State of Michigan's Environment 2014

Third Triennial Report

Message from the Governor

As a lifelong Michigander, I have always been deeply proud of what our state represents. We are known throughout the nation for a rich history of innovation and for our bountiful natural resources. Michigan's Great Lakes, expansive forests, coastline beaches, plentiful inland lakes and myriad outdoor recreation opportunities draw visitors from around the country and the world.

Natural resources are critical to defining who we are in Michigan. The state works tirelessly to protect and manage those resources through the efforts of several state agencies, most notably the Michigan Departments of Environmental Quality and Natural Resources.

In 1999, the Michigan Legislature mandated that the two departments develop a program to track and report changes in the environment. Program specialists assembled the appropriate scientific tools to monitor key biological, chemical and physical attributes of the state's land and water in ways that can show how we are changing over time.

By documenting changes in environmental indicators such as animal and fish populations, state forests, land cover, air quality and surface water, we can identify trends and craft policies to ensure that our natural treasures are protected and improved for our kids, their kids and beyond.

This report was conceived as a biennial document, issued in 2001, 2003 and 2005. The Legislature in 2005 directed that it be changed to a triennial report.

I am proud to present the "State of Michigan's Environment 2014." This comprehensive look at where we've been and where we are in terms of our environment and natural resources will help guide our focus in the years to come.

State leaders will find in these pages useful tools for guiding policy discussions. I welcome that dialogue. Every citizen of our state has a stake in ensuring that the Michigan we leave for future generations is better than the one we have been blessed to enjoy in our lifetimes.

Rick Snyder,
Governor

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Introduction

The Environmental Indicators Act of 1999 requires that the Michigan Department of Environmental Quality (DEQ) work with the Michigan Department of Natural Resources (DNR) to produce reports on the quality of Michigan's environment, based on scientifically supportable environmental indicators using sound scientific methodologies.

In July 2001, the Michigan Environmental Science Board developed a set of criteria from recommendations made by DEQ and DNR for evaluating the state's environmental quality. The first biennial report – State of Michigan's Environment – was published in November 2001. Subsequent reports were issued in December 2003 and January 2006.

In 2008, the first of what is now a triennial report was published after the Environmental Indicators Act was amended in 2005.

The third triennial report – State of Michigan's Environment 2014 – follows a pattern developed for the 2008 report. It is divided into three sections: Environmental Measures, Programmatic Measures, and Emerging Contaminants of Concern in Michigan.

The first section presents the ecological, physical, and chemical measures used to track environmental quality. The second section discusses state agency measures used to fulfill state and federal environmental programmatic requirements. The final section discusses recognized contaminants that may have potential for environmental and public health impacts that experts do not as yet fully understand.

The material contained in this report reflects assessments of highly complex issues; any change noted from the previous report should be understood as a simple snapshot in time. Three years is an extremely short time frame to evaluate natural influences or corrective actions within an ecosystem, and any changes could easily be short-term anomalies rather than long-term changes. It may take many, many years to determine actual trends.

Also note that simple value judgments – good, bad, or moderate; healthy or unhealthy – are not scientifically definable and may lead to incorrect conclusions. Additional information may be necessary to accurately identify the trends that various environmental measures may seem to indicate.

These reports provide the State of Michigan with a tool to track and evaluate its ever-changing environment. It is hoped that the triennial reports will serve to promote environmental stewardship activities which will ultimately improve the state's overall environmental quality.

Environmental Measures

Ecological Indicators

Trends in Land Use/Cover

Monitoring change in land use/cover types provides a useful indirect measure of trends in ecosystem health. High rates of land conversion place stress on natural ecosystems. Human population growth and/or dispersal usually cause a conversion of land use/cover types from natural vegetation or agricultural types to urban uses. While often economically beneficial in the short-term, these changes often have long-term negative impacts on ecosystem health through the loss of wildlife habitat and incremental increased water and air pollution.

Change is the only constant with Michigan's environment. Change occurs through natural processes such as ecological succession and fire, and through human activities such as agricultural, residential, urban, and industrial development. Since European settlement, Michigan's land cover has changed dramatically. At times, this change has occurred quite rapidly over relatively short periods of time. The original land surveyors of Michigan recorded a landscape dominated by forest in the north and a mix of forest and savanna in the south. Early settlers cleared land for agriculture while logging companies provided wood to a growing nation. The logging era of the late 19th and early 20th centuries changed Michigan's landscape dramatically. The 20th century was marked by a return of forest to the nocthern Michigan landscape and intensive agriculture and urban development in southern Michigan. **Exhibits 1 and 2** provide a graphic representation of the loss of wetlands in Michigan between 1800 and 1980 and the percent change in native vegetation, respectively, that has taken place due to competing uses of land resources in Michigan between the 1880s and the 1990s.

Michigan's land cover was mapped in 1978 by the DNR. At that time, Michigan was composed of 37 percent forest, 29 percent agricultural, 18 percent wetland, 8 percent open field, 6 percent urban, and 2 percent inland water. The United States Department of Agriculture (USDA) also tracks changes in Michigan's land cover through its

Exhibit 1. Changes in Michigan's Wetlands 1800-1980

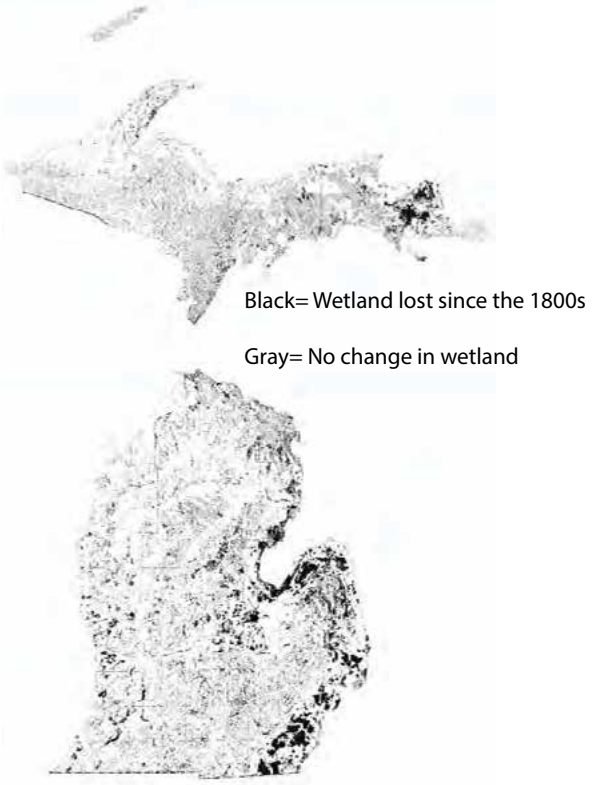
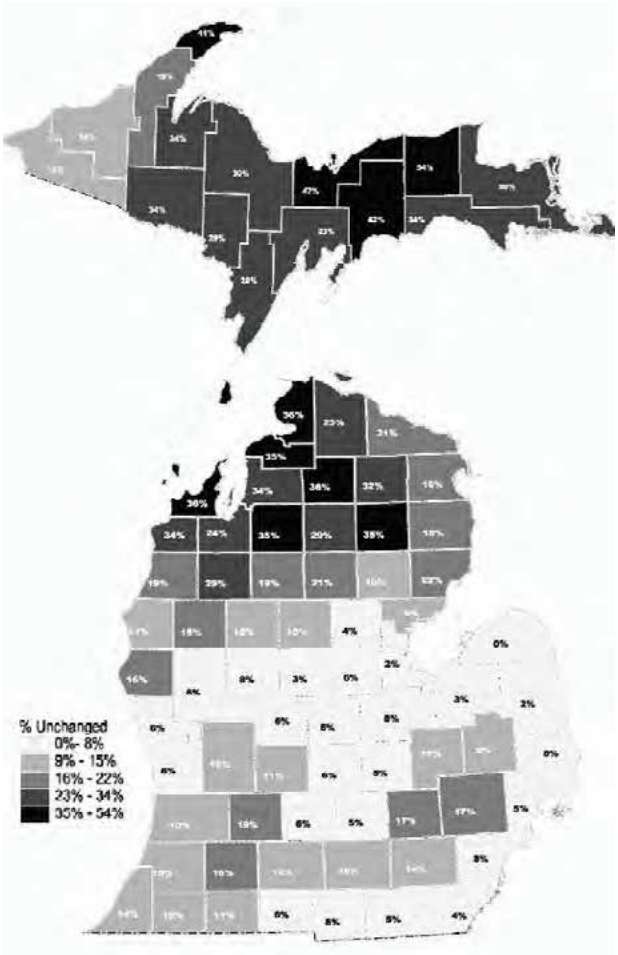


Exhibit 2. Percent Change in Native Vegetation by County between the 1880s and 1900s



National Resources Inventory program. According to the USDA, between 1982 and 2007 there was a 50-percent increase in developed land. Most of this development occurred on former agricultural land. During this same time period, there was a loss of approximately 1.3 million acres of crop and pasture land. However, between 2008 and 2010, cultivated cropland increased by 84,000 acres. Other noticeable recent trends include an increase in forests and a decrease in wetlands. Between 1982 and 2010, there was an increase of 741,000 acres of forest on nonfederal rural lands in Michigan and between 2007 and 2010 there was an increase of 2,000 acres of forests on nonfederal lands. The increase in forest was the result of natural succession of open fields and abandoned agricultural land. In 2010, Michigan had approximately 5.9 million acres of wetlands, a decline of 300,000 acres since 1978. The United States Fish and Wildlife Service (USFWS) reports that the rate of wetlands loss has declined dramatically across the nation compared to previous decades; however, loss of wetlands is still occurring with conversions to urban and agricultural uses.

