland Security with the mandate and legal authority to protect the American people from the continuing threat of terrorism. In the act, Congress assigned the DHS the primary mission to (1) prevent terrorist attacks within the United States, (2) reduce the vulnerability of the United States to terrorism at home, (3) minimize the damage and assist in the recovery from terrorist attacks that occur, and (4) act as the focal point regarding natural and manmade crises and emergency planning.

Public Health Security and Bioterrorism Preparedness Act of 2002

The events of September 11, 2001, reinforced the need to enhance the security of the United States food supply. Congress responded by passing the Public Health Security and Bioterrorism Preparedness and Response Act of 2002, Public Law 107-188, which President Bush signed into law on June 12, 2002. The Act is divided into the following five titles:

- Title I - National Preparedness for Bioterrorism and Other Public Health Emergencies
- Title II - Enhancing Controls on Dangerous Biological Agents and Toxins
- Title III - Protecting Safety and Security of Food and Drug Supply
- Title IV - Drinking Water Security and Safety
- Title V - Additional Provisions

This federal investment, combined with the efforts of states, local government and private sector entities, is increasing the capacity of our nation's public health system for confronting possible bioterrorism incidents as well as other health threats. These efforts can reduce the consequences of bioterrorism, especially through the development of new countermeasures to treat or prevent diseases that might be used by terrorists. At the same time, these efforts increase the nation's capacity to deal with all public health emergencies, including chemical or nuclear terrorism, natural outbreak of disease, or other mass casualty events.

The Maritime Transportation Security Act of 2002

The Maritime Transportation Security Act of 2002 (MTSA), Public Law 107-295, signed on November 25, 2002, is designed to protect the nation's ports and waterways from terrorist attacks. This law is the U.S. equivalent of the International Ship and Port Facility Security Code (ISPS), and was fully implemented on July 1, 2004. It requires vessels and port facilities to conduct vulnerability assessments and develop security plans that may include passenger, vehicle, and baggage screening procedures; security patrols; establishing restricted areas; personnel identification procedures; access control measures; and installation of surveillance equipment. By creating a consistent security program for all our nation's ports, we are better able to identify and deter threats.

The MTSA also required the establishment of committees in all the nation's ports to coordinate the activities of all port stakeholders, including other federal, local and state agencies, industry, and the boating public. These groups, called Area Maritime Security Committees, are tasked with collaborating on plans to secure their ports so that the resources of an area can be best used to deter, prevent, and respond to terror threats.

Terrorism Risk Insurance Program

On November 26, 2002, President Bush signed into law the Terrorism Risk Insurance Act of 2002, Public Law 107-297. The law establishes a temporary federal Terrorism Insurance Program that provides for a transparent system of shared public and private compensation for insured losses resulting from acts of terrorism, in order to protect consumers by addressing market disruptions and ensure the continued widespread availability and affordability of property and casualty insurance for terrorism risk. In addition, it allowed for a transitional period for the private markets to stabilize, resume pricing such insurance, and build capacity to absorb any future losses, while preserving state insurance regulation and consumer protections.

Presidential Decision Directive 39

In response to the World Trade Center and Oklahoma City bombings and the Tokyo subway sarin gas attack, in 1996 President Clinton signed Presidential Decision Directive (PDD) 39, U.S. Policy on Counter-terrorism, ordering federal agencies to prepare for nuclear, biological, and chemical attacks from inside the country as well as abroad. Although every presidential administration since the early 1980s has issued similar directives, PDD 39 was the first to make terrorism a top priority, and the first to recognize that significant terrorism threats exist from within. PDD 39 designated the FBI as the lead federal agency for the crisis management phase of terrorism incidents, and FEMA as the lead agency for post-incident consequence management. It also created the nationwide Metropolitan Medical Response Systems (MMRS – see description below) and significantly expanded the anti-terrorism responsibilities of a number of other agencies.

Presidential Decision Directive 62

In May 1998, President Clinton issued Presidential Decision Directive (PPD) 62, Combating Terrorism, which reinforces the mission of federal departments and agencies charged with roles in defeating terrorism.

Homeland Security Presidential Directive (HSPD)-5

HSPD-5 was issued on February 28, 2003 and is intended to enhance the ability of the United States to manage domestic incidents (which include terrorist attacks, major disasters, and other emergencies) by establishing a single, comprehensive National Incident Management System (NIMS). Refer to the Michigan Emergency Management Plan.

Homeland Security Presidential Directive (HSPD)-7

HSPD-7 was issued on December 17, 2003 and establishes a national policy for federal departments and agencies to identify and prioritize U.S. critical infrastructure and key resources and to protect them from terrorist attacks. (Note: the State of Michigan is actively involved in the critical infrastructure protection process. Refer to the Weapons of Mass Destruction Attack Procedures in the Michigan Emergency Management Plan.)

Homeland Security Presidential Directive (HSPD)-8

HSPD-8 was issued on December 17, 2003 and establishes policies to strengthen the preparedness of the United States to prevent and respond to threatened or actual domestic terrorist attacks, major disasters, and other emergencies by requiring a national domestic all-hazards preparedness goal, establishing mechanisms for improved delivery of federal preparedness assistance to states and local governments, and outlining actions to strengthen preparedness capabilities of federal, state, and local entities.

Presidential Policy Directive 8 (PPD-8)

PPD-8 was issued on March 30, 2011, to facilitate an integrated, all-of-nation, "whole community," capabilities-based approach to preparedness. It involves federal partners, state, local and tribal leaders, the private sector, non-governmental organizations, faith-based and community organizations, and the general public, to keep people and communities safe and prevent the loss of life and property when disasters strike. Implementation of the PPD-8 will require extensive outreach, collaboration, and input from stakeholders at all levels of government, the private and non-profit sectors, and also from the public.

Homeland Security Operations Center (HSOC)

The HSOC is the primary national-level multi-agency hub for domestic incident management, operational coordination, and situational awareness. It is a standing 24/7 interagency organization fusing law enforcement, national intelligence, emergency response, and private sector reporting. The HSOC facilitates homeland security information sharing and operational coordination with other federal, state, local, tribal, and nongovernmental EOCs.

National Counterterrorism Center (NCTC)

The NCTC is the primary federal organization for analyzing and integrating all intelligence possessed or acquired by the U.S Government pertaining to terrorism and counterterrorism. The NCTC may (consistent with applicable law) receive, retain, and disseminate information from any federal, state, or local government, or other source necessary to fulfill its responsibilities. The NCTC serves as the central and shared knowledge bank on known and suspected terrorists and international terror groups, as well as their goals, strategies, capabilities, and networks of contacts and support. The NCTC ensures that agencies have access to and receive the all-source intelligence support needed to execute their counterterrorism plans or perform independent, alternative analysis.

National Infrastructure Protection Center (NIPC)

Established in February 1998 by the FBI and expanded in scope and mission by PDD 63, the National Infrastructure Protection Center (NIPC) serves as the national critical infrastructure threat assessment, warning, vulnerability, and law enforcement investigation and response entity. PDD 63 specifically assigned the following missions to the NIPC:

- Detect, deter, assess, warn, respond, and investigate unlawful acts involving computer and information technologies and unlawful acts, both physical and cyber, that threaten or target critical infrastructures.
- Manage computer intrusion investigations.
- Support law enforcement, counter-terrorism, and foreign counter-intelligence missions related to cyber crimes and intrusion.
- Support national security authorities when unlawful acts go beyond crime and are found to be foreign-sponsored attacks on U.S. interests.
- Coordinate training for cyber investigators and infrastructure protectors in government and the private sector.

The NIPC, through its Awareness of National Security Issues and Response (ANSIR) Program, provides unclassified national security threat and warning information to U.S. corporate security directors and executives, law enforcement, and other government agencies. This information is disseminated nationwide via established e-mail and fax networks. Each of the FBI's field offices has an ANSIR coordinator and is equipped to provide national security threat and awareness information on a regular basis to corporate recipients within their jurisdiction. (Note: Individuals and U.S. corporations wishing to become direct recipients of FBI / ANSIR communications should provide business card information, i.e., company name, address, phone, facsimile, etc. to ansir@leo.gov for processing, with a brief description of the product and/or service provided by the individual or organization.)

Metropolitan Medical Response System (MMRS)

The MMRS was administered by the United States Department of Homeland Security, to build and sustain national preparedness capabilities against risks associated with potential terrorist attacks. The MMRS supports the integration of emergency management, health, and medical systems into a coordinated response to mass casualty incidents caused by any hazard. Successful MMRS grantees reduce the consequences of a mass casualty incident by having augmented their existing local operational response systems in advance of a hazardous event. MMRS sub-grantees collaborate with local, regional, and state health and medical partners, and leverage other federal programs, in order to coordinate and support plans, processes, and strategies related to response needs that include continuity of government, continuity of operations, equipment and supplies procurement, and emergency triage and medical services, among others. As of 2012, there are currently 124 MMRS jurisdictions across the country that are eligible for funding. Michigan's MMRS jurisdictions are Detroit, Grand Rapids, and Warren, which perform most of their MMRS functions in coordination with local, regional, and state health department programs.

