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, but at the end of this section, a collection of maps displays all of the official floodplains which have been identified and digitized through National Flood Insurance Program-related studies. (More floodplains exist than have been shown on those maps, but many of them have not yet been digitized for processing in Geographic Information Systems. The counties that have no flood information displayed in those maps are ones that have not yet had digital flood boundaries made available in GIS format.)

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.

A 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. The NCDC tallies shown in the table at the end of this section shows an average of $24 million per year from events significant enough to report on a community level. (Many individual households receive damage in addition to these events, and report only to their insurance companies.)

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.

<u>Urban and Other Flooding</u>

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.

"Urban flooding" may involve low-lying areas that collect runoff waters even though they are not adjacent to drains or bodies of water. This risk varies with the topography, soil types, runoff rates, drainage basin size, drainage channel sizes, and impervious ground surfaces in each area. 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 power systems can be a vital flood mitigation strategy in such cases.) Many communities have been upgrading their drainage systems, separating combined sewer systems (in which storm and sanitary sewer systems share many of the same components), and enforcing local codes, but they vary in the amount of long-term benefits so far realized from these actions.

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 <u>because</u> 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.

Both urban and riverine flooding tend to be a bit more of a problem in the southern part of the Lower Peninsula, due to the much larger amount of development that exists there. Most parts of the state do have flood risks, however. The upper peninsula often sees an elevated risk of flash flooding from dam failures, while the sprawling developments around the major cities in the southern part of the state have often caused water runoff patterns that severely strain or overwhelm aging drainage infrastructure downstream. The areas that appear to be significantly less at-risk are those on high ground and in headwater locations—also at a relatively high elevation—where waters tend to simply drain to lower-lying areas outside of the community, rather than building up into a local flood problem.

In Michigan, there tends to be a major flood event about every year or two. (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.

Climate Change Considerations

One of the Michigan trends connected with climate change is to experience increasing amounts of precipitation. Moreover, this precipitation is considered more likely to take the form of acute (and severe) weather events. As mentioned in the winter weather sections, a larger proportion of snow precipitation occurring in snowstorm events can cause more extensive snow accumulation which, under unlucky temperature patterns, may add to the drainage burdens of the normal melting and rainfall patterns of the spring season. In short, spring flood risks are likely to worsen, as are ice jam related winter flood risks.

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

Michigan has experienced 12 flood disasters since 1975 which resulted in both a Presidential Major Disaster Declaration and a Governor's Disaster Declaration (opening up the full range of federal and state supplemental disaster assistance). A slightly lower number of additional events have resulted only in a Governor's Disaster Declaration (activating state supplemental and limited federal disaster assistance). Combined, these flood disasters have caused hundreds of millions of dollars in damage to homes, businesses, personal property, and agriculture. The following are brief synopses of these and other Michigan flood events in the past few decades, and they do include some "urban flood" events in addition to the traditional riverine floods. Many other damaging flood events have occurred at the local level, without qualifying for a governor's disaster declaration, and some of these are included in the following descriptions.

Partial Listing of Significant Flood Events in Michigan

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.

December 1972 – Lower Peninsula (Federal Disaster #363 – 9 counties)

A series of severe storms produced a great deal of precipitation during the Spring thaw season. The resulting floods resulted in a federal disaster declaration for a set of counties in the southeastern two-thirds of the Lower Peninsula, stretching from Iosco County, at the northeastern extreme, down to Berrien County at the southwestern state boundary, with Arenac and Bay Counties in between. Another affected area was the "thumb" and metropolitan area of Wayne, Monroe, and Macomb Counties, on the south, and Tuscola and St. Clair Counties, farther north. Every one of these nine counties would soon face another flood disaster merely four months later, as the Spring season arrived with its snow thaws (see below).

April 1973 – Lower Peninsula (Federal Disaster #371 – 14 counties)

A series of severe storms produced a great deal of precipitation during the Spring thaw season. The resulting floods resulted in a major disaster declaration for 14 counties across much of the Lower Peninsula—from Iosco to Berrien, and from Huron County down to Wayne County. Most of the "thumb" and Detroit Metropolitan regions were heavily affected, as was the Upper Peninsula county of Menominee. Many of these same southeastern and Saginaw Bay area counties had been affected by the December 1972 event just a few months before.

April 1975 – Southern Lower Michigan (Federal Disaster #465 – 21 counties)

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 (Federal Disaster #486 – 16 counties)

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 (Federal Disaster #654)

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 (Federal Disaster #744 – 6 counties)

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 (Federal Disaster #774 – 30 counties)

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 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.

April 1996 – Western/Southern Upper Peninsula

The melting of a heavy snow pack combined with rain during the second half of April and caused many streams and rivers to flood—especially in Menominee, Iron, and Delta Counties. The flooding inundated and washed out several roads and bridges, flooded many yards and basements, and caused nearly $2 million in public damages. Up to 24 roads were closed off at the height of the flood event.

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 1996 – Thumb Area (Federal Disaster #1128 – 7 counties)

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.

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.

July 1997 – Southeastern Michigan (Federal Disaster #1181 – 6 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.

February 1998 – Southeast Michigan

Heavy rain, averaging almost 3 inches across many locations, caused flooding to occur in Wayne and Monroe Counties. (Three inches of rain is more than Detroit's average for the entire month of February.) The hardest-hit locations were in eastern Monroe County, where lakeshore flooding exacerbated the area's water runoff problems. East winds gusted to as high as 45mph, causing the Lake Erie water level to rise 3.5 feet above normal at Luna Pier and flooding many roads along the lakeshore. This event was topped by six-foot waves during the night of February 17th. The high water and pounding surf destroyed two private docks and prevented effective runoff further inland. Reports of basement and road flooding came in from all over Monroe County. Urban flooding was also significant in parts of Wayne County—hundreds of basements and many streets were flooded in cities around Detroit (especially Taylor, Dearborn Heights, Westland, and Grosse Ile), and a state of emergency was declared for much of the county. High water briefly closed the Southfield Freeway just north of Interstate 94 (in Dearborn). In Macomb County, the communities of Warren, St. Clair Shores, and Clinton Township also experienced urban and lowland flooding. Total damage exceeded $1 million.

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.

September 2000 – Wayne and Oakland Counties (Federal Disaster #1346)

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.

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.)

February 10-13, 2001 – Monroe County

Although Monroe County flood damage estimates were fairly low (mostly from flooded basements) during this event involving the cresting of the River Raisin, the incident is noteworthy because it was fatal to three young persons who drowned when their pickup truck attempted to cross a flooded road (near the Saline River) and ended up in a ditch filled with 10 feet of water. A fourth person in the truck was the only one able to escape, by squeezing out of a rear passenger window and swimming to safety.

April 2002 – Western Upper Peninsula (Federal Disaster #1413 – 6 counties)

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 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.

May-June 2004 – Southern Lower Michigan (Federal Disaster #1527 – 23 counties)

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 the southern Lower Peninsula.

June 2008 – Lower Peninsula (Federal Disaster #1777 – 12 counties)

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. Some of the worst damages were noted in Mason County ($3 million in property damage and $½ million in crop damage), Lake County ($2 million in property damage and $½ million in crop damage), Osceola County ($1 million in property damage and $¼ million in crop damage), Manistee County (nearly $1 million in property damage), and Wexford County (about $¾ million in property damage).

September 2008 – Southern Lower Peninsula

Excessive rainfall which started on September 13th resulted in extensive flooding over many days following. Many roads in the city of Kalamazoo were closed for several days, and damage to public infrastructure (mostly roads and bridges) was estimated at $11 million. At Augusta, the total rainfall was reported as 10.5 inches. A state of emergency was declared in Kalamazoo County—466 homes in the City of Kalamazoo were flooded, along with ten businesses. Surrounding counties were less extensively damaged, with Berrien County suffering about $750,000 in damage, and $½ million estimated for each of the counties of St. Joseph, Cass, and Oakland, and lesser amounts for the counties of St. Clair, Lapeer, Saginaw, Washtenaw, Wayne, Livingston, and Macomb.

June 2009 – Southwest Michigan (Ottawa and Allegan Counties)

After thunderstorms with heavy rainfall moved in from Lake Michigan, already saturated ground resulted in flooding that damaged numerous homes and streets, estimated at more than 2,000 homes damaged in some way, and 57 damaged or washed-out roads. A local state of emergency was declared in Ottawa County, where total damages were estimated at $34 million. In neighboring Allegan County, about $4 million in damage was estimated.

May 2012 – Heavy Rains and Flash Flood (Genesee and Shiawassee Counties)

Half a foot of rain fell on the Flint area during May 4, causing cars to be stranded on roadways, evacuation of some residents by boat, numerous roads shut down (including sections of Interstates 75 and 69), and some bridges to be washed out. In Genesee County, property damage totaled $7.1 million and the City of Swartz Creek and Township of Flint were particularly hard-hit. An apartment building, near Hill Road in Grand Blanc Township, saw $1.7 million in damage and had to be evacuated as electric power was taken out and 30 cars were nearly submerged. In neighboring Shiawassee County, about $1.1 million in property damage occurred.