Urbanization

As previously indicated, the percentage of Michigan land in urban use in 1978 was six percent. Numerous studies have documented the changes in Michigan's land cover since 1978, most notably the spreading of urbanization along with a population out-migration from core cities to surrounding undeveloped lands. According to one such study, if current land use patterns continue, between 1.5 and 2 million more acres of land area will be urbanized by 2020.

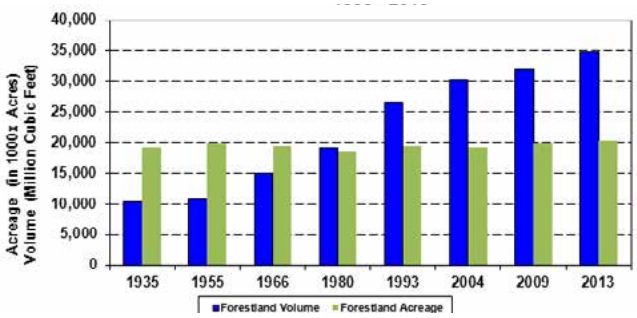
The recent economic downturn has potentially impacted the pace and spread of urbanization in Michigan. The 2010 United States Census found that Michigan was the only state in the nation which lost population, losing .6 percent of its population. Most of that loss occurred in Wayne County (10 percent of its population) and counties in the Upper Peninsula (Iron County -10 percent, Ontonagon County -13 percent). Updates to the 2010 census (U.S. Census Bureau, Estimated Population by County, 2010-2012) found that Michigan has reversed the population loss trend and that the population began to grow (.1 percent). In the census update, Ontonagon, Montmorency, Alcona, Arenac, and Branch counties suffered the most population loss. Marquette, Grand Traverse, Missaukee, Mecosta, Ottawa, Kent, Oakland, Washtenaw and Kalamazoo counties experienced the most population gain. While some of the counties' growth could be contributed to spreading urbanization (Oakland, Kent, Ottawa counties) other counties' growth could not be contributed to sprawl (Missaukee, Mecosta counties). Of the counties that grew in population between 2010-2012, only Grand Traverse County's growth occurred because of migration into the county was greater than that attributed to natural causes (more births than deaths).

Trends in Forest Acreage, Mortality, Growth, and Removals

The Forest Acreage, Mortality, Growth, and Removals indicator addresses several dimensions relating to the health and amount of Michigan's forests. As previously indicated, Michigan's forests have been regrowing following logging, fire and land clearing for farming at the end of the 19th Century and the beginning of the 20th Century.

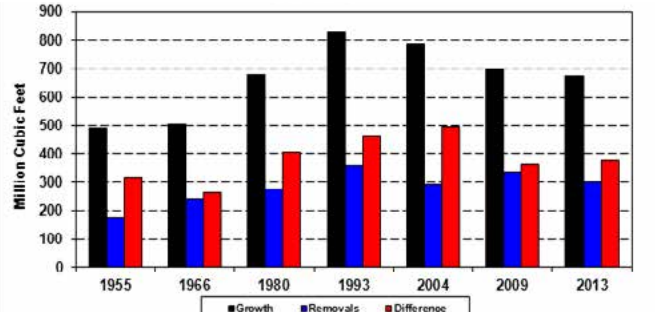
Seven statewide forest inventories have been conducted by the U.S. Forest Service, Forest Inventory and Analysis (FIA) program during the past 80 years. These inventories indicate that forest acreage has remained relatively stable since the 1950s. The only exceptions to this are a slight decrease between 1966 and 1980, which was followed by an expansion between 1980 and 1993 and a second modest expansion between 2004 and 2013. **(Exhibit 3)**

Exhibit 3. Michigan Forestland Acreage and Volume 1935-2013



In contrast to the stable forest acreage, total standing timber volumes have more than tripled since the middle of the last century and continue to increase through the 2013 inventory, reflecting a maturing forest **(Exhibit 4)**. This expanding volume also indicates that more growth has been continuously added to the forest than what has been removed or died through natural causes. However, increases in annual net growth peaked in the 1990s and are now decreasing, as natural mortality has been increasing **(Exhibit 4)**. This also reflects a maturing forest resource. The proportion of growth to removals increased slightly between 2009 and 2013, but remains about 2:1, reflecting decreased removals and slow recovery of the forest industry following the economic and housing market collapse in 2008-2009.

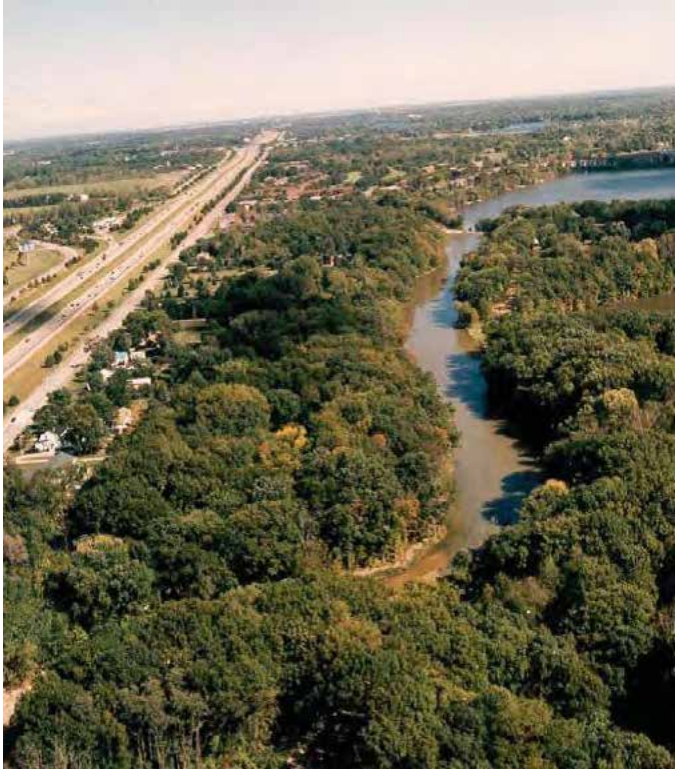
Exhibit 4. Michigan Annual Net Growth and Removals on Timberland 1955-2013



Trends in Vegetation Diversity and Structure

Michigan's forests are some of the most diverse in the United States. The FIA statewide forest inventories identify over 75 different tree species with substantial mixtures of species within each of the major forest cover types. This diverse forest provides habitat for a wide variety of plant and animal species.

In addition to maturing, Michigan's forests have been gradually transitioning toward more shade-tolerant, late successional tree species. For example, aspen and paper birch (species particularly adapted to full sunlight) have declined in both acreage and volume since 1980, while the more shade-tolerant species such as maple, spruce and oak-hickory types have increased. The acreage and volume of jack pine have also been declining since 1980, but the loss has been more



than offset by gains in red and white pine. The broad increase in volume across most cover types has been accompanied by a trend toward more saw timber-sized trees. Recent data indicate the trend toward more shade-tolerant, older trees may be stabilizing as timber harvesting of more mature trees perpetuates shade-intolerant, early successional species. Ash species are an exception to this trend, as extensive mortality is occurring from the continued spread of the exotic emerald ash borer throughout the state.

Similarly, animals that depend on pioneer tree species for habitat also have declined over the past several decades. For instance, ruffed grouse, American woodcock, golden-winged warbler and other songbirds dependent upon early successional tree species have suffered from this change in habitat, while other bird species dependent on the shade-tolerant tree species have benefited.