Strategic National Stockpile (SNS)

No one can anticipate exactly where a terrorist incident may occur, and few agencies have the resources to create a sufficient pharmaceutical stockpile on their own. Local health departments, hospitals, and the Michigan Department of Community Health have access to limited supplies of pharmaceutical inventories. However, the U.S. Centers for Disease Control (CDC) Strategic National Stockpile—a national repository of pharmaceuticals and life-saving medical materials—can be rapidly delivered to a site of biological or chemical terrorist attack.

Urban Search and Rescue (US&R) Task Forces

FEMA has developed, equipped, and trained a cadre of 28 National Urban Search and Rescue (US&R) task forces, strategically located in 19 states around the country, to provide assistance in incidents involving structural collapse. Any of the 28 task forces can deploy to a major disaster area to provide supplemental assistance in structural rescue. The US&R task forces can help locate, extricate, and provide onsite medical treatment to victims trapped in collapsed structures. These task forces are staffed primarily by local fire department and emergency services personnel who are experienced and trained in collapsed structure search and rescue operations. Many of the teams now carry the added responsibility of responding to hazardous material / WMD incidents, swift water rescue calls, and specialized technical rescue emergencies. Although Michigan does not have a certified task force within its borders, task forces are located in nearby Miami Valley, Ohio and Marion County, Indiana. (However, Michigan has recognized the need to support an intra-state team, Michigan Urban Search and Rescue (MUSAR), that is a vital component of its intra-state response capability.)

Federal Homeland Security Grants

Since the terrorist attacks of September 11, 2001, the federal government has made available billions of dollars in grants, under a variety of grant programs to state, local, and tribal governments nationwide, to aid in preventing, mitigating, preparing for, responding to, and recovering from terrorist attacks. This funding has been used to hire additional personnel, buy necessary equipment and supplies, develop terrorism plans and procedures, conduct targeted training for responders, hold terrorism-related exercises, and take other necessary actions to develop and enhance local and state emergency management and homeland security capabilities. The federal grant funding stream and processes continue to evolve from year to year, based on national priorities and national and international conditions.

Emergency Management Assistance Compact (EMAC)

The EMAC is an interstate mutual aid agreement that allows states to share resources and assist one another in responding to natural and man-made disasters. The strength of EMAC and the quality that distinguishes it from other plans and compacts lies in its governance structure, its relationship with federal organizations, states, counties, territories, and regions, and the ability to move just about any resource one state has to assist another state, including medical resources. All fifty states, plus four territories, have joined this compact through enacting legislation. Michigan became the 43rd participating state in January 2002. Although the EMAC is not

terrorism specific, it most likely would be activated in the event of a major sabotage/terrorism incident within the United States.

Computer Emergency Response Team / Coordination Center

The Computer Emergency Response Team (CERT) Coordination Center is a center of Internet security expertise located at the Software Engineering Institute, a federally funded research and development center at Carnegie Mellon University in Pittsburgh, Pennsylvania. The CERT was established at the behest of the Defense Advanced Research Projects Agency (DARPA), following a November 1988 Internet virus incident, to coordinate communication among experts during security emergencies and to help prevent future incidents. The CERT has helped to establish a number of other computer response teams, and the CERT's incident handling practices have been adapted by numerous response teams around the world. The CERT studies Internet security vulnerabilities, handles computer security incidents, publishes security alerts, researches long-term changes in networked systems, and develops information and training in network security for technical staff, managers, and system administrators.

Michigan Executive Directive 2002-1

On January 24, 2002, a Michigan Executive Directive issued by Governor John Engler (1) designated the State Director of Emergency Management as the State Director of Homeland Security, (2) designated the Emergency Management and Homeland Security Division, Department of State Police as the focal point for homeland security issues in Michigan, (3) redefined the mission of the Michigan Homeland Security Task Force, and (4) directed state agencies to actively support the Task Force and its ongoing activities. (Note: ED 2002-1 was repealed by Executive Order 2003-6, described below.)

Michigan Executive Order 2003-6

On April 15, 2003, a Michigan Executive Order issued by Governor Jennifer Granholm established (1) the office of Assistant Adjutant General for Homeland Security (within the Department of Military and Veterans Affairs) to advise the Governor and state agency directors on the development of homeland security policies, programs, and procedures, (2) the Michigan Homeland Protection Board (within the Department of State Police) to develop, implement, and revise a state homeland security strategy, and (3) the Michigan Homeland Security Advisory Council to advise the Board and provide input, advice, and recommendations on homeland security issues. EO 2003-6 also abolished the Michigan Homeland Security Task Force established by Executive Directive 2002-1, re-affirmed the existing homeland security roles and responsibilities within the Department of State Police, and directed state agencies to actively participate in state homeland security efforts.

Michigan Executive Director 2005-9

On September 29, 2005, a Michigan Executive issued by Governor Jennifer Granholm on adopted the National Incident Management System (NIMS) as the state standard for incident management in Michigan.

Michigan Emergency Management Assistance Compact (MEMAC)

The statewide mutual-aid assistance compact, authorized under 1976 PA 390, as amended, allows participating jurisdictions to render or receive assistance in time of crisis, and to share vital public safety services and resources more effectively and efficiently. The MEMAC is designed specifically for those situations in which (1) a participating jurisdiction has exhausted its local resources (including those available through local / regional mutual aid or reciprocal aid compacts or agreements), or (2) its resources are inadequate or overwhelmed in response to a threat or event being faced, and it requires additional resources (provided in a timely manner) to protect public health and safety, property, or the environment. (The EMHSD/MSP administers the MEMAC on behalf of the State of Michigan and is responsible for processing requests for resources by participating jurisdictions.)

Michigan State Agencies

Sabotage / terrorism is being addressed on a variety of fronts within Michigan State Government. The Michigan Department of State Police oversees and coordinates state agency actions related to homeland security and terrorism response, including the investigation of suspected or potential criminal enterprises and activities that might involve sabotage or terrorism. In addition, the State Police (in conjunction with other state agencies as well as federal and local counterparts) continuously prepares for terrorist incidents through emergency planning, training, information sharing, and exercising efforts. All state agencies have a role to play in the State's prevention, mitigation, preparedness, response, and recovery plans for sabotage/terrorism. Some state agencies, such as the Michigan National Guard and the Departments of Agriculture and Rural Development, Environmental Quality, Transportation, and Community Health (to mention a few), have especially critical roles in the State's response and recovery efforts. An overview of the State's anti-terrorism procedures can be found in the Michigan Emergency Management Plan (MEMP).

Michigan Regional Response Team Network (RRTN)

As part of its anti-terrorism response strategy, the State of Michigan has established the Michigan Regional Response Team Network (RRTN). The RRTN now includes 16 teams, geographically positioned around the state, that can respond to a weapons of mass destruction incident anywhere in Michigan within two hours of activation, to provide support to the local incident commander and appropriate federal agencies responsible for the mitigation and investigation of such an incident. These regional teams include local police, fire, and medical agencies, with support from the Michigan Urban Search and Rescue Team (MUSAR) and local and state bomb squads. The RRTN can provide technical assistance and a variety of support services, including scene reconnaissance, stabilization and rescue, crime scene and evidence preservation, mass decontamination, and coordination with the FBI and other involved federal agencies. The RRTN is activated through the State Emergency Operations Center.

Michigan Urban Search and Rescue (MUSAR)

The MUSAR Team is a privately funded organization working in cooperation with the fire service, local emergency management, the MSP, and private sector agencies, to provide a statewide capability for specialized response to structural collapse emergencies and incidents requiring specialized training in search and rescue. MUSAR is organized into four specialized teams—a Search Team, a Rescue Team, a Medical Team, and a Technical Team. In an event that involves the structural collapse of a building, MUSAR can provide immediate statewide response assistance upon activation through the State Emergency Operations Center. The Technical Team can also provide assistance in situations involving toxic chemicals.

51st Weapons of Mass Destruction Civil Support Team (WMD CST)

Stationed at the Michigan National Guard's Fort Custer Training Center in Augusta, the 51st WMD CST was created to augment local and regional terrorism response capabilities in attacks known or suspected to involve WMD. The CST consists of Michigan National Guard personnel, highly trained in the areas of chemical weapons, biological weapons, radiological materials, nuclear weapons, and/or high yield explosives (CBRNE), and capable of being en route to the site of an attack to support civil authorities within hours following notification.