April-May 2013 – Western Lower and Upper Peninsulas (Federal Disaster #4121 – 16 counties)

Record flooding occurred during the month of April, most directly caused by an accumulation of heavy rains and resulting in disaster declarations for numerous counties across the western portions of the state (plus the cities of Grand Rapids and Ionia, which were both specifically named in the Governor's disaster declaration). Hundreds of homes were flooded, more than 300 roads were closed, and the preliminary damage assessments totaled more than 32 million dollars. The flooding was exacerbated by the melting of significant snowpack—especially in the Western and Central Upper Peninsula. According to the NCDC website in 2014, the following damage amounts were sustained by each of the following counties: $5 million in Allegan, $5 million in Barry, $5 million in Calhoun, $3 million in Clare, $5 million in Clinton, $3 million in Eaton, $1 million in Gogebic, $3 million in Gratiot, $2.9 million in Houghton, $5 million in Ingham, $7 million in Ionia, $3 million in Isabella, $3 million in Jackson, $5 million in Kalamazoo, $3 million in Lake, $625,000 in Marquette, $3 million in Mason, $3 million in Mecosta, $1.4 million in Midland, $3 million in Montcalm, $5 million in Muskegon, $5 million in Newaygo, $3 million in Oceana, $550,000 in Ontonagon, $3 million in Osceola, $5 million in Ottawa, $1.3 million in Saginaw, and $3 million in Van Buren.

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.

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.

<u>State Flood Hazard Mitigation Plan</u>

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. Many guidance documents and publications are available to use in local assessments of this hazard, and local assessments are very important because of the much more detailed knowledge and more relevant authorities possessed at the local level. Much flooding affects individual locations that do not show up well in a statewide 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. Official floodplain maps that have been digitized are included in general form (smaller scale / less detail) at the end of this section.

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.

Hazard Mitigation Strategies for Riverine, Shoreline, and Urban Flooding

- Flood plain (and coastal zone) management – planning acceptable uses for areas prone to flooding (through comprehensive planning, code enforcement, zoning, open space requirements, subdivision regulations, land use and capital improvements planning) and involving drain commissioners, hydrologic studies, etc. in these analyses and decisions.
- Acceptable land use densities, coverage and planning for particular soil types and topography (decreasing amount of impermeable ground coverage in upland and drainage areas, zoning and open space requirements suited to the capacity of soils and drainage systems to absorb rainwater runoff, appropriate land use and capital improvements planning) and involving drain commissioners, hydrologic studies, etc. in these analyses and decisions.
- Dry floodproofing of structures within known flood areas (strengthening walls, sealing openings, use of waterproof compounds or plastic sheeting on walls).
- Wet floodproofing of structures (controlled flooding of structures to balance water forces and discourage structural collapse during floods).
- Elevation of flood-prone structures above the 100-year flood level.
- “Floating” architectural designs for structures in flood-prone areas
- Construction of elevated or alternative roads that are unaffected by flooding, or making roads more flood-resistant through better drainage and/or stabilization/armoring of vulnerable shoulders and embankments.
- Government acquisition, relocation, or condemnation of structures within floodplain or floodway areas.
- Employing techniques of erosion control within the watershed area (proper bank stabilization, techniques such as planting of vegetation on slopes, creation of terraces on hillsides, use of riprap boulders and geotextile fabric, etc.).
- Protection (or restoration) of wetlands and natural water retention areas.
- Obtaining insurance. (Requires community participation in the NFIP.)
- Joining the National Flood Insurance Program (NFIP). **VERY IMPORTANT!**
- Participation in the Community Rating System (CRS).
- Structural projects to channel water away from people and property (dikes, levees, floodwalls) or to increase drainage or absorption capacities (spillways, water detention and retention basins, relief drains, drain widening/dredging or rerouting, debris detention basins, logjam and debris removal, extra culverts, bridge modification, dike setbacks, flood gates and pumps, wetlands protection and restoration).
- Higher engineering standards for drain and sewer capacity, or the expansion of infrastructure to higher capacity.
- Drainage easements (allowing the planned and regulated public use of privately owned land for temporary water retention and drainage).
- Installing (or re-routing or increasing the capacity of) storm drainage systems, including the separation of storm and sanitary sewage systems.
- Farmland and open space preservation.
- Elevating mechanical and utility devices above expected flood levels.
- Flood warning systems and the monitoring of water levels with stream gauges and trained monitors.
- Increased coverage and use of NOAA Weather Radio.
- Anchoring of manufactured homes to a permanent foundation in flood areas, but preferably these structures would be readily movable if necessary or else permanently relocated outside of flood-prone areas and erosion areas.
- Control and securing of debris, yard items, or stored objects (including oil, gasoline, and propane tanks, and paint and chemical barrels) in floodplains that may be swept away, damaged, or pose a hazard when flooding occurs.

- Back-up generators for pumping and lift stations in sanitary sewer systems, and other measures (alarms, meters, remote controls, switchgear upgrades) to ensure that drainage infrastructure is not impeded.
- Detection and prevention/discouragement of illegal discharges into storm-water sewer systems, from home footing drains, downspouts and sump pumps.
- Employing techniques of erosion control in the area (bank stabilization, planting of vegetation on slopes, creation of terraces on hillsides).
- Increasing the function and capacity of sewage lift stations and treatment plants (installation, expansion, and maintenance), including possible separation of combined storm/sanitary sewer systems, if appropriate.
- Purchase or transfer of development rights – to discourage development in floodplain areas.
- Stormwater management ordinances or amendments.
- Wetlands protection regulations and policies.
- Use of check valves, sump pumps and backflow preventers in homes and buildings.

Tie-in with Local Hazard Mitigation Planning

Because many means of implementing mitigation actions occur through local activities, this updated MHMP places additional emphasis on the coordination of State-level planning and initiatives with those taking place at the local level. This takes two forms:

1. The provision of guidance, encouragement, and incentives to local governments by the State, to promote local plan development (including a consideration of riverine and urban flooding), and
2. The consideration of information contained in local hazard mitigation plans when developing State plans and mitigation priorities.

Regarding the first type of State-local planning coordination, MSP guidance has included the "Local Hazard Mitigation Planning Workbook" (EMD-PUB 207), which is currently being updated for release by 2015. For the second type of State-local planning coordination, a section later in this plan summarizes hazard priority information as it has been reported in local hazard mitigation plans. Here, it will merely be noted that flood hazards were identified as some of the most significant hazards in local hazard mitigation plans for the following counties: Allegan, Baraga, Bay, Benzie, Berrien, Calhoun, Charlevoix, Clinton, Eaton, Emmet, Gogebic, Grand Traverse, Gratiot, Houghton, Ingham, Ionia, Kent, Leelanau, Macomb, Manistee, Marquette, Mecosta, Menominee, Midland, Montcalm, Oakland, Osceola, Ottawa, Saginaw, St. Clair, Shiawassee, St. Joseph, Tuscola, Van Buren, Wayne, and Wexford.

Flooding History for Michigan Counties – arranged by region – Jan. 1996 to Oct. 2013
(The Lower Peninsula regions are ordered by "tiers" from south to north, west to east)
Please refer to the Michigan Profile Map section for an explanation of regional divisions

COUNTY or area	Riverine Flooding Events	Days with Riverine Flooding	Tot. property damage	Tot. crop damage	Injuries	Deaths
Washtenaw	30	28	$13,050,000			
Wayne	59	48	$22,460,000			
.Livingston	17	17	$1,304,000			
Oakland	22	22	$2,706,000			1
Macomb	34	29	$101,680,000			
5 Co Metro region	**32.4 avg.**	**28.8 avg.**	**$141,200,000**			**1**
Berrien	20	17	$6,810,000	$100,000		
Cass	21	14	$6,560,000	$100,000		
St. Joseph	18	14	$6,560,000	$100,000		
Branch	14	11	$6,060,000	$100,000		
Hillsdale	20	14	$6,210,000	$100,000		
Lenawee	36	36	$6,710,000	$100,000		
Monroe	29	26	$9,790,000	$100,000		3
.Van Buren	24	19	$10,553,000	$350,000		
Kalamazoo	27	23	$23,920,000	$360,000		
Calhoun	27	23	$12,695,000	$435,000		
Jackson	25	22	$11,020,000	$405,000		
.Allegan	34	29	$21,050,000	$7,425,000	4	2
Barry	29	23	$13,170,000	$800,000		
Eaton	25	21	$11,945,000	$825,000		
Ingham	26	21	$17,420,000	$475,000		
.Ottawa	34	28	$54,225,000	$2,005,000	3	2
Kent	38	32	$10,530,000	$610,000		
Ionia	21	17	$14,220,000	$350,000		
Clinton	26	21	$12,395,000	$475,000		
Shiawassee	27	24	$7,231,000	$100,000		
Genesee	38	31	$13,810,000	$100,000		
Lapeer	28	25	$15,680,000	$1,100,000		
St. Clair	24	24	$9,480,000	$100,000		
.Muskegon	28	22	$12,855,000	$635,000		
Montcalm	24	19	$10,345,000	$475,000		
Gratiot	26	21	$10,345,000	$475,000		
Saginaw	48	42	$8,737,000	$1,100,000		
Tuscola	32	26	$14,030,000	$100,000		
Sanilac	21	17	$8,145,000	$100,000		
.Mecosta	27	22	$16,115,000	$445,000		
Isabella	27	22	$14,350,000	$475,000		
Midland	25	21	$8,730,000	$100,000		
Bay	24	20	$8,920,000	$125,000		1
Huron	23	19	$6,219,000	$100,000		
34 Co S Lower Pen	**26.9 avg.**	**22.5 avg.**	**$426,835,000**	**$20,745,000**	**7**	**8**