The DNR, in conjunction with the University of Michigan, participates in a national program that conducts annual evaluation of the condition, changes and trends in the health of forest ecosystems in Michigan. The USDA Forest Service manages this national program, referred to as the Forest Health Monitoring Program (FHM Program).

The vegetation diversity and structure indicator is composed of a suite of measurements of forest understory diversity, vegetation structure, down woody debris and forest fire fuel loading. Variables collected for this indicator can provide information to help evaluate wildlife habitat, plant diversity, vitality, soil conservation and carbon cycling. As part of the FHM Program, botanists field-identify nearly all the plant species on-site, including locally rare species and exotic species from overseas. An immediate return from this evaluation is to detect areas of exotic plant invasion and spread. Multi-scale data on plant diversity can be used to evaluate species richness patterns over time. This information will help to evaluate the effect of exotic plants relative to their native counterparts. However, no data or formal reporting on vegetation diversity and structure are available at this time, nor anticipated, due to federal funding being eliminated for the further development or evaluation of this indicator.

Trends in Lichen Communities

Lichens are unique organism made up of cooperating algae and fungi. Individual species in this very diverse group are useful as environmental indicators. Epiphytic lichens, or lichens that live on other plants, are very sensitive to changes in air quality since they rely totally on the atmosphere as a source of nutrition. A large body of scientific literature has documented the close relationship between lichen communities and air pollution, especially acidifying nitrogen, fertilizing nitrogen, sulfur dioxide and other sulfur-based pollutants.

The composition of a lichen community is one of the best indicators of air pollution in forests.

Long-term observations of the abundance of a particular group or species of lichen can provide early indication of changes in air quality or changes in forest composition. A decline or increase in the abundance of a particular species of lichen can be a bellwether of declining or improving environmental conditions.

The USDA Forest Service's FHM Program developed the lichen community indicator. Lack of funding for this facet of the program has prevented collection of lichen indicator data since 1998, and it is not anticipated that this funding will be restored in the immediate future.

Trends in Mammal Populations

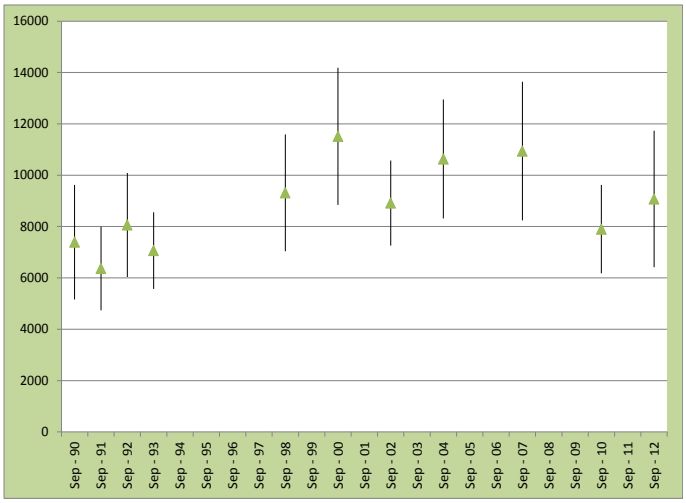
Many mammal populations in the state have remained stable or are increasing. For many Michigan residents, large mammals like bear, wolf and moose are important to the state's natural heritage. Mammals can tell us about the health of the environment in a variety of ways. The DNR gains much of its information on population trends in mammals through indices such as the winter track surveys for wolves, aerial surveys for moose and annual harvest surveys for most other mammals that are hunted or trapped.

For some more common mammals, like raccoons and coyotes, there is a perception that their populations have increased greatly. Yet harvest surveys indicate their populations statewide are stable or only slightly increasing. The misperception is likely due to more human-animal interactions as these species have become more adapted to urban and suburban habitats, and more people have moved into once-rural areas, rather than dramatic increases in mammal populations. The primary tools for managing these species are trapping and hunting.

Bear

Bear populations have remained relatively stable over the past several years **(Exhibit 5)**. Bears are naturally shy omnivores that feed opportunistically, which can create conflicts with people. They have been expanding their range into the southern Lower Peninsula, and it has become clear that bears can also inhabit areas

Exhibit 5. Population Estimates for Bear in the Western Upper Peninsula, 1989-2007

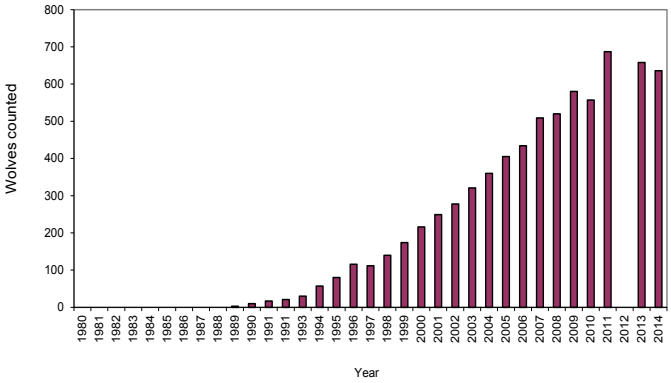


with people, provided some forested habitats exist, especially along riparian zones. The DNR manages bear populations sustainably to provide recreational opportunities through hunting and wildlife viewing, while balancing local communities' tolerance for bears. Hunting is the primary management tool to help limit negative human-bear interactions by keeping bear populations under biological and social carrying capacity. In 2008, a bear management plan was developed to guide thoughtful management for multiple values of bears. For more information about bears, visit www.michigan.gov/bear.

Wolves

Wolves have met and exceeded recovery goals for over a decade in Michigan. In January 2012, the U.S. Fish and Wildlife Service removed the gray wolf in the Western Great Lakes region from the federal endangered and threatened species list, but a federal court decision has since resulted in wolves being re-listed as endangered. The wolf population in the Upper Peninsula appears to be stabilizing after years of continued growth **(Exhibit 6)**. This is an expected population trajectory with a recovered wildlife population.

Exhibit 6. Michigan Wolf Populations

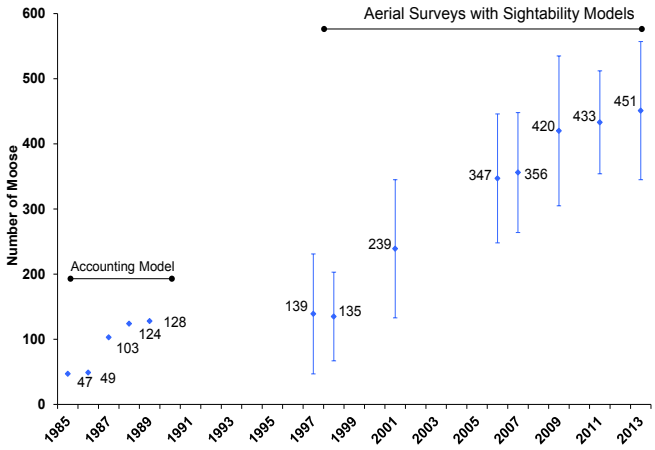


**no survey was conducted in 2012*

Moose

Moose were reintroduced to Michigan's Upper Peninsula in the mid-1980s to produce a self-sustaining population with an optimistic goal of 1,000 moose by the year 2000. Unfortunately, the population of this majestic animal grew slower than the predicted rate, and as a result, the herd has never met those initial expectations **(Exhibit 7)**. Michigan is at the southern edge of the range of moose in North America due to temperature restrictions. Some current climate change modeling suggests that temperatures in Michigan could rise by as much as 4-9 degrees Fahrenheit in the winter by the end of the 21st century, which likely will be too warm for moose.

Exhibit 7. Michigan Moose Populations



Bats

Bats make up a quarter of the world's mammal species and consume large amounts of insects. They provide pest-control services for local neighborhoods and the agricultural industry. Some estimates suggest that the pest control bats provide saves the agricultural industry over $3 billion a year. Unfortunately, they are currently at great risk. White-nose syndrome, an exotic disease in North America, has been killing bats. The syndrome was named for the white fungus that sometimes develops on the muzzle of the bat, giving the appearance of a

white nose. Infected bats prematurely awaken from hibernation, rapidly deplete their fat reserves, and are unable to survive the winter. The disease is thought to be spread through bat-to-bat contact or by humans visiting caves and mines. To date over 1 million bats have died from white-nose syndrome. Unfortunately, in April 2014, the disease was detected in three Michigan counties: Alpena, Dickinson and Mackinac. Five little brown bats (Myotis lucifugus) were collected and diagnosed with the disease through surveillance efforts in cooperation with researchers from Eastern Michigan University. Michigan has a white-nose syndrome response plan that is currently being implemented. For more information or to report large numbers of bats dead, dying or exhibiting unusual behavior, go to www.michigan.gov/emergingdiseases.