Specifically, the 51st CST deploys to an area of operation to (1) assess a suspected CBRNE event in support of a local Incident Commander, (2) advise civilian responders regarding appropriate response actions, and (3) facilitate requests for assistance to expedite the arrival of additional state and federal assets to help save lives, prevent human suffering, and mitigate property damage. Working in support of the Incident Commander, the CST can verify the perimeter of the exclusion zone and send teams into the "hot zone" to conduct reconnaissance, survey, detection, and sampling missions. The Team is trained to the Hazardous Materials Technician (and above) level and maintains highly specialized technical equipment designated for use with each type of WMD/CBRNE.

The Team is available on-call 24 hours-a-day, seven days-a-week. The 51st WMD CST is activated through the State Emergency Operations Center (SEOC), or through a lead emergency response organization's Request for Assistance (RFA), submitted to the Michigan National Guard's Joint Operations Center (JOC).

Michigan Epidemiological Response and Investigation Team (MERIT)

The MERIT was created by the Michigan Department of Community Health (MDCH) to provide a quick response to bio-terror attacks and other public health emergencies, and to coordinate resources and expertise at local, state, and federal levels across a wide range of public health disciplines. The MERIT consists of personnel from the MDCH Bureau of Epidemiology (Infectious Disease Physician, Communicable Disease Epidemiologists, Public Health Nurse, etc.), the Michigan Department of Agriculture and Rural Development (MDARD), the MDEQ, the FBI, and/or other state/local law enforcement agencies. The MERIT is activated through the MDCH Emergency Management Coordinator or Office of Public Health Preparedness (OPHP).

Regional Public Health Response Teams (RPHRTs)

Eight Michigan Department of Community Health (MDCH) operational regions have been identified that match the emergency management districts of the Michigan State Police. Through this regional system, the MDCH has established one state-level public health response team (the MERIT), eight regional public health response teams (RPHRTs), and approximately 18 health care worker response teams. Members of these teams may also be part of the Smallpox Response Teams (SRTs) located within the eight regions. These teams allow the rapid mobilization and utilization of public health and health care personnel for a large scale response to a WMD attack or other public health emergency. The regional system will also help to assure the coordination of efforts across regional lines.

Michigan Emergency Preparedness Pharmaceutical Plan (MEPPP)

The purpose of the MEPPP is to provide a comprehensive guide to pharmaceutical resources available at the local, regional, state, and national levels to assist emergency responders and citizens during a CBRNE event or other large-scale disaster within Michigan.

Michigan Emergency Drug Delivery and Resource Utilization Network (MEDDRUN)

During the early stages of a mass casualty incident, the health care system will likely be overwhelmed. In such cases, the availability of critical emergency pharmaceuticals and other vital medical supplies may be compromised. This may be particularly true in a terrorist incident—especially one involving chemical weapons in which the early use of certain antidotes may be life-saving. The MEDDRUN establishes standardized caches of medications and supplies, strategically located throughout Michigan. The MEDDRUN is intended to rapidly deliver these medications and supplies to hospitals and other sites. These caches are based primarily with Michigan's rotary air and other selected emergency medical service (EMS) agencies, to minimize deployment times during an incident.

CHEMPACK

State and local response agencies must be prepared to mount a swift and effective response to acts of terrorism involving nerve agents, as well as situations involving accidental releases of organophosphates, to minimize potential loss of life. The CHEMPACK Project provides the State of Michigan, in collaboration with the federal Centers for Disease Control and Prevention (CDC) and Department of Homeland Security (DHS), with a sustainable, supplemental source of pre-positioned nerve agent / organophosphate antidotes and associated pharmaceuticals that will be readily available for use when local supplies become depleted. The CHEMPACK Project is one component of the Michigan Emergency Preparedness Pharmaceutical Plan (MEPPP), a comprehensive statewide plan for coordinating the timely application of pharmaceutical resources in the event of an act of terrorism or other large-scale disaster within Michigan.

State Bioterrorism Response Plan

The Michigan Department of Community Health (MDCH) has developed a statewide bioterrorism response plan ("Public Health Planning and Response to Bioterrorism and Public Health Emergencies") under a cooperative agreement with the U.S. Centers for Disease Control. This plan provides a guide for MDCH response to bioterrorism events and covers in detail the following topical areas: communications and notifications, public health surveillance, the biological laboratory response network, emergency management roles and responsibilities, and treatments and prophylaxis of mass casualties. The plan also provides specific recommendations for local communities to prepare for an effective response to a public health emergency.

Terrorism Awareness Video

The "Seven Signs of Terrorism," a terrorism-awareness video created by the Michigan State Police in the aftermath of the September 11, 2001 terrorist attacks, describes the behavior that potential terrorists might exhibit. The video includes information about terrorists conducting surveillance, acquiring supplies, and going through trial runs of an attack, and is based on information used internationally. Originally produced for high school students, it was requested by other groups and is now being distributed on DVD to first responders across the country.

Michigan Homeland Security School Initiative

The Michigan Homeland Security Initiative was an $8.2 million project that identified Michigan school systems as critical infrastructure. It provided participating school districts with $2,200 per building to assess their state of emergency preparedness. As of 2005, about 94% of the public school buildings in the state were participating in the grant initiative. The U.S. Department of Homeland Security had identified Michigan's Homeland Security School Initiative as a national best practice.

School Safety Information Act: 1999 PA 102

In response to school shootings that occurred in the 1990s, the Michigan Legislature passed Act 102 in July 1999—The Michigan School Safety Information Act—which requires local school districts to meet with law enforcement officials to develop emergency plans to handle violent situations. School superintendents are then required to educate local communities about the plans. The plans spell out, among other things, how to evacuate schools, bring first aid and emergency resources to the scene, and handle parents that want to pick up their children. The law also requires the development and implementation of a statewide school safety information policy, the reporting and compiling of certain school safety information, and the expulsion of pupils for certain assaults.

Michigan Office of Safe Schools

In 1998, the Michigan Legislature established the Michigan Office of Safe Schools within the Michigan Department of Education. The Office of Safe Schools began operating in October, 1999. Its mission is to collect and distribute information about school safety. The Office of Safe Schools maintains a web site that serves as a one-stop clearinghouse for information on school safety, school bus safety, food safety, and current and proposed school safety legislation.

In March 2001, the Michigan Office of Safe Schools established a toll-free School Violence Hotline to provide a means for students to anonymously report specific threats of imminent school violence or other suspicious or criminal conduct. The toll-free hotline is operational 24-hours per day, 365 days a year, at 1-800-815-TIPS.

E Team and WebEOC Critical Incident Management Systems

Beginning in 2004, the State of Michigan began to use web-based proprietary software called "E Team" for its emergency management, event management, and homeland security functions, including integration with its Geographic Information System (GIS) applications in the SEOC. The Emergency Management and Homeland Security Division of the Michigan State Police (EMHSD/MSP) obtained an enterprise license for E Team that allowed it to provide an E Team license to all local emergency management agencies in Michigan. This statewide

integration effort allowed state agencies, local emergency management agencies, hospitals and other critical facilities, and certain federal agencies and non-governmental organizations to easily and quickly communicate with the SEOC, and with each other, during disasters or emergencies. During 2012 and 2013, the SEOC will be converting from E Team to WebEOC software.

Midwest Public Safety Communications Consortium

Representatives from the State of Michigan and four other Midwest states have created a consortium that will allow public safety agencies to coordinate radio communications systems across state lines. The Midwest Public Safety Communications Consortium (MPSCC) was formed in 2002 by law enforcement agencies in Illinois, Indiana, Kentucky, Michigan, and Ohio. The goal of the consortium is to create the nation's widest area of interoperable radio communications for police, fire, and emergency medical service departments, stretching from Zanesville in East Central Ohio to the Quad Cities in Illinois and from the Appalachian Mountains in Southern Kentucky to Michigan's Upper Peninsula. Currently, each state is building a unified communications network that allows a variety of public safety agencies to communicate on a single state-of-the-art radio network. This approach will allow agencies near a jurisdictional border to communicate with their peers in neighboring states. This will result in an improved public safety response to combat crime, enhanced coordination of response to traffic collisions, and a more efficient response to major catastrophic events. This effort will also serve to enhance the communications capability of neighboring states in response to a major sabotage/terrorism incident.

Local Governments and Private Industry

Local governments across Michigan, particularly those in southeastern Michigan, are becoming better prepared for sabotage/terrorism incidents. Local law enforcement, fire, public works, emergency medical agencies, and a variety of other local personnel are being trained in how to properly respond to and recover from sabotage/terrorism incidents and threats. In addition, communities are also developing plans and procedures for these incidents, and then testing those plans and procedures in disaster exercises. Local jurisdictions have initiated public information and awareness campaigns aimed at educating businesses and individual citizens of the risks associated with this hazard, as well as steps they can take to adequately protect themselves. Many businesses and critical industries/sectors in Michigan are developing and testing emergency plans and procedures, training personnel in anti-sabotage/terrorism methods, and taking other necessary and prudent actions to protect their critical facilities, infrastructures, and operations from acts of sabotage/terrorism. These combined efforts of government, business and industry, and individual citizens form the cornerstone of Michigan's (and the nation's) continuing fight against sabotage/terrorism.