Continued on next page…

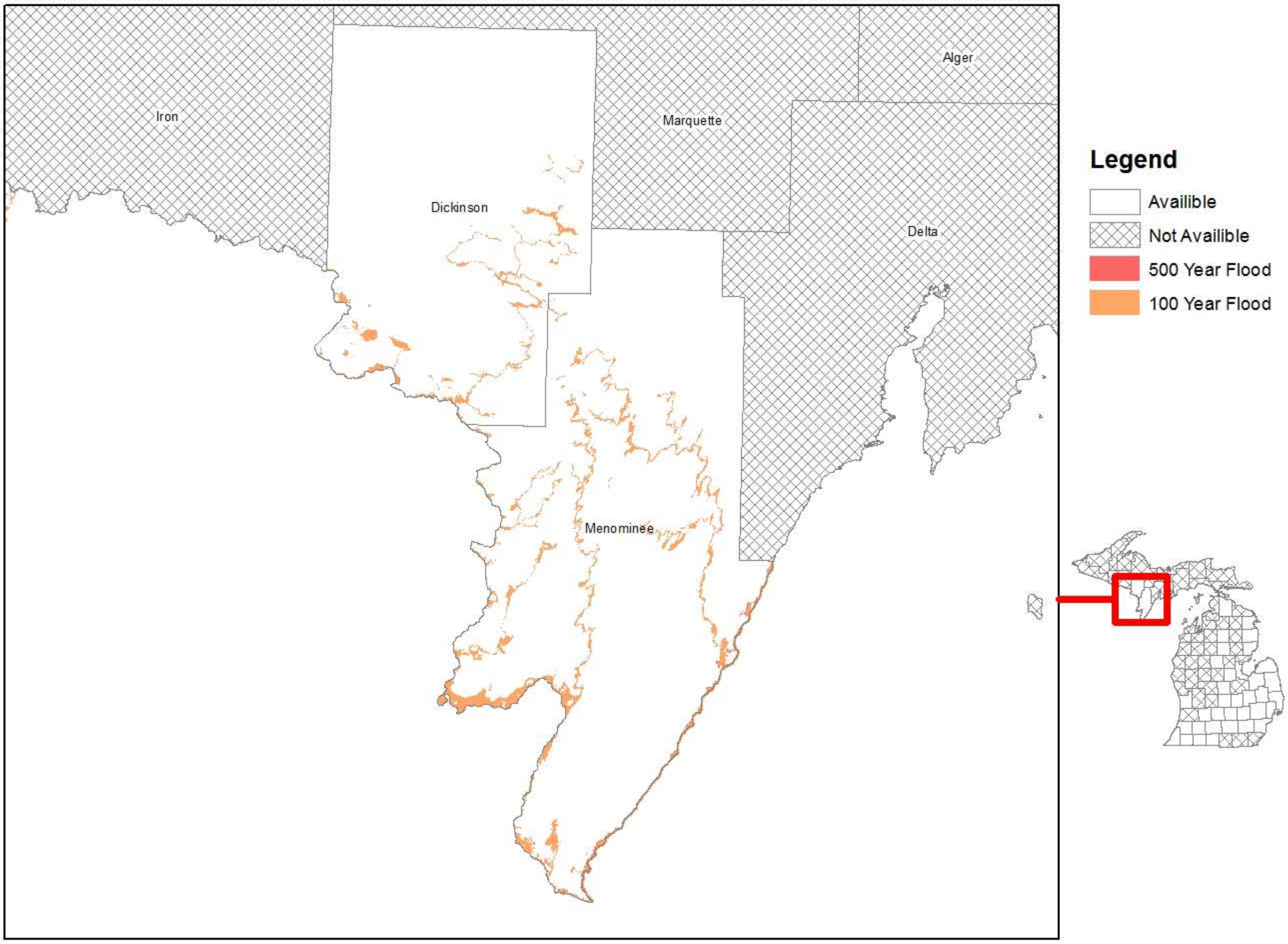
Part 2 of Michigan County Flood History Table

.Oceana	9	8	$4,660,000	$450,000		
Newaygo	10	8	$6,360,000	$350,000		
.Mason	13	11	$7,355,000	$850,000		
Lake	8	8	$6,190,000	$700,000		
Osceola	11	10	$5,250,000	$575,000		
Clare	8	8	$4,175,000	$275,000		
Gladwin	7	6	$103,000			
Arenac	13	13	$98,000			
.Manistee	8	7	$1,520,000			
Wexford	10	10	$872,000			
Missaukee	3	3	$160,000			
Roscommon	1	1	$4,000			
Ogemaw	3	3	$150,000			
Iosco	3	3	$3,000			
.Benzie	1	1				
Grand Traverse	6	6	$1,814,000			
Kalkaska	2	2	$20,000			
Crawford	1	1	$6,000			
Oscoda	3	3	$3,000			
Alcona	4	4	$110,000			
.Leelanau	2	2	$50,000			
Antrim	1	1				
Otsego	1	1	$3,000			
Montmorency	1	1				
Alpena	1	1				
.Charlevoix	1	1	$2,000			
Emmet	1	1	$18,000			
Cheboygan	3	3	$28,000			
Presque Isle						
29 Co N Lower Pn	**4.7 avg.**	**4.4 avg.**	**$38,954,000**	**$3,200,000**		
Gogebic	13	13	$19,011,000			
Iron	10	10	$645,000			
Ontonagon	12	12	$817,000			
Houghton	17	16	$2,900,000			
Keweenaw	7	7	$132,000			
Baraga	14	13	$2,044,000			
.Marquette	27	17	$14,725,000			
Dickinson	11	8	$31,000			
Menominee	5	5	$850,000			
Delta	22	16	$805,000			
Schoolcraft	3	3				
Alger	6	5				
.Luce	3	3				
Mackinac	5	4	$58,000			
Chippewa	6	6	$125,000			
15 Co Upp.Pen	**10.7 avg.**	**9.2 avg.**	**$42,143,000**			
MICHIGAN TOTAL	**925**	**338**	**$437,407,000**	**$20,645,000**	**7**	**9**

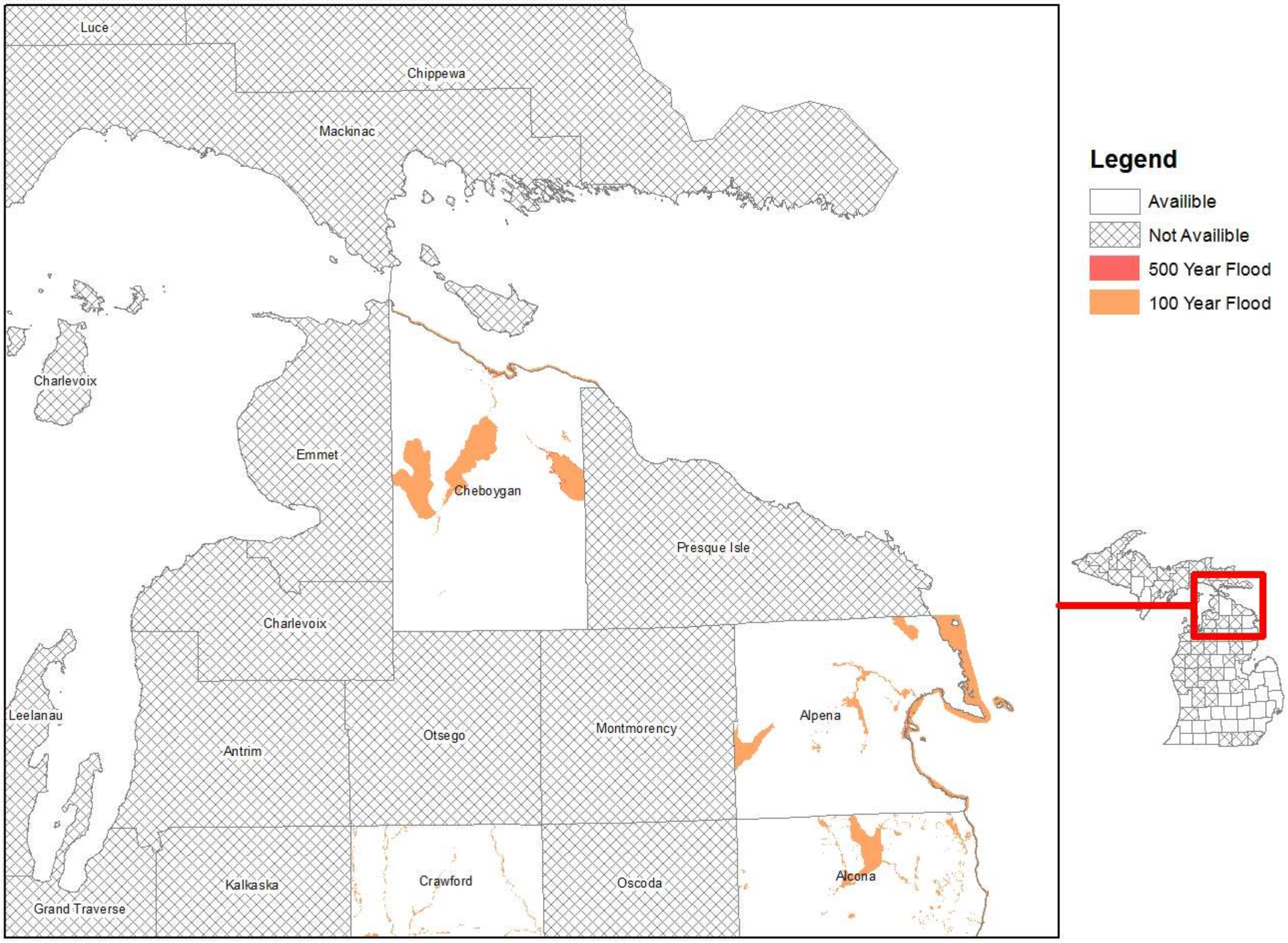
NOTE: Due to the double counting of multi-county events, state totals are less than the sum of the counties.