Trends in Breeding Bird Populations

As a group, grassland birds are the most at-risk of all North American birds. While there have been modest gains in the amount of forested land in Michigan in recent decades, abundance trends for some of our most sensitive forest interior birds continue to decline. Encouragingly, some species dependent on mature forest are showing small population increases. The decline in grassland

bird abundance has been attributed to changes in land use and agricultural practices. Those lands still maintained in hay or pasture are often being managed more intensively and harvested earlier, more frequently and at higher rates, which disturbs nesting or destroys nests of grassland birds. In addition to acreage declines, the average size of grassed parcels has shrunk, making them less attractive to grassland birds that require large grassland expanses. Similarly, decreasing parcel sizes produces more fragmented forest management and reduces the availability of large forested blocks on the landscape, which forest interior birds need. And both grassland and forests have been converted to urban and suburban uses, especially in the southern Lower Peninsula, as the population distribution around urban centers has shifted outward. All these changes are reducing

the quantity and quality of habitat available for grassland and forest interior birds, so declines continue to be seen in their populations.

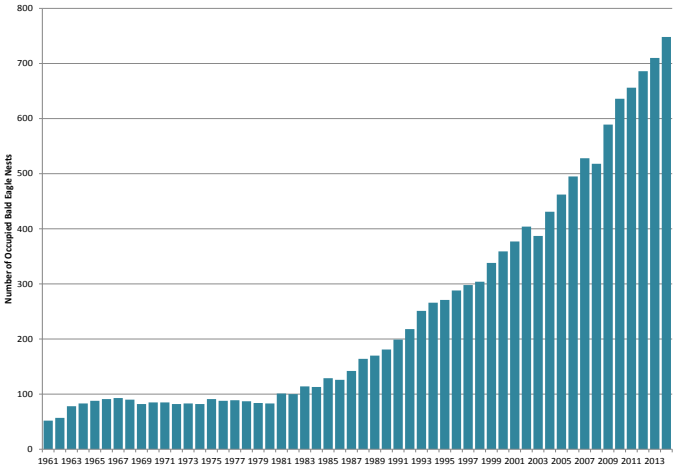
Trends in Bald Eagle Populations

The bald eagle is a top-level predator of aquatic ecosystems. Its position at the top of the food chain makes it highly vulnerable to impacts resulting from contaminants that accumulate in the food chain. During the late 1950s and early 1960s, the bald eagle and many other predator and colonial species of birds declined significantly due to years of widespread pesticide and other contaminant use. With the advent of strict environmental laws on the production and use of pesticides, the bald eagle and other bird populations began to recover.

As one measure of population change, the National Audubon Society began the National

Bald Eagle Census in 1961. The DNR began conducting annual censuses of bald eagle nests in Michigan in 1963. From a low of 50 nests recorded in 1961, the bald eagle population has continued to increase to a high of 748 known occupied nests in 2014 **(Exhibit 8)**. In addition to an increasing population, nest success – measured as number of nests producing fledged young – also has increased. Combined, these measures suggest that not only are bald eagles increasing in number, but they also are successfully raising more young per breeding pair than in the past.

Exhibit 8. Occupied Eagle Nests in Michigan 1961-2014



Trends in Frog and Toad Populations

Frogs and toads can be great indicators of environmental quality. They breathe through permeable skin and may absorb toxins and other gases directly into their systems. Also, their reliance on both aquatic and terrestrial habitats during their life cycle makes them particularly vulnerable to a variety of threats. Frogs and toads are sensitive to changes in water quality and adjacent land-use practices and are easily recognized by their vocal calls, making them excellent indicator species. In 1996, the DNR established a statewide volunteer calling survey to monitor frog and toad population trends. Volunteers, following a national protocol similar to the North American Amphibian Monitoring Program, visit survey routes three times during the breeding season. Data collected include species heard and an abundance index for each species.

Most of Michigan's 13 native species of frogs and toads appear to have stable population trends. Overall, this is great news for our frogs and toads and their habitats. **Exhibits 9 and 10** illustrate abundance trends of three of the less common frogs and toads (northern leopard frog, bullfrog, American toad) and three of the more common frogs and toads (spring peeper, eastern gray tree frog, green frog), respectively, that have statewide distribution and relatively stable populations. Fowler's toads have been rarely reported over the last few years. This has raised concerns, and research to understand what is happening is still needed. Mink frogs continue to raise concerns

with local herpetologists because they too are rarely reported in the survey.

This type of long-term trend data provides insight into the natural fluctuations of frog and toad populations, which can then be distinguished from threat-related factors. The DNR plans to

Exhibit 9. Common Frog Species. Number of sites/routes observed

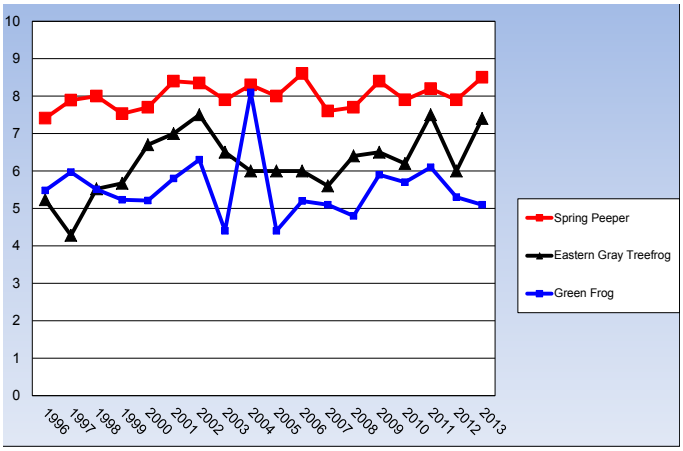
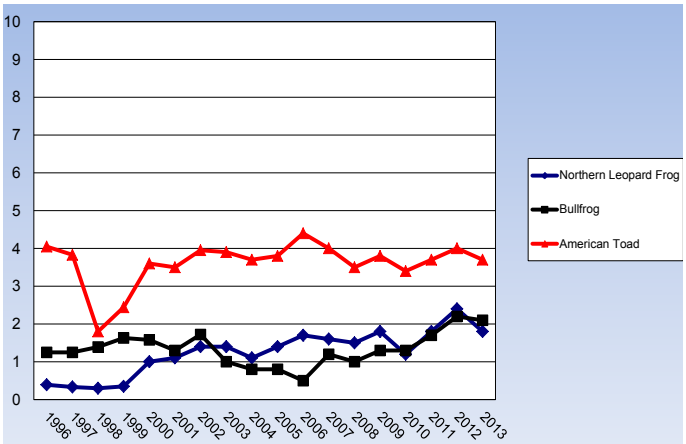


Exhibit 10. Less Common Frog Species. Number of sites/routes observed



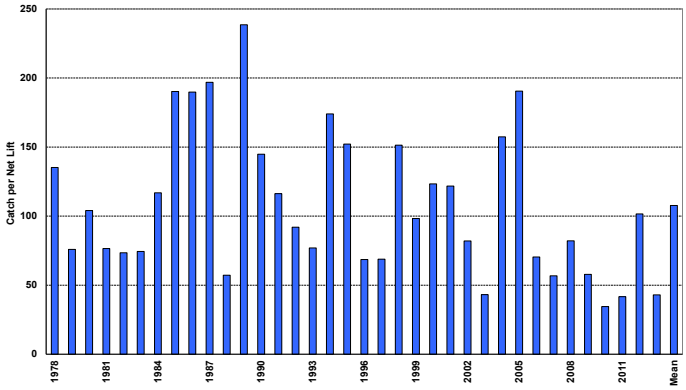
continue the statewide surveys indefinitely. This monitoring program is a great example of a state agency and volunteers working together to conserve and manage wildlife.

Trends in Fish Populations, Benthic Macroinvertebrates and Contaminant Levels

Walleye in Lake Erie

The DNR Fisheries Division has employed an experimental gill-net fish-sampling protocol at two stations in western Lake Erie since the fall of 1978 as part of a cooperative interagency walleye assessment program. This protocol, referred to as the Index Gill Net Survey, typically includes two 1,300-foot sets of variable-mesh, multi-filament gill nets at each sampling station. The gill nets are suspended 6 feet below the surface of the water, and sampling occurs annually in early October.