Presidential Declarations in Michigan: 1953-2012*

Date of Incident	Type of Incident	Affected Area	Type of Declaration / Federal ID Number**
7/14/ 08	Thunderstorms, flooding	12 counties: Allegan, Barry, Eaton, Ingham, Lake, Manistee, Mason, Missaukee, Osceola, Ottawa, Saginaw, and Wexford Co.	Major Disaster (1777)
9/07/05	Hurricane evacuation	All 83 counties	Emergency (3225)
5/20/04-6/8/04	Thunderstorms, flooding	23 counties: Barry, Berrien, Cass, Eaton, Genesee, Gladwin, Ingham, Ionia, Jackson, Kent, Livingston, Macomb, Mecosta, Muskegon, Oakland, Ottawa, Saginaw, Sanilac, Shiawassee, St. Clair, St. Joseph, Washtenaw, and Wayne Co.	Major Disaster (1527)
8/14-17/03	Electric power failure	14 counties: Calhoun, Eaton, Genesee, Hillsdale, Ingham, Kalamazoo, Lapeer, Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, and Wayne Co.	Emergency (3189)
4/10/02-5/9/02	Flooding	6 counties: Baraga, Gogebic, Houghton, Iron, Marquette, and Ontonagon Co.; plus the Keweenaw Bay Indian Community	Major Disaster (1413)
12/11-31/00	Blizzard, snowstorm	39 counties: Allegan, Barry, Bay, Berrien, Branch, Calhoun, Cass, Clare, Clinton, Eaton, Genesee, Gladwin, Gratiot, Hillsdale, Huron, Ingham, Ionia, Isabella, Jackson, Kalamazoo, Kent, Lapeer, Livingston, Macomb, Mecosta, Midland, Montcalm, Muskegon, Oakland, Osceola, Ottawa, Saginaw, St. Clair, St. Joseph, Sanilac, Shiawassee, Tuscola, Van Buren, and Washtenaw Co.	Emergency (3160)
9/10-11/00	Urban flooding	2 counties: Oakland and Wayne Co.	Major Disaster (1346)
5/2-10/99	Wildfire	2 counties: Marquette and Mackinac Co.; (Grant Recipient: Michigan Dept. of Natural Resources)	Fire Suppression
1/2-15/99	Blizzard, snowstorm	31 counties: Alcona, Allegan, Arenac, Barry, Berrien, Cass, Crawford, Ionia, Iosco, Jackson, Kalamazoo, Kent, Lenawee, Macomb, Marquette, Mecosta, Monroe, Montmorency, Muskegon, Newaygo, Oakland, Oceana, Ogemaw, Osceola, Oscoda, Otsego, Ottawa, St. Joseph, Van Buren, Washtenaw, and Wayne Co.	Emergency (3137)
7/21/98	Thunderstorms, high winds	2 counties: Macomb and Wayne Co.	Major Disaster (1237)
5/31/98	Thunderstorms, high winds	13 counties: Bay, Clinton, Gratiot, Ionia, Kent, Mason, Montcalm, Muskegon, Newaygo, Oceana, Ottawa, Saginaw, and Shiawassee Co.	Major Disaster (1226)
7/2/97	Tornadoes, flooding	5 counties: Genesee, Macomb, Oakland, Saginaw, and Wayne Co.	Major Disaster (1181)
6/21-7/1/96	Rainstorms, flooding, tornado	7 counties: Bay, Lapeer, Midland, Saginaw, Sanilac, St. Clair, and Tuscola Co.	Major Disaster (1128)
12/93-5/94	Underground freeze	10 counties: Charlevoix, Cheboygan, Chippewa, Delta, Gogebic, Houghton, Mackinac, Marquette, Ontonagon, and Schoolcraft Co.	Major Disaster (1028)
9/10-19/86	Flooding	30 counties: Allegan, Arenac, Bay, Clare, Clinton, Genesee, Gladwin, Gratiot, Huron, Ionia, Isabella, Kent, Lake, Lapeer, Macomb, Manistee, Mason, Mecosta, Midland, Montcalm, Muskegon, Newaygo, Oceana, Osceola, Ottawa, Saginaw, Sanilac, Shiawassee, Tuscola, and Van Buren Co.	Major Disaster (774)
9/5-6/85	Flooding	6 counties: Alcona, Genesee, Iosco, Lapeer, Saginaw and Shiawassee Co.	Major Disaster (744)
3/12-20/82	Flooding	2 counties: Berrien and Monroe Co.	Major Disaster (654)
7/15-20/80	High winds	10 counties: Allegan, Berrien, Calhoun, Cass, Jackson, Ottawa, St. Joseph, Van Buren, Washtenaw, and Wayne Co.	Major Disaster (631)
5/13/80	Tornado	2 counties: Kalamazoo and Van Buren Co.	Major Disaster (621)
1/26-27/78	Blizzard, snowstorm	Statewide	Emergency (3057)
1/26-31/77	Blizzard, snowstorm	15 counties: Allegan, Barry, Berrien, Cass, Chippewa, Hillsdale, Kalamazoo, Kent, Monroe, Muskegon, Newaygo, Oceana, Ottawa, St. Joseph, and Van Buren Co.	Emergency (3030)
3/20/76, 3/2-7/76	Ice storm, tornadoes	29 counties: Allegan, Bay, Clare, Clinton, Genesee, Gladwin, Gratiot, Ionia, Isabella, Jackson, Kent, Lapeer, Macomb, Mecosta, Midland, Montcalm, Muskegon, Newaygo, Oakland, Oceana, Osceola, Ottawa, Roscommon, Saginaw, St. Clair, Sanilac, Shiawassee, Tuscola, and Wayne Co.	Major Disaster (495)
8/20/75-9/6/75	Rainstorms, high winds, flooding	16 counties: Allegan, Clare, Genesee, Gratiot, Ingham, Isabella, Mecosta, Midland, Montcalm, Muskegon, Newaygo, Oceana, Osceola, Ottawa, Saginaw, and Shiawassee Co.	Major Disaster (486)
4/18-30/75	Flooding, rain, tornadoes	21 counties: Allegan, Barry, Berrien, Calhoun, Clinton, Crawford, Eaton, Genesee, Ingham, Ionia, Kalamazoo, Kent, Lapeer, Livingston, Macomb, Oakland, Ottawa, Saginaw, St. Clair, Shiawassee, and Van Buren Co.	Major Disaster (465)

Presidential Declarations in Michigan: 1953-2012* (cont.)

Date of Incident	Type of Incident	Affected Area	Type of Declaration / Federal ID Number**
4/3/74	Tornado	1 county: Hillsdale Co.	Major Disaster 429)
4/12/73	Severe storms, flooding	14 counties: Arenac, Bay, Berrien, Huron, Iosco, Macomb, Menominee, Monroe, Saginaw, Sanilac, St. Clair, Tuscola, Van Buren, and Wayne Co.	Major Disaster (371)
12/1/72	Severe storms, flooding	9 counties: Arenac, Bay, Berrien, Iosco, Macomb, Monroe, St. Clair, Tuscola, and Wayne Co.	Major Disaster (363)
4/5/72	Snowstorm, freezing rain	9 counties: Allegan, Barry, Calhoun, Clinton, Eaton, Ingham, Ionia, Jackson, and Kalamazoo Co.	Major Disaster (330)
4/11/65	Tornadoes, severe storms	16 counties: Allegan, Barry, Bay, Branch, Clinton, Eaton, Gratiot, Hillsdale, Kalamazoo, Kent, Lenawee, Monroe, Montcalm, Ottawa, Shiawassee, and Washtenaw Co.	Major Disaster (190)
4/3/56	Tornado	4 counties: Benzie, Leelanau, Manistee, and Ottawa Co.	Major Disaster (53)
6/8/53	Tornado	3 counties: Genesee, Iosco, and Monroe Co.	Major Disaster (6)
5/21/53	Tornado	1 county: St. Clair Co.	Major Disaster (4)
Totals for 1953-2012:	**32 Incidents**		**25 Major Disasters; 6 Emergencies; 1 Fire Suppression**

Notes

*Does not include separate Secretary of Agriculture or Small Business Administration (SBA) disaster declarations, which are issued under other authorities. Declarations after 1974 were issued under PL 93-288 (Disaster Relief Act), as amended by the Robert T. Stafford Disaster Relief and Emergency Assistance Act (1988) and the Disaster Mitigation Act (2000).