Michigan Digital Flood Insurance Rate Map (DFIRM) Availibility
Keweenaw
Keweenaw
Houghton
Ontonagon
Baraga
Gogebic
Marquette
Luce
Alger
Iron
Schoolcraft
Chippewa
Dickinson
Delta
Mackinac
Menominee
Charlevoix
Emmet
Cheboygan
Presque Isle
Charlevoix
Leelanau
Antrim
Otsego
Montmorency
Alpena
Leelanau
Grand Traverse
Kalkaska
Crawford
Oscoda
Alcona
Benzie
Manistee
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Arenac
Mason
Lake
Osceola
Clare
Gladwin
Huron
Bay
Oceana
Newaygo
Mecosta
Isabella
Midland
Tuscola
Sanilac
Muskegon
Montcalm
Gratiot
Saginaw
Lapeer
Genesee
St. Clair
Ottawa
Kent
Ionia
Clinton
Shiawassee
Oakland
Macomb
Allegan
Barry
Eaton
Ingham
Livingston
Van Buren
Kalamazoo
Calhoun
Jackson
Washtenaw
Wayne
Berrien
Cass
St. Joseph
Branch
Hillsdale
Lenawee
Monroe
Legend
Availible
Not Availible

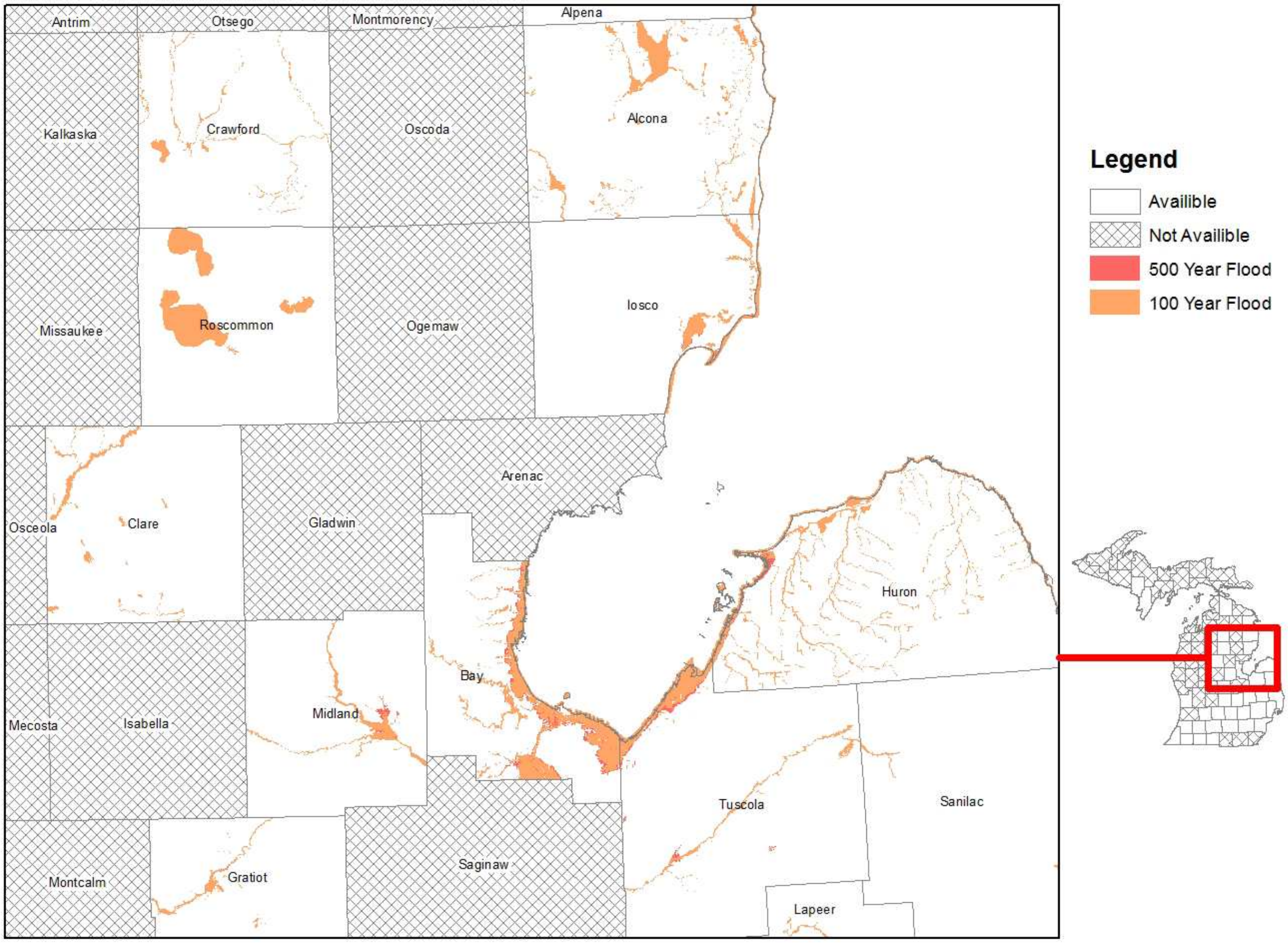
Michigan Digital Flood Insurance Rate Map (DFIRM) - Area 1



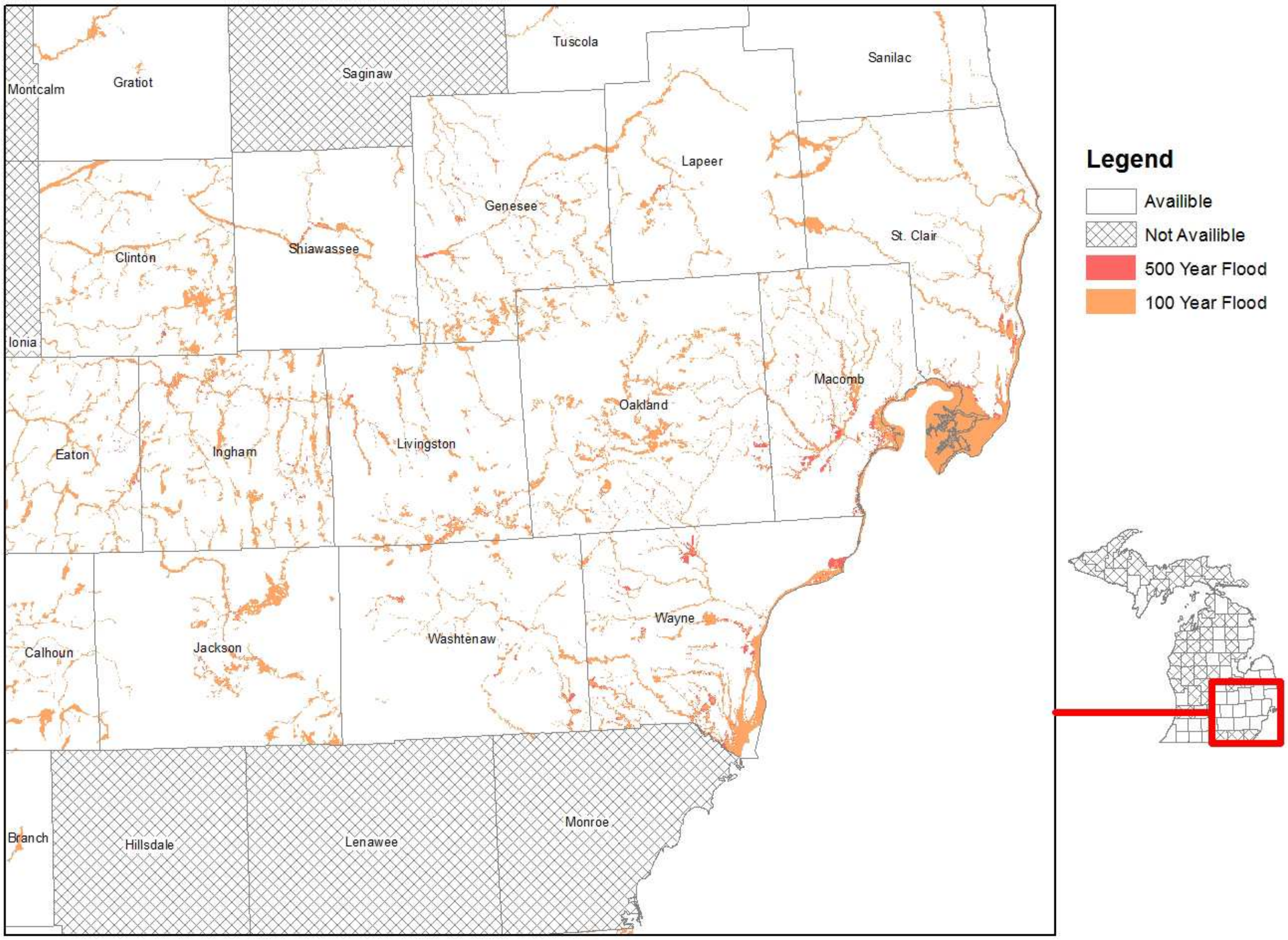
Michigan Digital Flood Insurance Rate Map (DFIRM) - Area 2