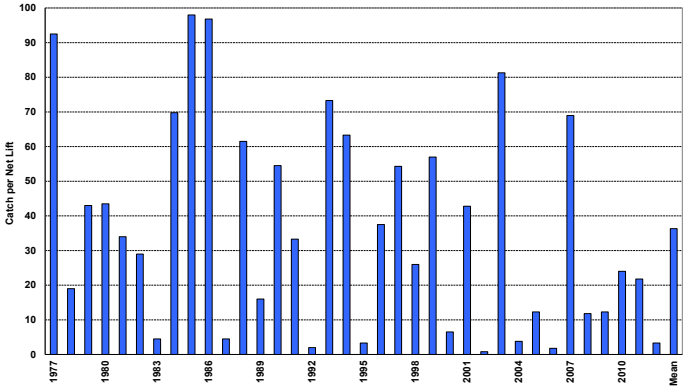
Exhibit 11. Annual and Mean Indices of Abundance for Walleye in Michigan's Waters of Lake Erie, 1978-2013



Gill-net catch rates reflect trends in walleye abundance. **Exhibit 11** shows the trend in the total walleye catch rate for each year of the DNR Fisheries Division Lake Erie Index Gill Net Survey. In general, walleye abundance was relatively low in the late 1970s and early 1980s, increased in the 1980s and peaked in 1989. From 2000 to 2003, walleye abundance declined to the lowest level observed since 1978. In 2004 and 2005, abundance rebounded to levels well above the mean on the strength of the strong 2003 year class. Since 2006, catch rates have been below the long-term mean, with the 2010, 2011 and 2013 relative abundance levels at or near the lowest recorded since the survey began in 1978.

Annual walleye abundance is strongly related to annual variation in reproductive success. This is reflected in yearling catch rates each year

Exhibit 12. Indices of Abundance by Year Class for Yearling Walleye in Michigan's Waters of Lake Erie, 1977-2012



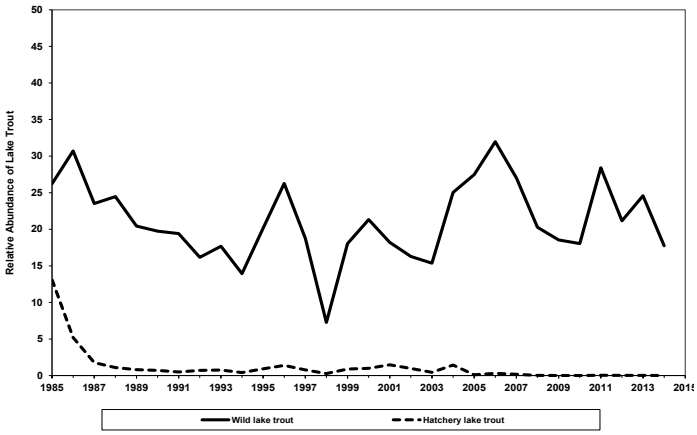
(Exhibit 12). While the yearling catch for the 2003 year class indicated reproductive success was the highest achieved since the mid-1980s, and the yearling catch for the 2007 cohort was also well above the mean, the overall poor recruitment for Lake Erie walleye since the late 1990s is well illustrated in the low catch rates observed for yearlings from the 2000, 2002, 2004, 2006 and 2008-2012 year classes.

Lake Trout in Lake Superior

The lake trout is the dominant native predator fish in the cold-water fish communities of the upper Great Lakes and, as such, is a good indicator of overall aquatic ecosystem health. Lake trout are long-lived and known to accumulate toxins in their bodies. The Michigan departments of Environmental Quality and Community Health monitor the concentrations of these toxins to evaluate potential health risks to the public. Imbalances in fish communities also are reflected in shifts in lake trout populations. During the 1940s and 1950s, lake trout populations significantly declined due to high levels of

commercial fishing exploitation and parasitism by the non-native sea lamprey. Subsequently, an extensive lake trout rehabilitation program was implemented in the late 1950s and 1960s to re-establish self-sustaining populations. Lake trout populations increased during the 1970s and early 1980s as a result of intensive sea lamprey control

Exhibit 13. Trends in Abundance of Wild and Hatchery Lake Trout (Geometric Mean CPUE (fish/km/night)) in Michigan Waters of Lake Superior from 1985-2014.



efforts, restrictions on commercial fisheries and stocking of hatchery-raised lake trout. During the mid-1980s, wild lake trout populations (sustained by natural reproduction) were increasing in most areas of Michigan's waters of Lake Superior. By the mid-1990s, wild lake trout abundance increased to the point where stocking of hatchery-produced fish was discontinued in all areas of Michigan's waters of Lake Superior, except in Keweenaw Bay and Whitefish Bay **(Exhibit 13)**. During the period of increasing wild lake trout abundance, hatchery lake trout abundance and survival declined. In recent years, hatchery lake trout comprise less than 5 percent of lake trout abundance in Michigan's waters of Lake Superior, except in Whitefish Bay, where most fish are of hatchery origin.

Currently, lake trout populations are nearly rehabilitated in all areas of Michigan's waters of Lake Superior, except Whitefish Bay. High levels of commercial exploitation and lack of significant natural reproduction have been inhibiting lake trout abundance in Whitefish Bay. In addition, moderate levels of fishery exploitation on the west side of the Keweenaw Peninsula may be affecting recovery of lake trout and are being monitored closely. Further, lake trout growth rates have

declined to the lowest levels since the 1970s due to the higher abundance of lake trout and lower abundance of prey fish.

Brown and Brook Trout in the Au Sable River System

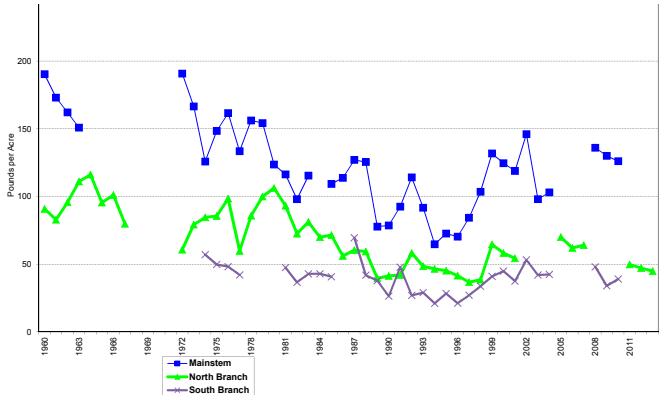
Trends in stream fish populations can be useful environmental indicators, because the quality of their habitat is shaped by conditions in the watershed upstream. Stream trout may be a particularly good indicator, since healthy, self-reproducing trout populations require specialized environmental conditions. Trout need relatively cold and well-oxygenated water. They also require clean gravel for spawning, shelter from predators, high-velocity water, a diverse and abundant food supply, and free access to different habitats at different stages of their lives.

Human activities in a watershed have the potential to either enhance or degrade trout habitat quality. Activities that reduce groundwater yield to streams can result in a warming of the water body, which reduces the area available for trout to survive. Cutting or clearing trees from land adjacent to streams reduces shading, reduces the potential for trees to fall into the stream to provide shelter and nutrients, and may increase erosion of sediment into the channel. Any construction in a watershed that increases soil erosion to streams degrades trout habitat. Activities in a watershed that change the magnitude or timing of flood flows also diminish habitat quality. Examples of such activities include construction of drains and storm sewers, increases in water-impermeable surfaces such as parking lots and operation of lake-level control structures.

The DNR has sampled trout populations for many years at fixed sites in portions of the upper Au Sable River system in Crawford County. Fall standing stock of brook and brown trout (expressed in pounds per acre) in the main stem and North Branch of the Au Sable River were generally higher during the 1960s and 1970s than in subsequent decades **(Exhibit 14)**. Trout standing stock was substantially lower than average in all three branches from about 1985 to 1995 but has increased since that time.

The decline in total trout standing stock was primarily due to declines in growth, survival and reproductive rates for brown trout. Extensive additions of large woody material intended to increase availability of protective cover may be

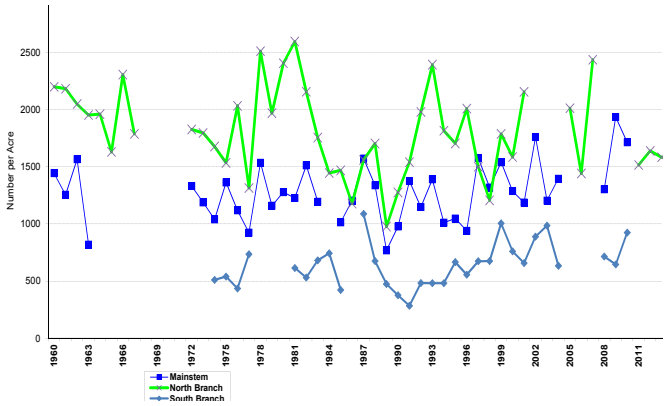
Exhibit 14. Fall Standing Stock of Brown and Brook Trout in Three Branches of the Au Sable River System 1960-2013 (Pounds per Acre): Sampling is currently conducted in 3 years of sampling followed by 3 years no sampling



partially responsible for the recent increases in trout standing stock. In addition, privately and publicly funded habitat-restoration efforts have been directed toward reducing erosion of sediment into the river system. Relatively stable spring flow conditions during most years over the past decade also likely contributed to the increase in stocks, because stable spring flows promote better survival of young trout.