******Indicates federal declaration number assigned by FEMA and its predecessor agencies

Frequency Distribution of Presidential Declarations in Michigan: 1953-2012+

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
3	0	2	6	6	3	4	2	4	0	1	1	32
9%	0%	6%	19%	19%	9%	13%	6%	13%	0%	3%	3%	100%

Notes

+For the incident period, not the declaration date. However, the December 1993-May 1994 underground freeze declaration was assigned to the month of May (the date of the declaration). The May 2004-June 2004 thunderstorms and flooding declaration was assigned to June (the date of the declaration). Percentages may not add up to 100% due to rounding.

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Presidential Declarations in Michigan: 1974-2012†
Public and Private Damage Costs

Date of Incident	Incident	Type of Declaration / Federal ID Number	Area Covered	Public Damage: $ millions*	Private Damage: $ millions*	Public Assistance: $ millions**	Individual Assistance: $ millions**
4/3/74	Tornado	Major Disaster (429)	1 County	N/A	0.1	None	0.1
4/18-30/75	Flooding, rain, tornadoes	Major Disaster (465)	21 Counties	9.3	48.4	3.3	0.7
8/20/75-9/6/75	Rainstorms, high winds, flooding	Major Disaster (486)	16 Counties	1.3	1.4	0.7	0.1
3/20/76 3/2-7/76	Ice storms, tornadoes	Major Disaster (495)	29 Counties	13.4	25.0	10.3	0.2
1/26-31/77	Blizzard, snowstorm	Emergency (3030)	15 Counties	7.9	2.3	0.9	None
1/26-27/78	Blizzard, snowstorm	Emergency (3057)	Statewide	18.7	4.3	10.0	None
5/13/80	Tornado	Major Disaster (621)	2 Counties	2.2	40.3	0.6	0.1
7/15-20/80	High winds	Major Disaster (631)	10 Counties	17.2	134.2	7.3	None
3/12-20/82	Flooding	Major Disaster (654)	2 Counties	2.4	8.6	None	0.1
9/5-6/85	Flooding	Major Disaster (744)	6 Counties	4.8	41.8	2.4	3.5
9/10-19/86	Flooding	Major Disaster (774)	30 Counties	67.3	137.9	14.8	16.0
12/93-5/94	Underground freeze	Major Disaster (1028)	10 Counties	7.1	N/A	5.7	None
6/21-7/1/96	Rainstorms, flooding, tornado	Major Disaster (1128)	7 Counties	10.4	15.3	7.4	13.8
7/2/97	Tornadoes, flooding	Major Disaster (1181)	5 Counties	31.6	28.6	31.2	12.4
5/31/98	Thunderstorms, high winds	Major Disaster (1226)	13 Counties	35.9	1.1	36.2	None
7/21/98	Thunderstorms, high winds	Major Disaster (1237)	2 Counties	6.9	2.0	7.4	None
1/2-15/99	Blizzard, snowstorm	Emergency (3137)	31 Counties	11.5	N/A	11.5	None
5/2-10/99	Wildfire	Fire Suppression	2 Counties	1.0	13.5	1.0	None
9/10-11/00	Urban flooding	Major Disaster (1346)	2 Counties	0.3	7.3‡	(HMA only) 33.2	217.9‡
12/11-31/00	Blizzard, snowstorm	Emergency (3160)	39 Counties	11.7	N/A	11.7	None
4/10/02-5/9/02	Flooding	Major Disaster (1413)	6 Counties	10.8	1.3	10.8	None
8/14-17/03	Electric power failure	Emergency (3189)	14 Counties	20.3	N/A	5.0	None
5/20/04-6/8/04	Thunderstorms, flooding	Major Disaster (1527)	23 Counties	7.4	13.3‡	(HMA only) 3.1	82.4‡
9/7/05-2/28/06	Hurricane evacuation	Emergency (3225)	Statewide	N/A	N/A	2.1	N/A
6/6/08-6/13/08	Thunderstorms, flooding	Major Disaster (1777)	12 Counties	19.9	9.2	17.3	N/A
Totals for 1974-2012:	**25 Incidents**	**18 Disaster; 6 Emergency; 1 Fire Suppression**		**319.3**	**535.9**	**233.9*** **	**347.3**

Table Summary:

Total Reported Public and Private Damage:..... $855.2 Million
Total Federal Disaster Grants Received:..... $581.2 Million
Percent of Damages Covered by Grants: 68%

Notes

† Under PL 93-288, as amended.

*Private damage totals do NOT include agricultural damage. Public and private damage totals are estimates based on initial damage assessment reports submitted to the State Emergency Operations Center or more refined totals from the federal/state Preliminary Damage Assessment (PDA). Some private damage costs were reimbursed by private insurance payouts.

Public and Individual Assistance totals do **NOT include disaster loans; **ONLY** grants are included.

***Includes FEMA public assistance (and FHWA assistance, if applicable), PLUS FEMA hazard mitigation assistance (HMA), if applicable.

‡The PDA for private damage in these two disasters significantly underestimated the amount of individual assistance required. As a result, the individual assistance figures are considerably higher than the PDA private damage estimates.

Governor's Declarations in Michigan: 1977-2012

Date of Incident	Type of Incident	Affected Area	Type of Declaration**
2011-present			
5/25/12	Wildfire	Luce and Schoolcraft Co.	Disaster
5/11/12	Flooding	Genesee County	Emergency
5/31/11	Thunderstorms	City of Battle Creek (Calhoun Co.); Calhoun Co.	Emergency
2000-10			
7/27/10	Oil pipeline spill	Calhoun Co.	Disaster
6/9/10	Thunderstorms, tornadoes	Monroe Co.	Emergency
7/21/09	Tanker truck explosion, fire	Oakland Co.	Emergency
6/19/08 6/19/08 6/19/08 6/19/08 6/19/08	Thunderstorms Thunderstorms Thunderstorms Thunderstorms Thunderstorms	Manistee Co. Wexford Co. Lake Co. Ottawa Co. Osceola Co.	Emergency+ Emergency+ Emergency+ Emergency+ Emergency+
6/13/08 6/13/08 6/13/08 6/13/08 6/13/08	Thunderstorms Thunderstorms Thunderstorms Thunderstorms Thunderstorms	City of Saginaw (Saginaw Co.) Eaton Co. Allegan Co. City of Lansing (Ingham Co.) Mason Co.	Emergency+ Emergency+ Emergency+ Emergency+ Emergency+
8/27/07	Tornado	City of Fenton (Genesee Co.)	Emergency
8/10/07 8/9/07	Wildfire	Luce Co.	Emergency
7/28/06	Thunderstorms, heavy rain	Oscoda Co.	Emergency
2/27/06	Severe winds, ice storm	Montcalm Co.	Emergency
9/4/05	Hurricane evacuation	All 83 counties	Disaster
6/3/04	Thunderstorms, flooding	Arenac, Barry, Berrien, Cass, Genesee, Gladwin, Ingham, Ionia, Jackson, Kent, Livingston, Macomb, Mecosta, Newaygo, Oakland, Ottawa, Saginaw, St. Clair, St. Joseph, Sanilac, Shiawassee, Van Buren and Wayne Co.	Disaster
4/30/04	Insect infestation (Emerald Ash Borer)	Genesee, Ingham, Jackson, Lapeer, Livingston, Macomb, Monroe, Oakland, Washtenaw and Wayne Co.; City of Allen Park (Wayne Co.); City of Ann Arbor (Washtenaw Co.); City of Birmingham (Oakland Co.); City of Dearborn (Wayne Co.); City of Dearborn Heights (Wayne Co.); City of Detroit (Wayne Co.); City of Fraser (Macomb Co.); City of Livonia (Wayne Co.); City of River Rouge (Wayne Co.); City of Romulus (Wayne Co.); City of Southfield (Oakland Co.); City of Sterling Heights (Macomb Co.); City of Trenton (Wayne Co.); City of Warren (Macomb Co.); City of Wayne (Wayne Co.); Bloomfield Township (Oakland Co.); Canton Township (Wayne Co.); Charter Township of Plymouth (Wayne Co.); Lathrup Village (Oakland Co.)	Emergency
8/15/03	Electric power failure	Macomb, Monroe, Oakland, Washtenaw, and Wayne Co.	Emergency
5/15/03	Flooding	City of Marquette, Marquette Township, and Negaunee Township (Marquette Co.)	Emergency
5/10/02 4/30/02 4/16/02	Flooding	Baraga, Houghton, Iron, Marquette, and Ontonagon Co.; City of Ironwood (Gogebic Co.)	Disaster
12/29/01	Heavy snow	Emmet Co.	Emergency
10/26/01	Severe winds	Kalamazoo Co.	Disaster
3/9/01	Flooding	Genesee Co.	Disaster
9/20/00	Urban flooding	Wayne Co.	Disaster
6/7/00	Gasoline pipeline rupture	Blackman Twp. (Jackson Co.)	Emergency
2000-10 Total:	**19 Incidents**		
1990-99			
8/5/99	Subsidence (mine shaft cave in)	Dickinson Co.	Emergency
7/5/99	Tornado	Oscoda Co.	Disaster
1/15/99	Blizzard, snowstorm	City of Detroit (Wayne Co.)	Emergency

Governor's Declarations in Michigan: 1977-2012 (cont.)