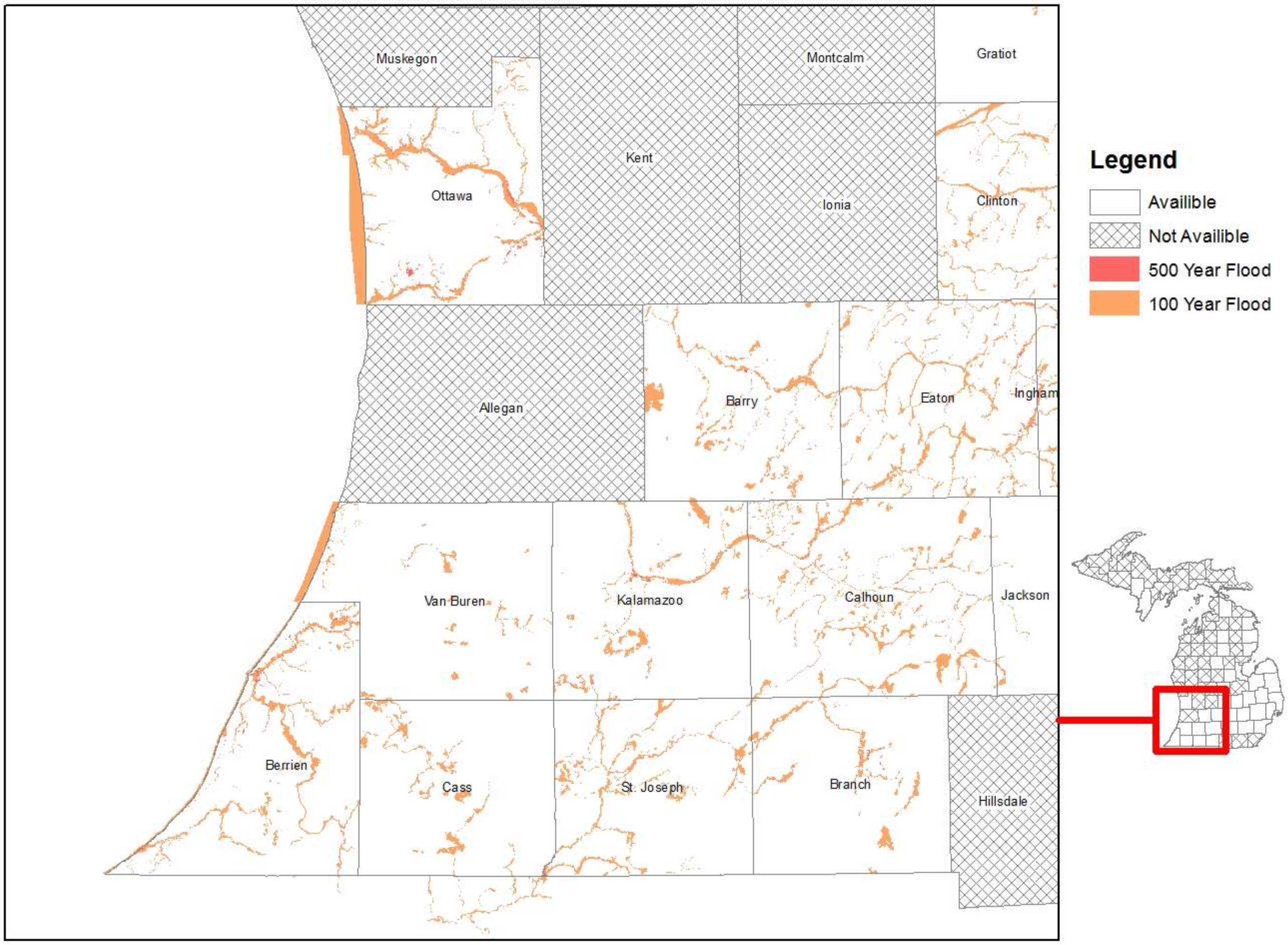
Michigan Digital Flood Insurance Rate Map (DFIRM) - Area 3



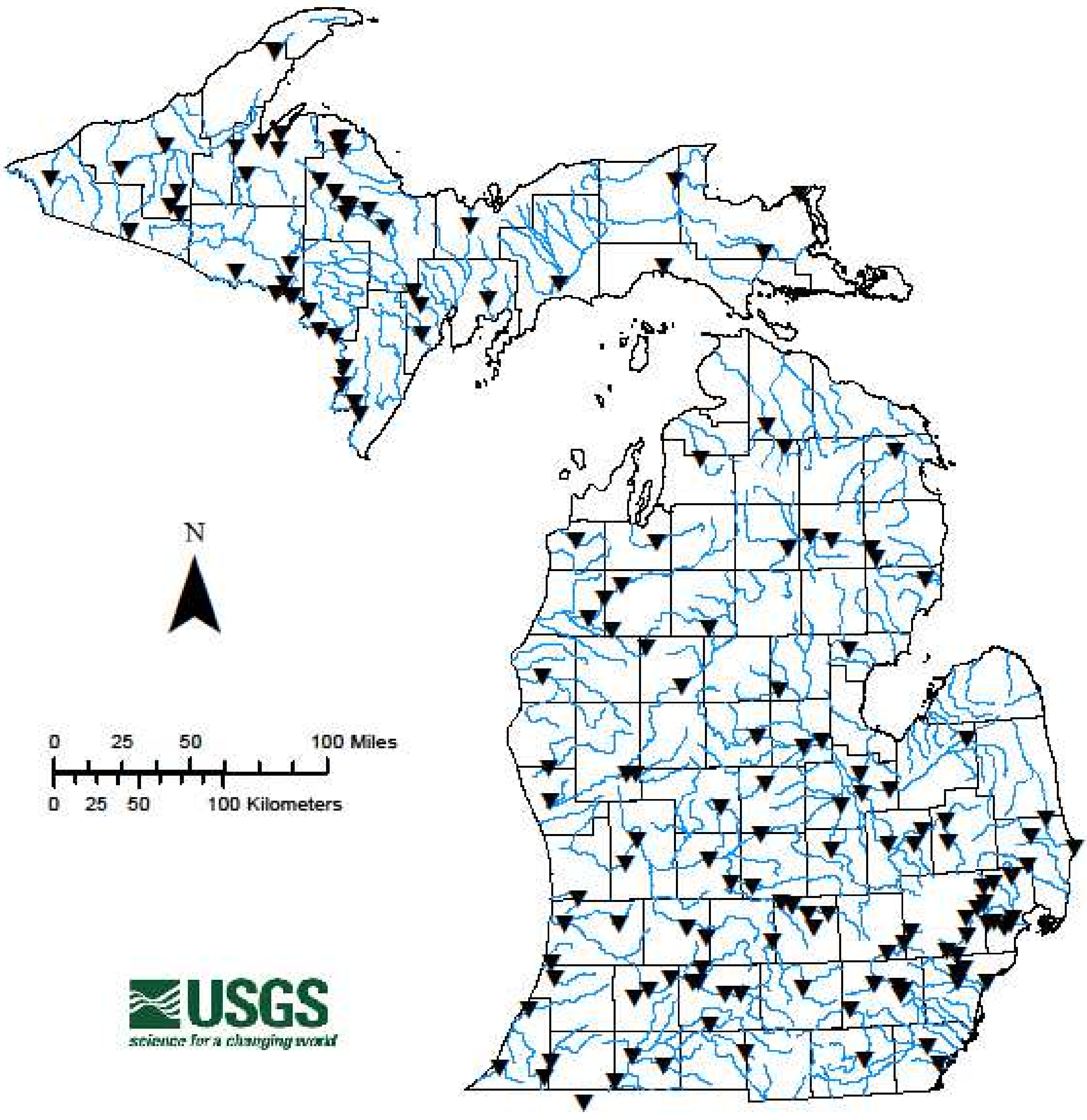
Michigan Digital Flood Insurance Rate Map (DFIRM) - Area 4



Michigan Digital Flood Insurance Rate Map (DFIRM) - Area 5



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.

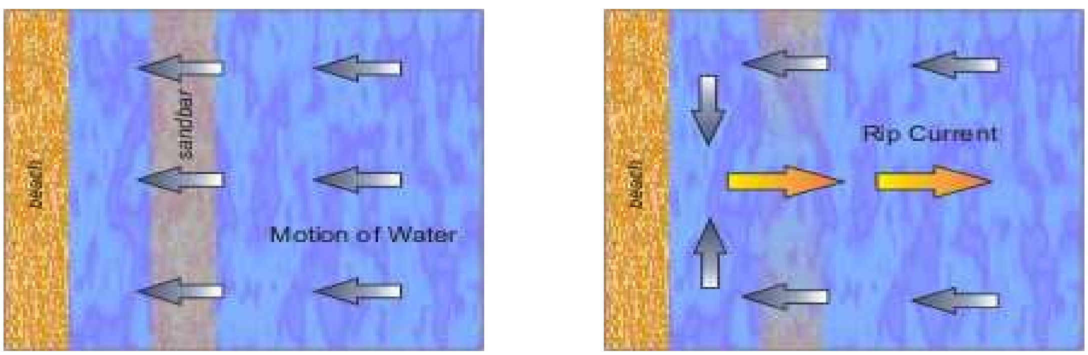
Storm Surges (Seiches)

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.

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 29 deaths and 9 injuries caused by rip currents or other shoreline hazards since 1996. Out of 36 events, 17 took place in the Lake Michigan waters off of Berrien County (a total of 15 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). A two-page table that summarizes all shoreline hazard events and casualties appears within this section.

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).

Shoreline flooding can sometimes be treated in a manner similar to riverine flooding, when there are specifically identified shoreline areas with significant flood risks that have been calculated and mapped (e.g. by the NFIP). In some cases, these areas may suffer unusually heavy damages due to the added effects of wave action and seiche activities on the Great Lakes.

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 seem similar, but the potential for sudden damaging impacts tends to be greater on the shoreline areas. Worst case scenarios typically involve occupied structures or important streets and infrastructure 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 in the analysis. Travel on shoreline highways can also be made treacherous by sand, mists, and snow blown in by wind gusts.

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.

Significant Shoreline Hazard Events in Michigan

November 11, 1940 – Lake Michigan Seiche

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.

July 4, 2006 – Berrien County Rip Current

Wave on Lake Michigan ranged from 2 to 6 feet and allowed for several rip current occurrences near Berrien County shores. County officials conducted at least 6 rescues, despite numerous warnings and advisories having been announced. 4 persons were treated at beaches, but 1 rescued woman died several days later.

October 28-29, 2006 – Lake Erie Seiche

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.