Long-term trends in total numbers of brook and brown trout combined are not as obvious since the range of trout densities observed was quite large **(Exhibit 15)**. Average total brook and brown trout density during each decade (1960s through 1990s) has been very similar. Total density of trout

Exhibit 15. Fall Standing Stock of Brown and Brook Trout in Three Branches of the Au Sable River System 1960-2013 (Density of Trout): Sampling is currently conducted in 3 years of sampling followed by 3 years no sampling



since 2000 is higher than the long-term average for the period of record in all three branches. Current trout abundance in the upper Au Sable River is indicative of good overall habitat quality.

Benthic Macroinvertebrates

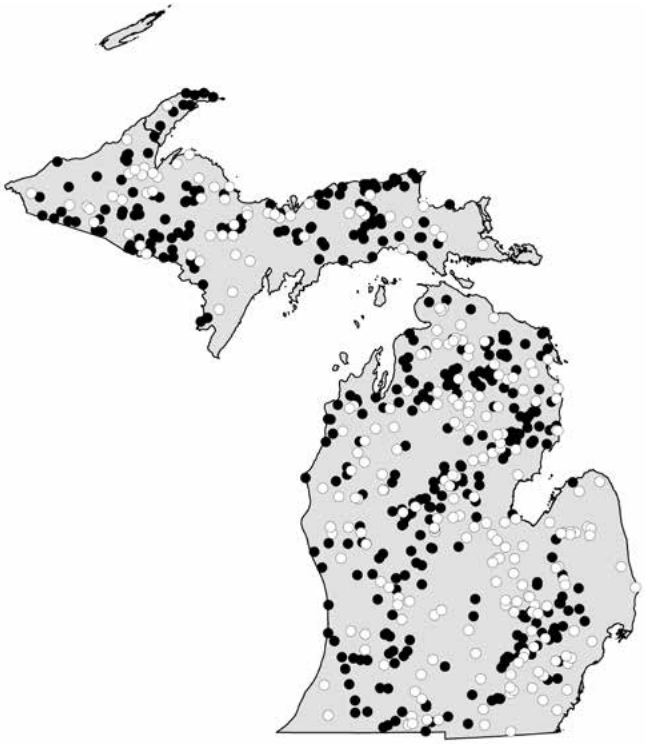
Aquatic biologists in the DEQ perform biological integrity surveys in rivers and streams throughout Michigan every year to assess current water quality conditions and track changes. These surveys support the goals of the Water Resources Division (WRD) Monitoring Strategy, including assistance to the National Pollutant Discharge Elimination System and nonpoint source protection programs. The primary sampling method is a rapid assessment protocol designed to assess aquatic life conditions in wadeable rivers and streams. A second procedure to assess macroinvertebrate communities in large non-wadeable rivers became available in 2005, which helps the DEQ provide a full assessment of all rivers and streams in Michigan. Both procedures evaluate benthic macroinvertebrate communities to determine whether the designated use "Other Indigenous Aquatic Life and Wildlife" (OIALW) is supported and therefore attaining Michigan Water Quality Standards (WQS).

Watersheds are sampled using a five-year basin approach. This means about 20 percent of rivers and streams are eligible for sampling each year, and it takes a full cycle, or five years, to make a statewide evaluation. The statewide evaluation can be made annually using the most recent five years of data. Within a watershed, site selection is made using a probabilistic, or random, design that allows the DEQ to evaluate WQS attainment at sites individually, at the watershed scale, and as part of a statewide status and trends assessment. Using the most recent five-year data, 2009-2013, 896 sites representing approximately 20,200 river and stream miles were assessed. Overall statewide attainment was 96 percent +/- 1.3 percent. Attainment percentages by watershed ranged from 40 percent in the Detroit River (Ecorse River, Frank and Poet Drain, and Brownstown/ Marsh Creek) watershed to 100 percent in many watersheds. These numbers apply only to the OIALW designated use based on benthic macroinvertebrates; many other water bodies are listed as non-attaining for other designated uses based on other sources of data, such as chemical contaminants, temperature, dissolved oxygen, E. coli, etc.

Status and Trends Program

Assessing the status of over 10,000 inland lakes and over 70,000 miles of permanent and intermittent rivers and streams in Michigan in a timely fashion is a difficult task. Over the past several decades, the DNR Fisheries Division has conducted numerous surveys of fish populations in lakes, rivers and streams across the state. Although a few assessments have been conducted with consistent methods over a long period of time, most surveys have been short-term, focused on addressing immediate, site-specific issues. While this strategy has proven useful for providing information to support fisheries management on individual water bodies, it does not provide an adequate statistical framework for broad

Exhibit 16. Lake (closed circle) and Stream (open circle) Sampling by Location



inferences regarding status and trends in fish populations and communities across broader spatial or temporal scales. Consequently, the older site-specific strategy does not allow fishery

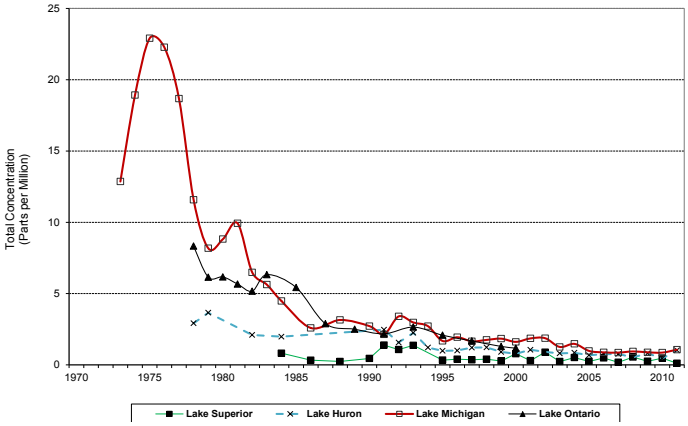
managers to put the results of individual lake surveys in the context of larger-scale trends that need to be understood.

Recognizing the limitations of the previous sampling approach to provide regional or statewide trends in fish populations, the DNR Fisheries Division began its Status and Trends sampling program in 2002. This program annually evaluates the status and trends of habitat conditions and fish communities at randomly selected streams and lakes throughout the state within classified groups of waters. Further detail on the temporal trends of high-quality trout and smallmouth bass streams is recorded from a network of 44 fixed sites throughout the Upper and Lower peninsulas. In addition to the fixed stream sites, 409 randomly selected lakes and 203 randomly selected streams were sampled from 2002-2013 **(Exhibit 16)**. Data analysis for the first six-year reporting period of the Status and Trends Program was completed in 2010, with similar work for the second six-year reporting period scheduled to begin in 2014. The results provide biologists and stakeholders statistically sound estimates of the status and trends of game fish, non-game fish and aquatic habitat while still providing information essential for effective fisheries management.

Contaminants in Fish

The DEQ monitors persistent, toxic pollutants in fish from waters of the state. Extremely low concentrations of some of these pollutants in water can bioaccumulate to relatively high concentrations in fish tissue. In some cases, contaminant concentrations in fish tissue may

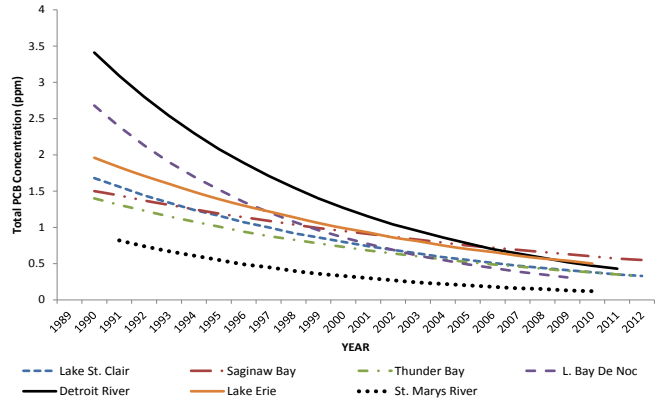
Exhibit 17. Polychlorinated Biphenyl Concentration in Lake Trout from Four Great Lakes 1970-2001



reach levels that pose a wildlife or human health risk. Currently, Michigan collects and analyzes over 700 fish tissue samples from approximately 50 locations annually. Since 1980, Michigan has collected and analyzed over 17,000 fish tissue samples from more than 800 locations. Edible portion (fillet) samples are used to develop sport fish consumption advisories. Fish from 22 fixed Great Lakes, connecting channel and inland lake sites are collected every two to five years and analyzed as whole fish as a means to measure temporal trends in contaminant concentrations.