Date of Incident	Type of Incident	Affected Area	Type of Declaration**
1990-99 (cont.)			
9/27/98	High winds	Otsego Co.	Emergency
9/1/98	Thunderstorms, high winds	City of Niles (Berrien Co.)	Emergency
7/24/98 7/23/98	Thunderstorms, high winds	Wayne Co.; City of Dearborn (Wayne Co.); City of Warren (Macomb Co.)	Disaster
6/5/98 6/4/98 6/3/98	Thunderstorms, high winds	Bay, Clinton, Gratiot, Ionia, Kent, Mason, Mecosta, Montcalm, Muskegon, Newaygo, Oceana, Ottawa, Saginaw, and Shiawassee Co.; Village of Armada (Macomb Co.)	Disaster
4/1/98	Flooding	Alpena Co.	Emergency
7/6/97 7/3/97	Tornadoes, flooding	Genesee, Macomb, Oakland and Wayne Co.; City of Detroit (Wayne Co.); Village of Chesaning (Saginaw Co.)	Disaster
6/27/97	Rainstorms, flooding	Allegan and Ottawa Co.	Disaster
6/26/96 6/21/96	Rainstorms, flooding, tornado	Bay, Lapeer, Saginaw, Sanilac, St. Clair, and Tuscola Co.; City of Midland (Midland Co.)	Disaster
5/22/96	Flooding	Berrien Co.	Disaster
12/13/95	Snowstorm	City of Sault St. Marie (Chippewa Co.)	Emergency
7/8/94	Flooding	Lapeer, Tuscola and Sanilac Co.	Disaster
3/10/94 3/4/94 2/25/94 2/23/94	Underground freeze	Charlevoix, Cheboygan, Chippewa, Delta, Gogebic, Houghton, Mackinac, Marquette, Ontonagon, and Schoolcraft Co.	Emergency
4/20/93	Flash flood	Shiawassee Co.	Disaster
7/16/92	Heavy rain	Gogebic Co.	Disaster
7/14/92	Tornado	Cass Co.	Disaster
10/6/90	Tornado	Genesee Co.	Disaster
9/16/90	Ship explosion, fire	Bay Co.	Emergency
5/9/90	Wildfire	Crawford Co.	Emergency
1990-99 Total:	**21 Incidents**		
1980-89			
6/8/89	Flooding, high winds	Branch, Kalamazoo and St. Joseph Co.; Village of Manchester (Washtenaw Co.)	Disaster
6/9/88	Fire	City of Corunna (Shiawassee Co.)	Disaster
8/18/87	Airline crash	City of Romulus (Wayne Co.)	Disaster
10/28/86 9/15/86 9/12/86	Flooding, heavy rain	Allegan, Arenac, Bay, Clare, Clinton, Genesee, Gladwin, Gratiot, Huron, Ionia, Isabella, Kent, Lake, Lapeer, Macomb, Manistee, Mason, Mecosta, Midland, Montcalm, Muskegon, Newaygo, Oceana, Osceola, Ottawa, Saginaw, Shiawassee, Tuscola, and Van Buren Co.	Disaster
2/21/86	Great Lakes flooding, wave action	Allegan, Arenac, Bay, Berrien, Grand Traverse, Iosco, Macomb, Marquette, Menominee, Monroe, Muskegon, Ottawa, Saginaw, St. Clair, Tuscola, Van Buren, and Wayne Co.	Disaster
9/13/85	Heavy rain, flash flood	Alcona Co.	Disaster
9/10/85	Heavy rain, flooding	Genesee, Lapeer, and Saginaw Co.	Disaster
4/13/85	Great Lakes flooding, wave action	Arenac, Bay, Macomb, Monroe, Saginaw, St. Clair, Tuscola, and Wayne Co.	Disaster
1/15/85	Ice storm	Allegan, Barry, Berrien, Calhoun, Eaton, Genesee, Ingham, Jackson, Kalamazoo, Lapeer, Livingston, Oakland, and Van Buren Co.	Disaster***
7/15/83	Wildfire	Schoolcraft Co.	Disaster
3/19/82	Flooding	Berrien and Monroe Co.	Disaster
7/21/80	Thunderstorms, high winds	Allegan, Berrien, Calhoun, Cass, Jackson, St. Joseph, Van Buren, Washtenaw, and Wayne Co.; City of Grand Haven and Village of Spring Lake (Ottawa Co.)	Disaster
5/13/80	Tornado	Kalamazoo and Van Buren Co.	Disaster
1980-89 Total:	**13 Incidents**		
1977-79			
8/9/78	Sewer main break	Macomb Co.	Disaster
6/30/78	Thunderstorms, high winds, hail, rain	Berrien Co.	Disaster

Governor's Declarations in Michigan: 1977-2012 (cont.)

Date of Incident	Type of Incident	Affected Area	Type of Declaration**
1977-79 (cont.)			
6/28/78	Thunderstorms	Allegan Co.	Disaster
1/26/78	Blizzard, snowstorm	Statewide	Disaster
12/10/77	Snowstorm	City of Hamtramck (Wayne Co.)	Disaster
4/6/77	Tornado, high winds	Clinton, Eaton, Kalamazoo, and Livingston Co.	Disaster
1/28/77	Blizzard	Allegan, Barry, Berrien, Cass, Chippewa, Eaton, Hillsdale, Ionia, Muskegon, Newaygo, Oceana, Ottawa, Sanilac, Shiawassee, and Van Buren Co.	Disaster
1977-79 Total:	**7 Incidents**		
Totals for 1977-2012	**63 Incidents**		**40 Disaster Declarations; 23 Emergency Declarations**

Notes

**Declarations since 1977 were issued under 1976 PA 390, as amended (Michigan Emergency Management Act).

***A "State of Emergency" was also declared for this incident under 1945 PA 302 (Emergency Powers of Governor Act).

+Some incidents have resulted in multiple declarations for the same incident (each jurisdiction declared separately). These are counted as one declaration only for the purposes of this list.

Frequency Distribution of Governor's Declarations in Michigan: 1977-2012*

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
4	3	2	6	7	11	11	6	8	2	0	3	63
6%	5%	3%	10%	11%	17%	17%	10%	13%	3%	0%	5%	100%

Notes

*For the declaration date, not the incident period. Percentages may not add up to 100% due to rounding.

Governor's and Presidential Declarations by County: 1953-2012*

Jurisdiction	# of Governor's Declarations	Dates**	# of Presidential Declarations	Dates**
COUNTIES				
Alcona County	3	9/05; 9/85; 1/78	4	9/05; 1/99; 9/85; 1/78
Alger County	2	9/05; 1/78	2	9/05; 1/78
Allegan County	10	6/08; 9/05; 6/97; 9/86; 2/86; 1/85; 7/80; 6/78; 1/78; 1/77	13	7/08; 9/05; 1/01; 1/99; 9/86; 7/80; 1/78; 1/77; 3/76; 9/75; 4/75; 4/72; 4/65
Alpena County	3	9/05; 4/98; 1/78	2	9/05; 1/78
Antrim County	2	9/05; 1/78	2	9/05; 1/78
Arenac County	6	9/05; 6/04; 9/86; 2/86; 4/85; 1/78	6	9/05; 1/99; 9/86; 1/78; 4/73; 12/72
Baraga County	3	9/05; 4/02; 1/78	3	9/05; 5/02; 1/78
Barry County	5	9/05; 6/04; 1/85; 1/78; 1/77	10	7/08; 9/05; 6/04; 1/01; 1/99; 1/78; 1/77; 4/75; 4/72; 4/65
Bay County	8	9/05; 6/98; 6/96; 9/90; 9/86; 2/86; 4/85; 1/78	10	9/05; 1/01; 6/98; 7/96; 9/86; 1/78; 3/76; 4/73; 12/72; 4/65
Benzie County	2	9/05; 1/78	3	9/05; 1/78; 4/56
Berrien County	10	9/05; 6/04; 5/96; 2/86; 1/85; 3/82; 7/80; 6/78; 1/78; 1/77	11	9/05; 6/04; 1/01; 1/99; 3/82; 7/80; 1/78; 1/77; 4/75; 4/73; 12/72
Branch County	3	9/05; 6/89; 1/78	4	9/05; 1/01; 1/78; 4/65
Calhoun County	6	5/11; 7/10; 9/05; 1/85; 7/80; 1/78	7	9/05; 8/03; 1/01; 7/80; 1/78; 4/75; 4/72
Cass County	6	9/05; 6/04; 7/92; 7/80; 1/78; 1/77	7	9/05; 6/04; 1/01; 1/99; 7/80; 1/78; 1/77
Charlevoix County	3	9/05; 3/94; 1/78	3	9/05; 5/94; 1/78
Cheboygan County	3	9/05; 3/94; 1/78	3	9/05; 5/94; 1/78

Governor's and Presidential Declarations by County: 1953-2012* (cont.)