August to September 2007 – Muskegon County Water Level Recession

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.

August 15, 2009 – Mackinac County Rip Current

Onshore winds and significant wave action resulted in rip currents on the far northern beaches of Lake Michigan. Two persons died near the Pointe Aux Chemes sand dunes (about 10 miles northwest of St. Ignace), when a 16-year-old teen was carried into deeper water by currents, and his 66-year-old grandfather attempted to rescue him. Both were overcome by waves and currents, and revival attempts were unsuccessful when the two were finally retrieved.

August 5, 2010 – Rip Currents (Marquette and Alger Counties)

Two teenaged swimmers drowned in high waves and rip currents near Presque Isle (Marquette County), where winds gusted to over 30mph at times. In Grand Marais Harbor (Alger County), a father and son both drowned in similar high waves, winds, and rip currents.

September 3, 2010 – Berrien County Rip Current

Strong winds created dangerous conditions on far southeastern Lake Michigan, where waves as high as 16 feet caused extremely strong rip currents. A man from Chicago drowned after he became separated from a rubber raft (which saved his two companions), and was swept out into deeper waters. Numerous agencies attempted to find and rescue the man, but lake conditions caused a rescue craft to capsize, injuring four rescue workers and causing the search mission to be called off.

October 15, 2011 – Berrien County High Surf

One person died when a kayak capsized inside a New Buffalo break-wall, amidst waves of 8 to 10 feet (cresting to 14 feet at the shoreline). Strong winds had caused these rough waters to arise. Two teenaged kayakers were rescued, but the third was lost underwater.

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.

<u>Community Education</u>

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.

<u>National Weather Service Watches/Warnings</u>

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.

<u>State-Administered Shoreline Hazard Mitigation Programs</u>

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.

Hazard Mitigation Alternatives for Shoreline Flooding and Erosion

- Floodplain/coastal zone management – planning acceptable uses for areas prone to flooding (comprehensive planning, zoning, open space requirements, subdivision regulations, land use and capital improvements planning).
- Dry floodproofing of structures within known flood areas (strengthening walls, sealing openings, use of waterproof compounds or plastic sheeting on walls).
- Wet floodproofing of structures (controlled flooding of structures to balance water forces and discourage structural collapse during floods).
- Elevation of flood-prone structures above the 100-year flood level.
- Construction of elevated or alternative roads that are unaffected by flooding, or making roads more flood-resistant through better drainage and/or stabilization/armoring of vulnerable shoulders and embankments.
- Government acquisition, relocation, or condemnation of structures within floodplain or floodway areas.
- Employing techniques of erosion control in the area (bank stabilization, planting of vegetation on slopes, creation of terraces on hillsides).
- Enforcement of basic building code requirements related to flood mitigation.
- Joining the National Flood Insurance Program, obtaining insurance, and participating in the Community Rating System (CRS).
- Structural projects to channel water away from people and property (dikes, levees, floodwalls) or to increase drainage or absorption capacities (spillways, water detention and retention basins, relief drains, drain widening/dredging or rerouting, debris detention basins, logjam and debris removal, extra culverts, bridge modification, dike setbacks, flood gates and pumps, wetlands protection and restoration).
- Elevating mechanical and utility devices above expected flood levels.
- Flood warning systems.
- Monitoring of water levels with stream gauges and trained monitors.
- Anchoring of manufactured homes to a permanent foundation in flood areas, but preferably these structures would be permanently relocated outside of flood-prone areas and erosion areas.
- Control and securing of debris, yard items, or stored objects in floodplains that may be swept away, damaged, or pose a hazard when flooding occurs.
- Increased coverage and use of NOAA Weather Radio.

Tie-in with Local Hazard Mitigation Planning

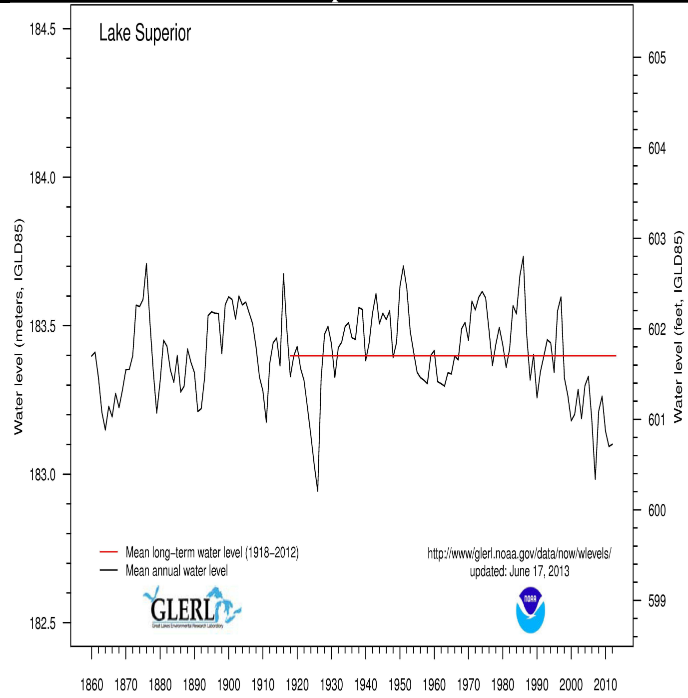
Because many means of implementing mitigation actions occur through local activities, this updated MHMP places additional emphasis on the coordination of State-level planning and initiatives with those taking place at the local level. This takes two forms:

1. The provision of guidance, encouragement, and incentives to local governments by the State, to promote local plan development (including a consideration of shoreline flooding and erosion conditions), and
2. The consideration of information contained in local hazard mitigation plans when developing State plans and mitigation priorities.

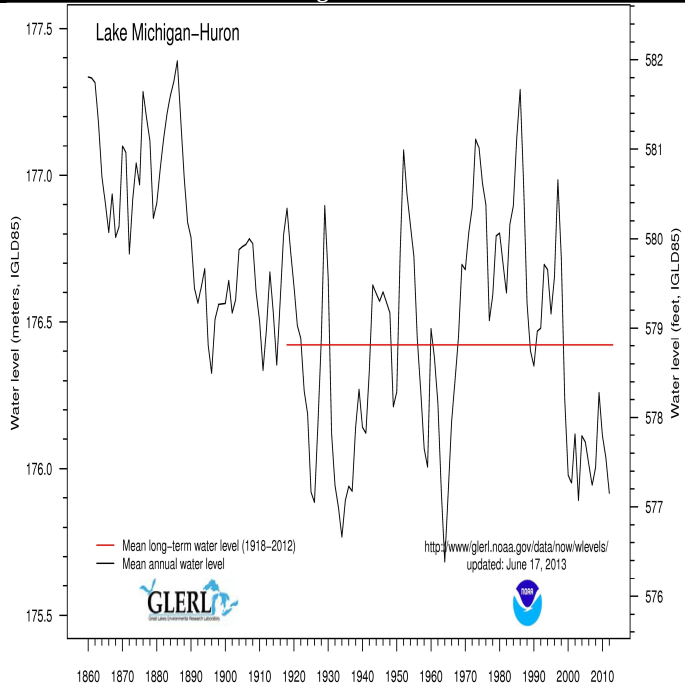
Regarding the first type of State-local planning coordination, MSP guidance has included the “Local Hazard Mitigation Planning Workbook” (EMD-PUB 207), which is currently being updated for release by 2015. For the second type of State-local planning coordination, a section later in this plan summarizes hazard priority information as it has been reported in local hazard mitigation plans. Here, it will merely be noted that shoreline hazards were identified as some of the most significant hazards in local hazard mitigation plans for the following counties: Antrim, Baraga, Bay, Benzie, Emmet, Grand Traverse, Houghton, Keweenaw, Leelanau, Luce, Macomb, Manistee, and Menominee.

Great Lakes Water Levels Since 1860
(Plus Lake St. Clair Since 1900)
Measurements are in meters