Since the 1970s, pollution control efforts have resulted in significant reductions of many contaminants. Data collected by the U.S. Environmental Protection Agency (USEPA) indicate

Exhibit 18. Temporal Changes in PCB Concentrations in Walleye at Selected Great Lake Whole-Fish Trend Monitoring Sites 1990-2012



that PCBs in whole lake trout from the Great Lakes have declined dramatically **(Exhibit 17)**. In addition, temporal trend data collected by the DEQ indicate that PCB levels in walleye from the Great Lakes and connecting channels have declined since 1990 **(Exhibit 18)**. Similar trends for PCBs and the

Exhibit 19. Temporal Changes in Mercury Concentrations in Walleye at Selected Great Lake Whole-Fish Trend Monitoring Sites 1990-2012

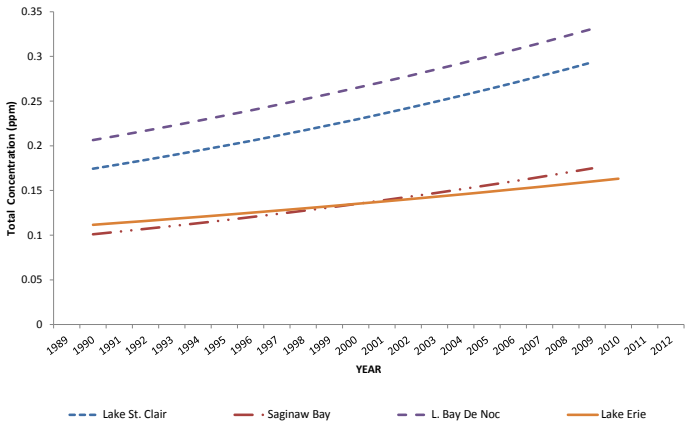
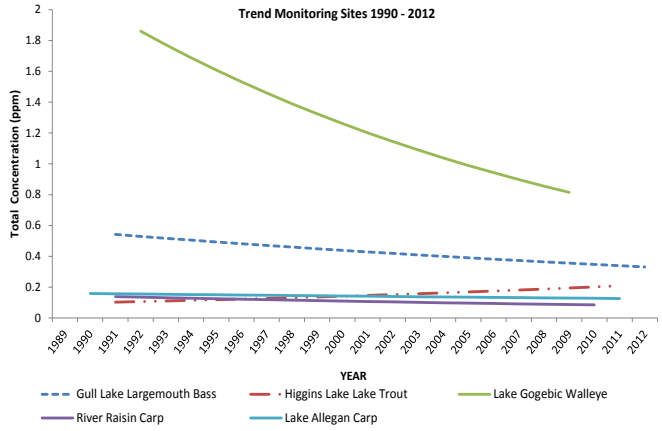


Exhibit 20. Temporal Changes in Mercury Concentrations at Selected Inland Whole Fish Trend Monitoring Sites 1990-2012



pesticides DDT and chlordane have been measured in other species, both in the Great Lakes and in inland waters.

The DEQ trend data indicate that mercury concentrations have increased in at least one species of fish from six of 10 Great Lakes or connecting channel trend sites, including walleye from Lake Michigan, Lake Huron, Lake Erie and Lake St. Clair **(Exhibit 19)**. In contrast, significant declines in mercury concentrations have been measured at four of 12 inland lakes **(Exhibit 20)**; mercury concentrations have increased in lake trout from Higgins Lake, but no significant changes in mercury concentration have been measured at the other seven inland lakes.

Trends in Endangered, Threatened and Special Concern Species

The Department of Natural Resources is celebrating the 40th anniversary of Michigan's Endangered Species Act, the important law that has been critical to the recovery of many different species.

A state endangered species is one that is in danger of extinction throughout all or a significant part of its range in Michigan. A state threatened species is one that is likely to become endangered within the foreseeable future throughout all or a significant portion of its range in Michigan. These species have legal protection under the Michigan Endangered Species Act. Special concern species are species thought to be declining, and if they continue to decline, may warrant legal protection under the act. **Exhibit 21** presents the number of plants and animals in Michigan and how many are considered endangered, threatened, special concern and presumed extirpated (no longer occurring) in the state.

Conservation, protection and restoration of Michigan's endangered, threatened and special concern species take multiple approaches. Monitoring populations provides critical data to determine the need for listing a species on the state list. This monitoring and survey data is included in the state's natural heritage database, which tracks known information on rare species. This database provides critical information to help land managers make well-informed decisions and to determine if conservation actions directed at a species are working.

Exhibit 21. Number of Plants and Animals in Michigan, and the Number Considered Endangered, Threatened, Special Concern or Extirpated in Michigan.

Category	Total Number	Endangered	Threatened	Special Concern	Presumed Extirpated
Plants	2,833	79	198	91	52
Mussels and Clams	77	13	6	16	0
Snails	180	13	10	38	0
Insects	15,000-20,000	7	14	81	1
Fish	152	9	9	8	9
Amphibians	23	2	1	3	0
Reptiles	29	2	3	6	0
Birds	414+	9	14	18	1
Mammals	66	4	4	4	0
Totals		**138**	**259**	**265**	**63**

Source: Michigan Natural Features Inventory, 2011; there have been no changes to the list since 2011.
+ This number includes the 233 species known to breed in Michigan, as well as species that migrate through the state.

On-the-ground management efforts are also used to help conserve these special wildlife species. The endangered Kirtland's warbler is one of the rarest warblers in North America. It nests in just a few counties in Michigan's northern Lower and Upper peninsulas, in Wisconsin and Ontario, and currently nowhere else in the world. This songbird is dependent on dense, young jack pine habitats for breeding. The recovery efforts for this species have been a true success, while maintaining commercial harvest of jack pine. The recovery goals for Kirtland's warbler have been met, and land-managing agencies are working to remove the species from the endangered species list while ensuring suitable breeding habitat is maintained. This effort has been a model for recovering a species.

The Mitchell's satyr is one of the world's rarest butterflies, found only in Michigan and Indiana. This butterfly is endangered in Michigan, and the biggest threat to its continued survival is habitat loss and alteration. The species is dependent on a special kind of wetland habitat, called a fen, where the main source of water is groundwater. Conservation of groundwater will be the key to the continued existence of Mitchell's satyr and many other rare species that rely on fen habitats. Fen hydrology includes recharge areas, which are often miles from the fen itself. The recent interest in large groundwater withdrawals may have a significant negative impact on the Mitchell's satyr butterfly. Further work is needed to develop tools to help managers make well-informed decisions.

Michigan's endangered and threatened species list is based on known habitat requirements and population trend information of species, and over time can serve as a measure of the state's biological diversity and provide an indirect measure of a changing environment. When targeted efforts and resources are put towards the needs of endangered and threatened species, Michigan has achieved success and recovery. Great examples of this are the wolf, eagle and Kirtland's warbler. However, threats to Michigan's wildlife and its habitat continue to increase. Between 2000 and 2011, the endangered and threatened list increased by 20 percent, evidence that rare species continue to decline. More work is needed to conserve Michigan's natural heritage for the future.

Trends in Invasive Species

An invasive species is defined as a species that is not native and whose introduction causes, or

is likely to cause, economic or environmental harm or harm to human health. The introduction of invasive species into Michigan's aquatic and terrestrial ecosystems is resulting in significant negative effects on natural resources, human health, recreational opportunities and other human values throughout the state and region.

- Terrestrial invasive species
- Emerald ash borer
- Beech bark disease
- Oak wilt
- Drought effects on short-lived oak species on light soils
- Feral swine

Terrestrial Invasive Species

Currently, 47 exotic terrestrial plant and animal species are known to have successfully invaded the Great Lakes Basin. Additional information on this and other exotic terrestrial species may be found at the Internet sites for the Michigan Department of Agriculture and Rural Development (MDARD)

www.michigan.gov/eab,

Michigan Technological University's Center for Exotic Species

www.forest.mtu.edu/research/ces,

and the National Invasive Species Council's Internet site

www.invasivespecies.gov.