Jurisdiction	# of Governor's Declarations	Dates**	# of Presidential Declarations	Dates**
COUNTIES (cont.)				
Chippewa County	4	9/05; 3/94; 1/78; 1/77	4	9/05; 5/94; 1/78; 1/77
Clare County	3	9/05; 9/86; 1/78	6	9/05; 1/01; 9/86; 1/78; 3/76; 9/75
Clinton County	5	9/05; 6/98; 9/86; 1/78; 4/77	9	9/05; 1/01; 6/98; 9/86; 1/78; 3/76; 4/75; 4/72; 4/65
Crawford County	3	9/05; 5/90; 1/78	4	9/05; 1/99; 1/78; 4/75
Delta County	3	9/05; 3/94; 1/78	3	9/05; 5/94; 1/78
Dickinson County	3	9/05; 8/99; 1/78	2	9/05; 1/78
Eaton County	6	6/08; 9/05; 1/85; 1/78; 4/77; 1/77	9	7/08; 9/05; 6/04; 8/03; 1/01; 1/78; 4/75; 4/72; 4/65
Emmet County	3	9/05; 12/01; 1/78	2	9/05; 1/78
Genesee County	11	5/12; 9/05; 6/04; 4/04; 3/01; 7/97; 10/90; 9/86; 9/85; 1/85; 1/78	12	9/05; 6/04; 8/03; 1/01; 7/97; 9/86; 9/85; 1/78; 3/76; 9/75; 4/75; 6/53
Gladwin County	4	9/05; 6/04; 9/86; 1/78	6	9/05; 6/04; 1/01; 9/86; 1/78; 3/76
Gogebic County	4	9/05; 2/94; 7/92; 1/78	4	9/05; 5/02; 5/94; 1/78
Gd. Traverse County	3	9/05; 2/86; 1/78	2	9/05; 1/78
Gratiot County	4	9/05; 6/98; 9/86; 1/78	8	9/05; 1/01; 6/98; 9/86; 1/78; 3/76; 4/75; 4/65
Hillsdale County	3	9/05; 1/78; 1/77	7	9/05; 8/03; 1/01; 1/78; 1/77; 4/74; 4/65
Houghton County	4	9/05; 4/02; 2/94; 1/78	4	9/05; 5/02; 5/94; 1/78
Huron County	3	9/05; 9/86; 1/78	5	9/05; 1/01; 9/86; 1/78; 4/73
Ingham County	5	9/05; 6/04; 4/04; 1/85; 1/78	9	7/08; 9/05; 6/04; 8/03; 1/01; 1/78; 9/75; 4/75; 4/72
Ionia County	6	9/05; 6/04; 6/98; 9/86; 1/78; 1/77	10	9/05; 6/04; 1/01; 1/99; 6/98; 9/86; 1/78; 3/76; 4/75; 4/72
Iosco County	3	9/05; 2/86; 1/78	7	9/05; 1/99; 9/85; 1/78; 4/73; 12/72; 6/53
Iron County	3	9/05; 5/02; 1/78	3	9/05; 5/02; 1/78
Isabella County	3	9/05; 9/86; 1/78	6	9/05; 1/01; 9/86; 1/78; 3/76; 9/75
Jackson County	6	9/05; 6/04; 4/04; 1/85; 7/80; 1/78	8	9/05; 6/04; 1/01; 1/99; 7/80; 1/78; 3/76; 4/72
Kalamazoo County	7	9/05; 10/01; 6/89; 1/85; 5/80; 1/78; 4/77	10	9/05; 8/03; 1/01; 1/99; 5/80; 1/78; 1/77; 4/75; 4/72; 4/65
Kalkaska County	2	9/05; 1/78	2	9/05; 1/78
Kent County	5	9/05; 6/04; 6/98; 9/86; 1/78	11	9/05; 6/04; 1/01; 1/99; 6/98; 9/86; 1/78; 1/77; 3/76; 4/75; 4/65
Keweenaw County	2	9/05; 1/78	2	9/05; 1/78
Lake County	4	6/08; 9/05; 9/86; 1/78	4	7/08; 9/05; 9/86; 1/78
Lapeer County	8	9/05; 4/04; 6/96; 7/94; 9/86; 9/85; 1/85; 1/78	9	9/05; 8/03; 1/01; 7/96; 9/86; 9/85; 1/78; 3/76; 4/75
Leelanau County	2	9/05; 1/78	3	9/05; 1/78; 4/56
Lenawee County	2	9/05; 1/78	4	9/05; 1/99; 1/78; 4/65
Livingston County	6	9/05; 6/04; 4/04; 1/85; 1/78; 4/77	6	9/05; 6/04; 8/03; 1/01; 1/78; 4/75
Luce County	4	5/12; 8/07; 9/05; 1/78	2	9/05; 1/78
Mackinac County	3	9/05; 2/94; 1/78	3	9/05; 5/94; 1/78
Macomb County	10	9/05; 6/04; 4/04; 8/03; 7/97; 9/86; 2/86; 4/85; 8/78; 1/78	13	9/05; 6/04; 8/03; 1/01; 1/99; 7/98; 7/97; 9/86; 1/78; 3/76; 4/75; 4/73; 12/72
Manistee County	4	6/08; 9/05; 9/86; 1/78	5	7/08; 9/05; 9/86; 1/78; 4/56
Marquette County	5	9/05; 4/02; 2/94; 2/86; 1/78	5	9/05; 5/02; 1/99; 5/94; 1/78
Mason County	5	6/08; 9/05; 6/98; 9/86; 1/78	5	7/08; 9/05; 6/98; 9/86; 1/78
Mecosta County	5	9/05; 6/04; 6/98; 9/86; 1/78	8	9/05; 6/04; 1/01; 1/99; 9/86; 1/78; 3/76; 9/75
Menominee County	3	9/05; 2/86; 1/78	3	9/05; 1/78; 4/73
Midland County	3	9/05; 2/86; 1/78	7	9/05; 1/01; 7/96; 9/86; 1/78; 3/76; 9/75
Missaukee County	2	9/05; 1/78	3	7/08; 9/05; 1/78
Monroe County	8	6/10; 9/05; 4/04; 8/03; 2/86; 4/85; 3/82; 1/78	10	9/05; 8/03; 1/99; 3/82; 1/78; 1/77; 4/73; 12/72; 4/65; 6/53
Montcalm County	5	2/06; 9/05; 6/98; 9/86; 1/78	8	9/05; 1/01; 6/98; 9/86; 1/78; 3/76; 9/75; 4/65

Governor's and Presidential Declarations by County: 1953-2012* (cont.)