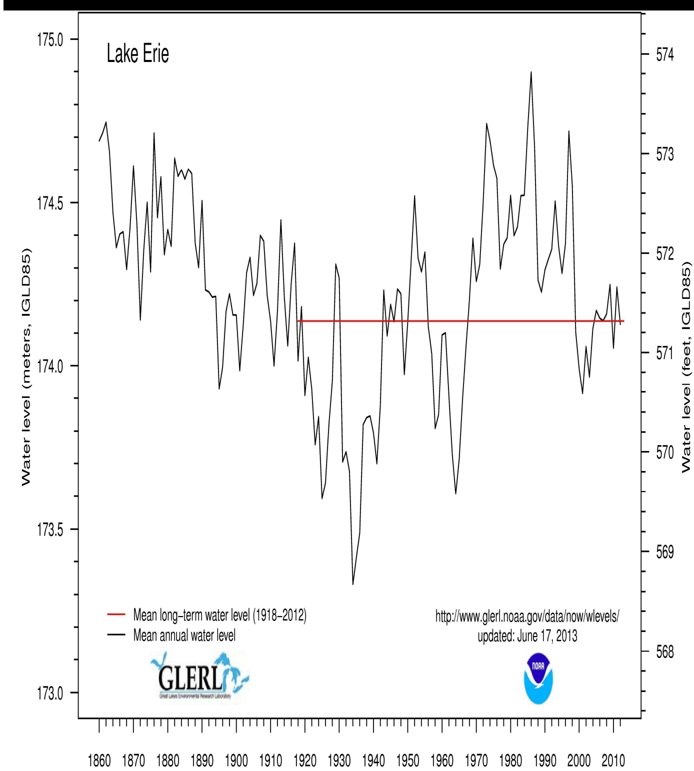
Superior



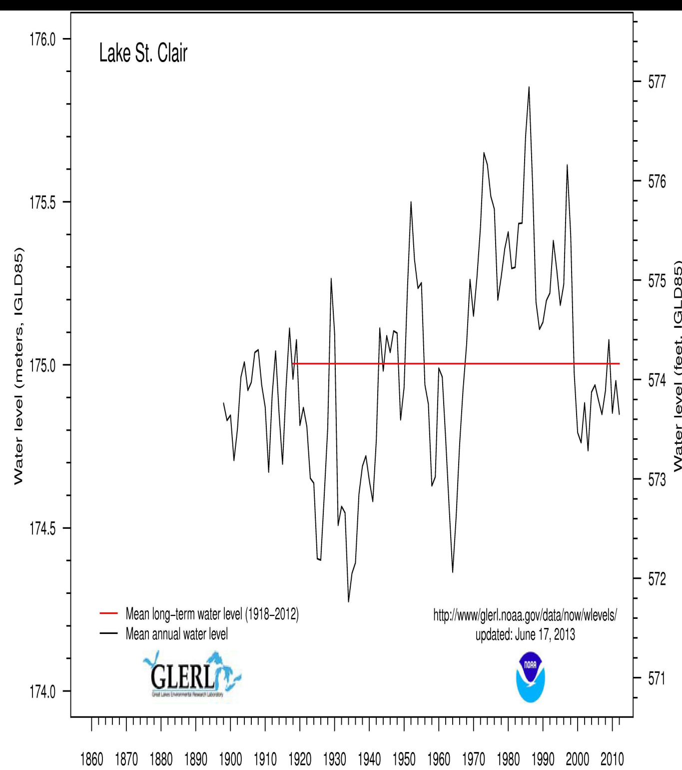
Michigan / Huron



Erie



Lake St. Clair



Source: National Oceanic and Atmospheric Administration hydrographs from http://www.glerl.noaa.gov/data/now/wlevels/levels.html

Shoreline Hazard History for Michigan Counties – arranged by region – Jan. 1996 to Oct. 2013
(The Lower Peninsula regions are ordered by "tiers" from south to north, west to east)
Please refer to the Michigan Profile Map section for an explanation of regional divisions

COUNTY or area	**Shoreline Events**	**Days with Shoreline Hazards**	**Tot. property damage**	**Injuries**	**Deaths**
Washtenaw					
Wayne					
.Livingston					
Oakland					
Macomb					
5 Co Metro region					
Berrien	17	17		8	15
Cass					
St. Joseph					
Branch					
Hillsdale					
Lenawee					
Monroe					
.Van Buren					
Kalamazoo					
Calhoun					
Jackson					
.Allegan	1	1			
Barry					
Eaton					
Ingham					
.Ottawa					
Kent					
Ionia					
Clinton					
Shiawassee					
Genesee					
Lapeer					
St. Clair					
.Muskegon	1	1	$20,000		
Montcalm					
Gratiot					
Saginaw					
Tuscola					
Sanilac					
.Mecosta					
Isabella					
Midland					
Bay					
Huron					
34 Co S Lower Pen	**0.56 avg.**	**0.56 avg.**	**$20,000**	**8**	**15**

Continued on next page…

Part 2 of Michigan County Shoreline Hazards History Table

.Oceana					
Newaygo					
.Mason					
Lake					
Osceola					
Clare					
Gladwin					
Arenac					
.Manistee	1	1			1
Wexford					
Missaukee					
Roscommon					
Ogemaw					
Iosco					
.Benzie	2	2		1	1
Grand Traverse					
Kalkaska					
Crawford					
Oscoda					
Alcona					
.Leelanau	1	1			1
Antrim					
Otsego					
Montmorency					
Alpena					
.Charlevoix					
Emmet	1	1			1
Cheboygan					
Presque Isle					
29 Co N Lower Pn	**0.17 avg.**	**0.17 avg.**		**1**	**4**
Gogebic					
Iron					
Ontonagon					
Houghton	1	1			
Keweenaw	1	1			
Baraga	1	1			
.Marquette	6	6			5
Dickinson					
Menominee					
Delta					
Schoolcraft					
Alger	3	3			
.Luce	1	1			
Mackinac	1	1			2
Chippewa					
15 Co Upp.Pen	**0.39 avg.**	**0.39 avg.**			**7**
MICHIGAN TOTAL	**36**	**34**	**$20,000**	**9**	**29**

NOTE: Some qualifying shoreline events have been classified by NCDC under other hazards, such as flooding. This table is not considered to be fully representative of the impacts of the shoreline erosion hazard, but more representative of the impact of rip currents and high tide hazards.

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. As of 2012, 136 of the dams in Michigan were classified as “high hazard” (meaning there was at least some development downstream, in the dam’s “hydraulic shadow”), down from the count of 161 from just a few years before. 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.

Federal and State laws require the owners of high and significant hazard potential dams to prepare and keep current an Emergency Action Plan for their dams. They are also required to submit such plans to their local emergency management officials and/or Dam Safety Officer for review and coordination. The EAP includes mapping and/or listing of buildings that would be inundated in the event of dam failure.

Information on dams with low hazard potential may be found in the National Inventory of Dams. Most dams in Michigan, have not been classified as having “high hazard” potential, although that designation technically refers to the fact that at least some development exists downstream, in the dam’s “hydraulic shadow”). 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.

The actual risk of dam failures in general needs to be calculated from fairly rare past occurrences. Not all dam 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. In most years, there will be no incident. If there is an incident, it tends to be relatively minor in its impact. 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, with most involving small impacts and rural locations.

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 to 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.

October 6, 2012 – Dam Failure and Flash Flood (Grand Traverse County)

East of the town of Grawn, a temporary dam and de-watering structure had been in place alongside the Brown Bridge Dam on the Boardman River, to assist in drawing down the small lake behind the dam (Brown Bridge Pond) before the dam's permanent removal. This temporary dam failed and caused the release of all remaining water, causing road closures and home evaluations within the hour. A total of 53 homes sustained varying degrees of damage. Docks, small footbridges, and some small outbuildings were destroyed. Total damages were estimated at $1.8 million.

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.

Hazard Mitigation Alternatives for Dam Failures

- Regular inspection and maintenance of dams.
- Garnering community support for a funding mechanism to assist dam owners in the removal or repair of dams in disrepair.
- Regulate development in the dam's hydraulic shadow (where flooding would occur if a severe dam failure occurred).
- Ensuring that dams meet or exceed the design criteria required by law.
- Public warning systems.
- Obtaining insurance.
- Increased coverage and use of NOAA Weather Radio
- Increased funding for dam inspections and enforcement of the Dam Safety Program (Part 315 of the Natural Resources and Environmental Protection Act) requirements and goals.
- Constructing emergency access roads to dams, where needed.
- Pump and flood gate installation/automation.

Tie-in with Local Hazard Mitigation Planning

Because many means of implementing mitigation actions occur through local activities, this updated MHMP places additional emphasis on the coordination of State-level planning and initiatives with those taking place at the local level. This takes two forms:

1. The provision of guidance, encouragement, and incentives to local governments by the State, to promote local plan development (including a consideration of dam failures), and
2. The consideration of information contained in local hazard mitigation plans when developing State plans and mitigation priorities.

Regarding the first type of State-local planning coordination, MSP guidance has included the “Local Hazard Mitigation Planning Workbook” (EMD-PUB 207), which is currently being updated for release by 2015. For the second type of State-local planning coordination, a section later in this plan summarizes hazard priority information as it has been reported in local hazard mitigation plans. Here, it will merely be noted that dam failures were identified as one of the most significant hazards in local hazard mitigation plans for the following counties: Allegan, Alpena, Calhoun, Eaton, Gladwin, Houghton, Iron, Kalkaska, Leelanau, Manistee, Marquette, Midland, and Roscommon.

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
Miles
0 25 50 100 150
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 durations 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. This does not mean that Michigan is also experiencing a dry spell at the same time.

Drought can be a "low-profile" hazard that does not get a lot of public attention in Michigan, compared with the Rocky Mountain or Great Plains states. Nevertheless, parts of Michigan have tended to experience significant drought conditions an average of about 20% of the time (depending upon how this is measured). Even if the occurrence of drought appears at first to be of lesser concern for a community, it is important to include a consideration of the drought hazard in local hazard mitigation planning, since plans are an excellent way to deal with gradual or longer-term hazards such as drought.

When a drought takes place, there are many impacts that can result from the extended dry period. These impacts can be classified as economic, social, and/or environmental. Of great significance is the economic loss of crop production through lower yields, poorer crop quality, and reduced productivity of the land. (Michigan's fruit production is especially vulnerable to lesser yields, as was seen in a 2001 drought event that caused the destruction of one-third of the state's fruit and vegetable crop.) Timber production is also reduced through possible forest fires/tree diseases, and fisheries also have lesser amounts of fish. Lessened production in the agricultural sector leads to income losses for farmers and industries dependent on agricultural products. Lower hydrologic levels lead to water shortages for municipalities and possible shutdowns of industries and businesses that depend on large volumes of water. The quality of water tends to diminish with lower water levels, as well. Tourism becomes hampered by lower lake and river depths, due to the recreational difficulties and inconveniences that are caused. Severe and prolonged droughts could have catastrophic effects on the economy, in cases when adverse conditions lead to disruptions in the regional and national economy and when widespread economic losses affect the supply and distribution of goods and services.

Droughts can come to threaten 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. Water is frequently needed for emergency responses to fires, either those in structures or wildfires in natural areas.

Environmentally, a drought brings the aforementioned lowering of water levels and water quality for surface lakes and rivers, and strains the subterranean aquifers in the state. Various animal and plant populations decline and are at heightened risk of disease. 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.

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 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.

<u>Urbanized Areas</u>

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.

Climate Change Considerations
Although the effect of climate change on Michigan has been an overall increase in precipitation, and the severity of droughts has generally been decreasing over the past half-century, nevertheless there will still be drought events and dryer seasonal phases, especially in areas that are locally more susceptible. With sufficient planning and water infrastructure, the climate change effects upon this hazard may actually be beneficial on the whole, although the hazard will not disappear anytime soon.

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.

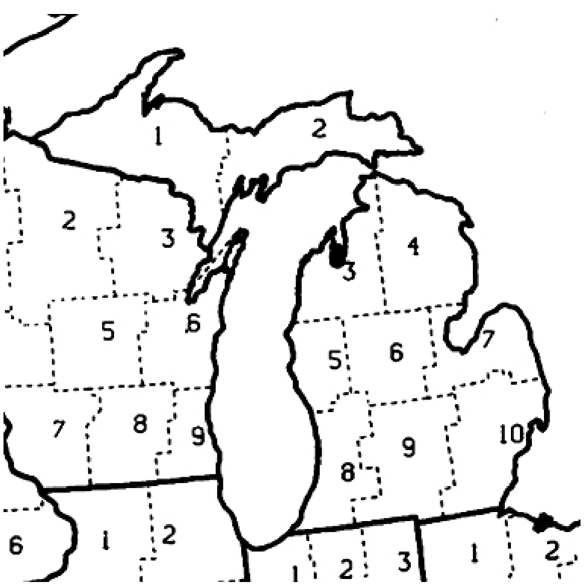
Significant U.S. Droughts: 1900-present

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.

Significant Droughts affecting 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

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.

Drought History for Michigan Counties – arranged by region – Jan. 1996 to Oct. 2013
(The Lower Peninsula regions are ordered by "tiers" from south to north, west to east)
Please refer to the Michigan Profile Map section for an explanation of regional divisions

COUNTY or area	**Drought Events**	**Days with Event**	**Tot. crop damage**
Washtenaw	2	2	
Wayne	2	2	$150,000,000
.Livingston	2	2	
Oakland	2	2	
Macomb	2	2	
5 Co Metro region	**2 avg.**	**2 avg.**	**$150,000,000**
Berrien			
Cass			
St. Joseph			
Branch			
Hillsdale			
Lenawee	2	2	
Monroe	2	2	
.Van Buren			
Kalamazoo			
Calhoun			
Jackson			
.Allegan			
Barry			
Eaton			
Ingham			
.Ottawa			
Kent			
Ionia			
Clinton			
Shiawassee	2	2	
Genesee	2	2	
Lapeer	2	2	
St. Clair	2	2	
.Muskegon			
Montcalm			
Gratiot			
Saginaw			
Tuscola	2	2	
Sanilac	2	2	
.Mecosta			
Isabella			
Midland	2	2	
Bay	2	2	
Huron	2	2	
34 Co S Lower Pen	**0.6 avg.**	**0.6 avg.**	

Continued on next page…

Part 2 of Michigan County Drought Hazard History Table

.Oceana			
Newaygo			
.Mason			
Lake			
Osceola			
Clare			
Gladwin			
Arenac			
.Manistee			
Wexford	1	1	
Missaukee	1	1	
Roscommon			
Ogemaw			
Iosco			
.Benzie			
Grand Traverse	1	1	
Kalkaska	1	1	
Crawford			
Oscoda			
Alcona			
.Leelanau	1	1	
Antrim	1	1	
Otsego	1	1	
Montmorency			
Alpena			
.Charlevoix	2	2	
Emmet	2	2	
Cheboygan	2	2	
Presque Isle			
29 Co Nrthrn Lower Pen	**0.4 avg.**	**0.4 avg.**	
Gogebic			
Iron			
Ontonagon			
Houghton			
Keweenaw			
Baraga			
.Marquette			
Dickinson			
Menominee			
Delta			
Schoolcraft			
Alger			
.Luce			
Mackinac	4	4	
Chippewa	3	3	
15 Co Upp.Pen	**0.5 avg.**	**0.5 avg.**	
MICHIGAN TOTAL	**54**	**8**	**$150,000,000**

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

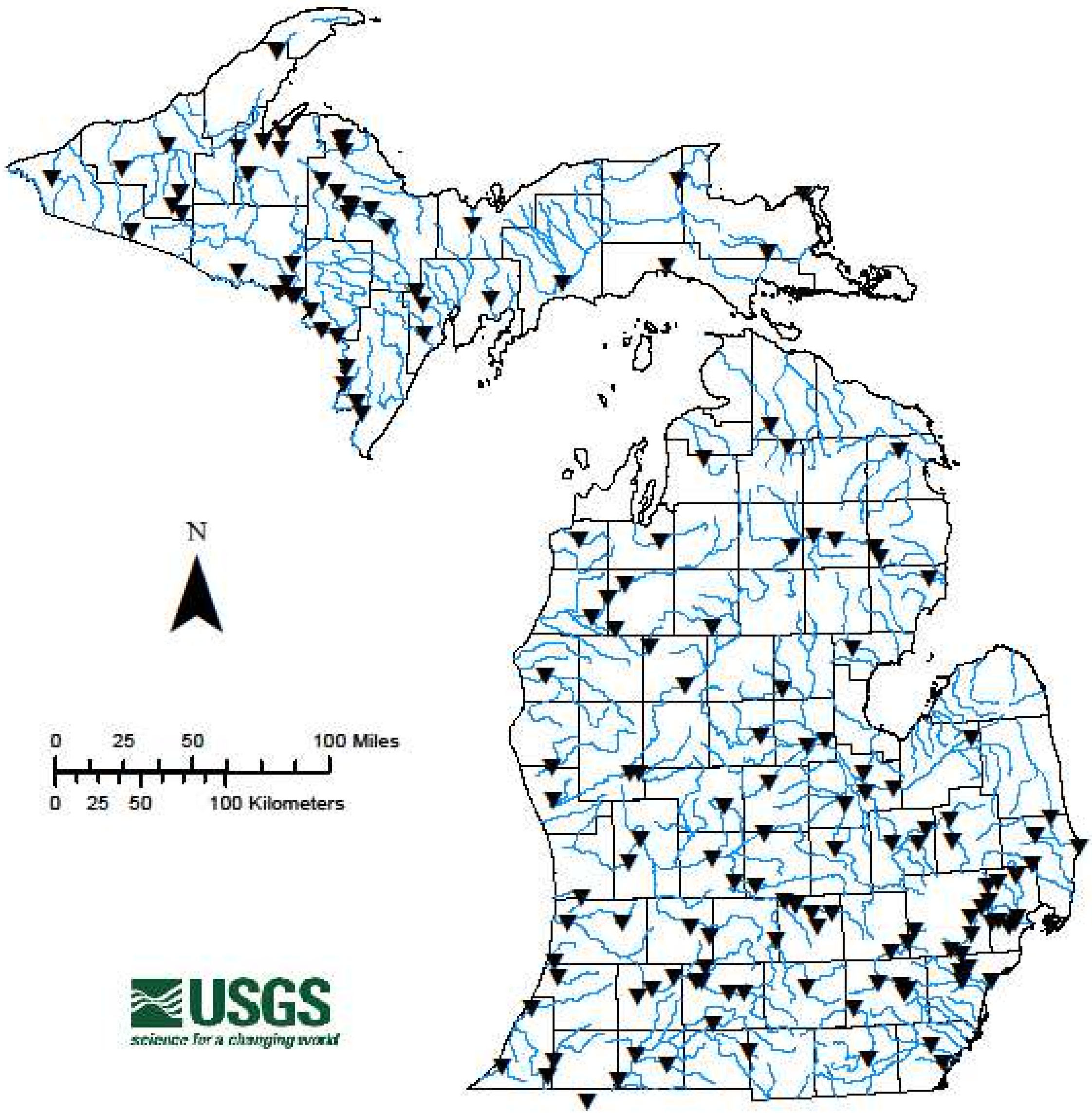
The National Weather Service (NWS) is the primary Federal agency that collects and publishes precipitation data. The NWS publishes precipitation data from approximately 9,100 non-recording and 2,100 recording stations in the United States. This data is published monthly in reports for each state, titled 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.

Mitigation Alternatives for the Drought Hazard

- Storage of water for use in drought events (especially for human needs during periods of extreme temperatures, and for responding to structural fire and wildfire events).
- Legislative acts, local ordinances, and other measures to prioritize or control water use.
- Encouragement of water-saving measures by consumers (including landscaping, irrigation, farming, and low-priority lawn maintenance and non-essential auto washing).
- Anticipation of potential drought conditions, and the preparation of drought contingency plans.
- Designs, for recreational and other water-related structures and land uses, that take into account the full range of water levels (of lakes, streams, and groundwater).
- Designs and plans for water delivery systems that include a consideration of drought events.
- Obtaining agricultural insurance.

Tie-in with Local Hazard Mitigation Planning

Because many means of implementing mitigation actions occur through local activities, this updated MHMP places additional emphasis on the coordination of State-level planning and initiatives with those taking place at the local level. This takes two forms:

1. The provision of guidance, encouragement, and incentives to local governments by the State, to promote local plan development (including a consideration of drought conditions), and
2. The consideration of information contained in local hazard mitigation plans when developing State plans and mitigation priorities.

Regarding the first type of State-local planning coordination, MSP guidance has included the "Local Hazard Mitigation Planning Workbook" (EMD-PUB 207), which is currently being updated for release by 2015. For the second type of State-local planning coordination, a section later in this plan summarizes hazard priority information as it has been reported in local hazard mitigation plans. Here, it will merely be noted that drought was identified as one of the most significant hazards in local hazard mitigation plans for the counties of Antrim and Monroe.