Jurisdiction	# of Governor's Declarations	Dates**	# of Presidential Declarations	Dates**
COUNTIES (cont.)				
Montmorency County	2	9/05; 1/78	3	9/05; 1/99; 1/78
Muskegon County	6	9/05; 6/98; 9/86; 2/86; 1/78; 1/77	10	9/05; 6/04; 1/01; 1/99; 6/98; 9/86; 1/78; 1/77; 3/76; 9/75
Newaygo County	6	9/05; 6/04; 6/98; 9/86; 1/78; 1/77	8	9/05; 1/99; 6/98; 9/86; 1/78; 1/77; 3/76; 9/75
Oakland County	8	7/09; 9/05; 6/04; 4/04; 8/03; 7/97; 1/85; 1/78	10	9/05; 6/04; 8/03; 1/01; 10/00; 1/99; 7/97; 1/78; 3/76; 4/75
Oceana County	5	9/05; 6/98; 9/86; 1/78; 1/77	8	9/05; 1/99; 6/98; 9/86; 1/78; 1/77; 3/76; 9/75
Ogemaw County	2	9/05; 1/78	3	9/05; 1/99; 1/78
Ontonagon County	4	9/05; 4/02; 2/94; 1/78	4	9/05; 5/02; 5/94; 1/78
Osceola County	4	6/08; 9/05; 9/86; 1/78	8	7/08; 9/05; 1/01; 1/99; 9/86; 1/78; 3/76; 9/75
Oscoda County	4	7/06; 9/05; 7/99; 1/78	3	9/05; 1/99; 1/78
Otsego County	3	9/05; 9/98; 1/78	3	9/05; 1/99; 1/78
Ottawa County	9	6/08; 9/05; 6/04; 6/98; 6/97; 9/86; 2/86; 1/78; 1/77	15	7/08; 9/05; 6/04; 1/01; 1/99; 6/98; 9/86; 7/80; 1/78; 1/77; 3/76; 9/75; 4/75; 4/65; 4/56
Presque Isle County	2	9/05; 1/78	2	9/05; 1/78
Roscommon County	2	9/05; 1/78	3	9/05; 1/78; 3/76
Saginaw County	9	9/05; 6/04; 6/98; 6/96; 9/86; 2/86; 9/85; 4/85; 1/78	14	7/08; 9/05; 6/04; 1/01; 6/98; 7/97; 7/96; 9/86; 9/85; 1/78; 3/76; 9/75; 4/75; 4/73
St. Clair County	6	9/05; 6/04; 6/96; 2/86; 4/85; 1/78	11	9/05; 6/04; 8/03; 1/01; 7/96; 1/78; 3/76; 4/75; 4/73; 12/72; 5/53
St. Joseph County	5	9/05; 6/04; 6/89; 7/80; 1/78	7	9/05; 6/04; 1/01; 1/99; 7/80; 1/78; 1/77
Sanilac County	6	9/05; 6/04; 6/96; 7/94; 1/78; 1/77	8	9/05; 6/04; 1/01; 7/96; 9/86; 1/78; 3/76; 4/73
Schoolcraft County	5	5/12; 9/05; 2/94; 7/83; 1/78	3	9/05; 5/94; 1/78
Shiawassee County	7	9/05; 6/04; 6/98; 4/93; 9/86; 1/78; 1/77	11	9/05; 6/04; 1/01; 6/98; 9/86; 9/85; 1/78; 3/76; 9/75; 4/75; 4/65
Tuscola County	6	9/05; 7/94; 9/86; 2/86; 4/85; 1/78	8	9/05; 1/01; 7/96; 9/86; 1/78; 3/76; 4/73; 12/72
Van Buren County	9	9/05; 6/04; 9/86; 2/86; 1/85; 7/80; 5/80; 1/78; 1/77	10	9/05; 1/01; 1/99; 9/86; 7/80; 5/80; 1/78; 1/77; 4/75; 4/73
Washtenaw County	5	9/05; 4/04; 8/03; 7/80; 1/78	8	9/05; 6/04; 8/03; 1/01; 1/99; 7/80; 1/78; 4/65
Wayne County	11	9/05; 6/04; 4/04; 8/03; 9/00; 7/98; 7/97; 2/86; 4/85; 7/80; 1/78	12	9/05; 6/04; 8/03; 10/00; 1/99; 7/98; 7/97; 7/80; 1/78; 3/76; 4/73; 12/72
Wexford County	3	6/08; 9/05; 1/78	3	7/08; 9/05; 1/78

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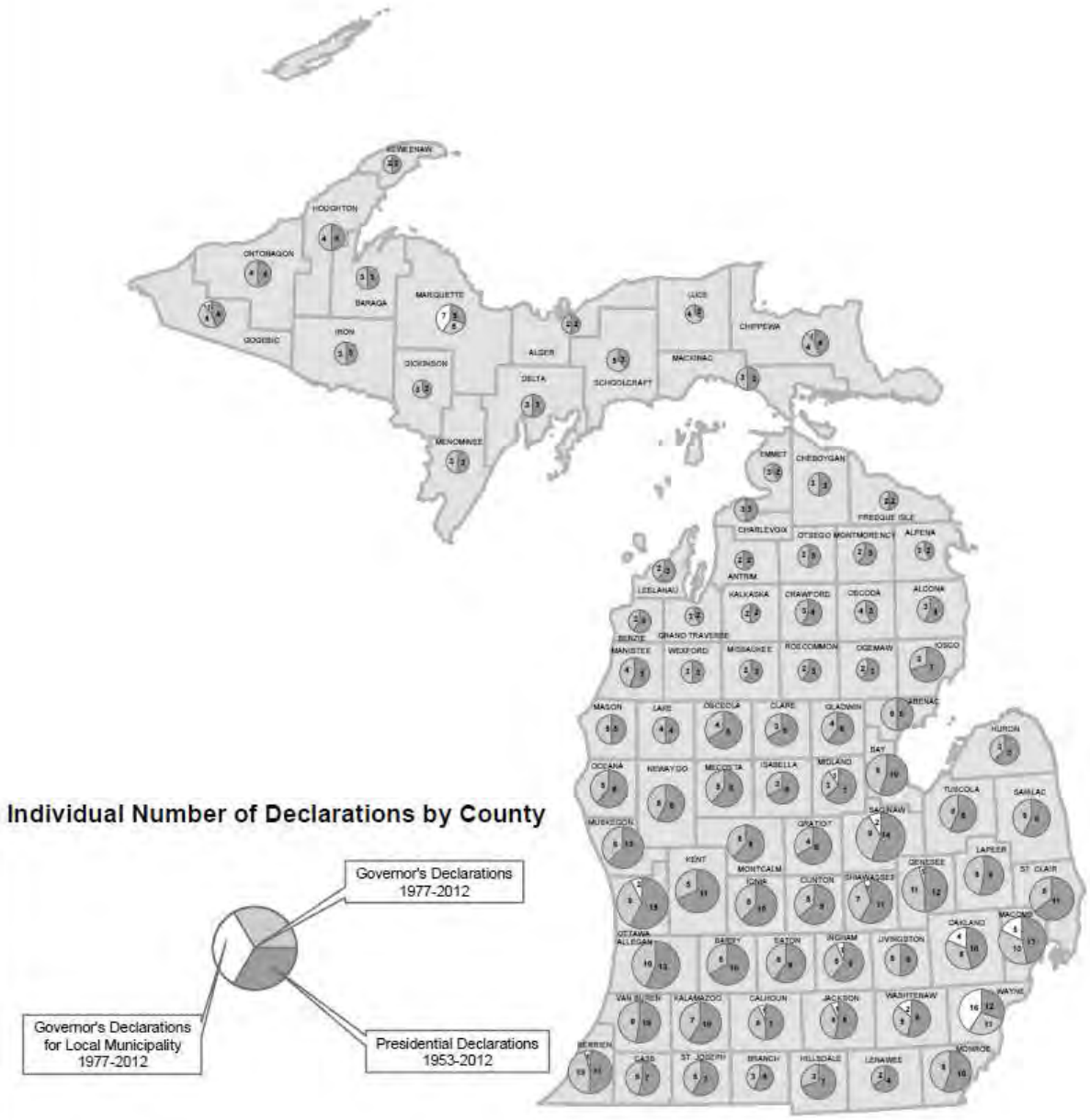
Governor's Declarations by Municipality: 1977-2012

Jurisdiction	# of Governor's Declarations	Dates*
MUNICIPALITIES		
City of Battle Creek (Calhoun County)	1	5/11
City of Saginaw (Saginaw County)	1	6/08
City of Lansing (Ingham County)	1	6/08
City of Fenton (Genesee County)	1	8/07
City of Allen Park (Wayne County)	1	4/04
City of Ann Arbor (Washtenaw County)	1	4/04
City of Birmingham (Oakland County)	1	4/04
City of Dearborn Heights (Wayne County)	1	4/04
City of Fraser (Macomb County)	1	4/04
City of Livonia (Wayne County)	1	4/04
City of River Rouge (Wayne County)	1	4/04
City of Southfield (Oakland County)	1	4/04
City of Sterling Heights (Macomb County)	1	4/04
City of Trenton (Wayne County)	1	4/04
City of Wayne (Wayne County)	1	4/04
Bloomfield Township (Oakland County)	1	4/04
Canton Township (Wayne County)	1	4/04
Charter Township of Plymouth (Wayne County)	1	4/04
Lathrup Village (Oakland County)	1	4/04
Negaunee Township (Marquette County)	1	5/03
Marquette Township (Marquette County)	1	5/03
City of Ironwood (Gogebic County)	1	4/02
Blackman Township (Jackson County)	1	6/00
City of Niles (Berrien County)	1	9/98
City of Warren (Macomb County)	2	7/98; also 4/04
City of Dearborn (Wayne County)	2	7/98; also 4/04
Village of Armada (Macomb County)	1	6/98
City of Detroit (Wayne County)	3	7/97; also 4/04, 1/99
Village of Chesaning (Saginaw County)	1	7/97
City of Midland (Midland County)	1	6/96
City of Sault Ste. Marie (Chippewa County)	1	12/95
City of Marquette (Marquette County)	2	2/94; also 5/03
City of Negaunee (Marquette County)	1	2/94
City of Ishpeming (Marquette County)	1	2/94
Powell Township (Marquette County)	1	2/94
Village of Manchester (Washtenaw County)	1	6/89
City of Corunna (Shiawassee County)	1	6/88
City of Romulus (Wayne County)	2	8/87; also 4/04
City of Grand Haven (Ottawa County)	1	7/80
Village of Spring Lake (Ottawa County)	1	7/80
City of Hamtramck (Wayne County)	1	12/77

Notes

*Many municipal declarations issued concurrent with a county declaration.

Governor's & Presidential Declarations, by Jurisdiction



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