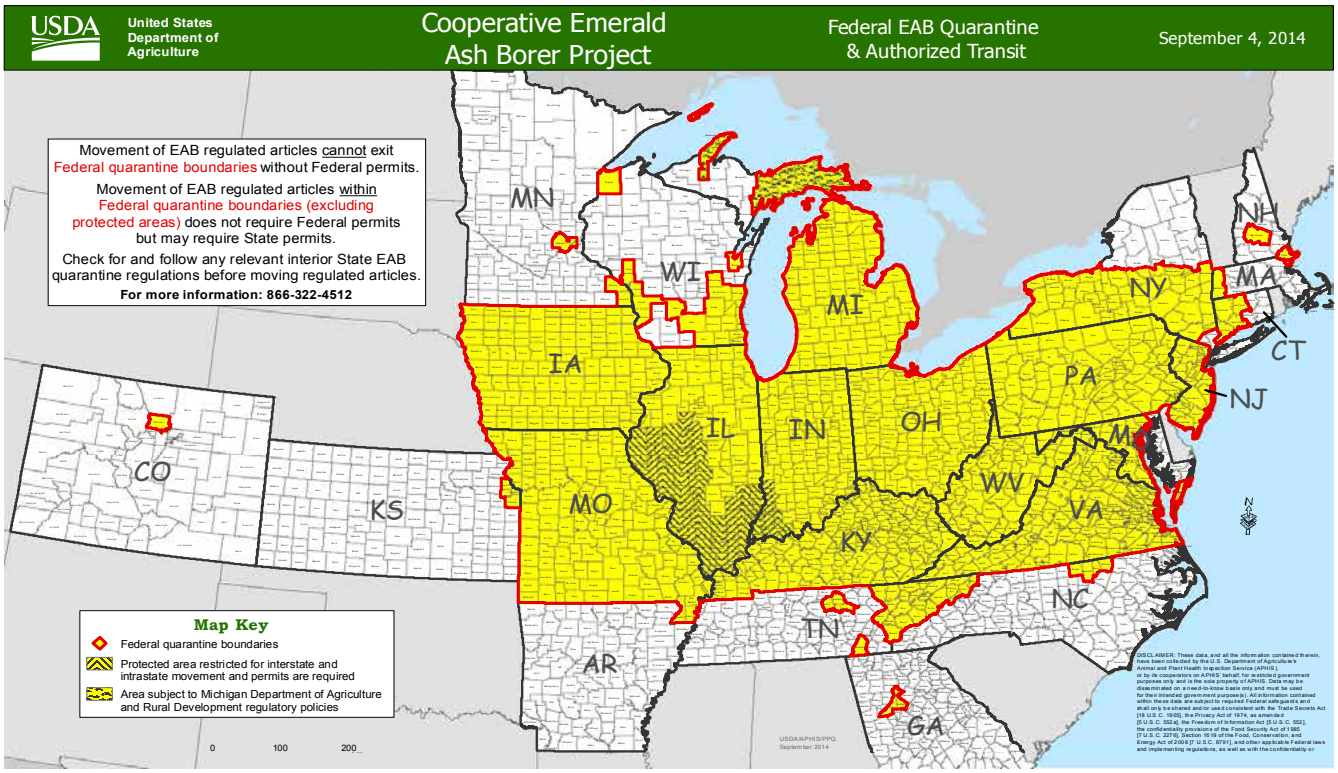
Emerald Ash Borer

The DNR is involved in many projects to prepare Michigan's unaffected urban and rural forests for the inevitable arrival of the emerald ash borer (EAB). These projects will address the loss of ash trees and provide for restoration of affected forests and neighborhoods.

Funding from the Great Lakes Restoration Initiative and the USDA Forest Service Pest and Disease Loan Fund were used by Michigan Technological University (MTU), in cooperation with the Michigan DNR, to inventory 9,146 acres of potentially high-value ash stands.

Ash stands on state forest land in the western Upper Peninsula and the northern Lower Peninsula were intensively inventoried over the last two years. In the process, MTU developed a protocol for evaluating a stand's need for immediate treatment, ranking them into general categories of "treat immediately," "treat next year" and "treat in the next three years."

Exhibit 22. Federal EAB quarantine and authorized transit



MTU also trained the DNR's Forest Resources Division (FRD) foresters in using this evaluation protocol. The foresters then surveyed an additional 24,946 acres and reviewed 126,825 acres using staff knowledge and data from completed inventories. In 2013, a total of 160,917 acres were evaluated for EAB.

Michigan's Ash Resource

According to the latest USDA Forest Service FIA data for the period 2008-2012, there are 162.8 million ash trees greater than 5 inches in diameter, and 17.9 million standing dead ash in the same size category. This number does not include ash on non-forest lands, such as urban environments. FIA estimates annual ash mortality in forested environments of 49.3 million cubic feet annually, and 142.9 million board feet of ash saw timber per year.

Surveys and Quarantines

No new Michigan counties were added to the EAB quarantine in 2013. MDARD, in cooperation with the USDA Animal and Plant Health Inspection Service, continues to survey uninfested counties in the western Upper Peninsula. They deploy purple traps baited with an aromatic lure called manuka oil.

Traps are placed around high-risk areas such as campgrounds and sawmills and along travel pathways. There were no detections in the uninfested, non-quarantined counties of the western Upper Peninsula.

EAB quarantine requirements for regulated articles moved entirely within Michigan are unchanged. For movement of regulated articles across state lines **(Exhibit 22),** relevant changes to the federal EAB quarantine include:

- A federal certificate or limited permit is no longer needed to ship articles regulated by the EAB quarantine out of Michigan's Lower Peninsula into or through Ohio or Indiana. However, if the final destination of the articles is outside the contiguous federal quarantine boundaries or into the protected area of Illinois or Indiana, a federal certificate or limited permit is still required.

- A federal certificate or limited permit is no longer needed to move articles regulated by the EAB quarantine into Michigan's Lower Peninsula from areas inside the contiguous federal quarantine boundaries.

Regulated articles, including all hardwood firewood, are not to be moved without a compliance agreement, from:

- The Lower Peninsula to the Upper Peninsula;
- Quarantined areas of the eastern Upper Peninsula to unquarantined counties; and
- The central and western Upper Peninsula.

There is still a general advisory against moving any firewood due to associated accidental introduction or spread of potentially devastating forest pests such as EAB, Asian longhorned beetle, oak wilt and others. People are encouraged to purchase firewood as close to where they will use it as possible and should not take any unused firewood home with them or move it to another camping location.

Remember: Burn it where you buy it!

Healthy Forests Restoration Act (HFRA)

In accordance with the Healthy Forests Restoration Act (HFRA) provisions of the 2014 Farm Bill, Governor Rick Snyder requested two sub-watershed designations as landscape-scale insect and disease treatment areas on the Huron-Manistee National Forest for up to 6,000 acres of treatment for oak wilt, emerald ash borer, and beech bark disease. After review, Forest Service Chief Thomas L. Tidwell made the requested designations.

For more information about EAB, visit www.emeraldashborer.info or visit the MDARD website at www.michigan.gov/mdard.

Beech Bark Disease (American Beech)(BBD)

Since discovery of beech bark disease (BBD) in Michigan in 2000, BBD has spread widely through Michigan's forests. This disease is initiated by a scale insect that attaches to the tree and feeds on sap. Damage from this feeding allows one of two

Neonectria fungi to invade the tree. The fungus inhibits the flow of sap through infested portions of the tree, causing a general decline in tree health and eventually killing the entire tree. Controlling the natural spread of the disease is not feasible, because both the scale and fungus are moved by the wind. Scales also are moved by birds, bears and other animals feeding on beech nuts in the fall.

An infested tree is "painted" white by the tiny scale insects. A scale-infested tree may still have a healthy appearing canopy, although its main stem is weakened by the fungus. These trees are subject to breakage known as beech snap. The main stem of the tree breaks or snaps in half somewhere below the canopy. All such "hazard trees" are removed from state parks and campgrounds.

According to the latest USDA Forest Service FIA data for the period 2008-2012, there are 31.7 million American beech trees greater than 5 inches in diameter and 2.5 million standing dead beech in the same size category. FIA estimates annual beech mortality in this time period of 6.15 million cubic feet of growing stock beech and 23.4 million board feet of sawtimber beech. To date, 74 percent of this loss is in the eastern Upper Peninsula. Michigan's American beech resource is under attack as newly infested areas are being reported in the Lower Peninsula every year.

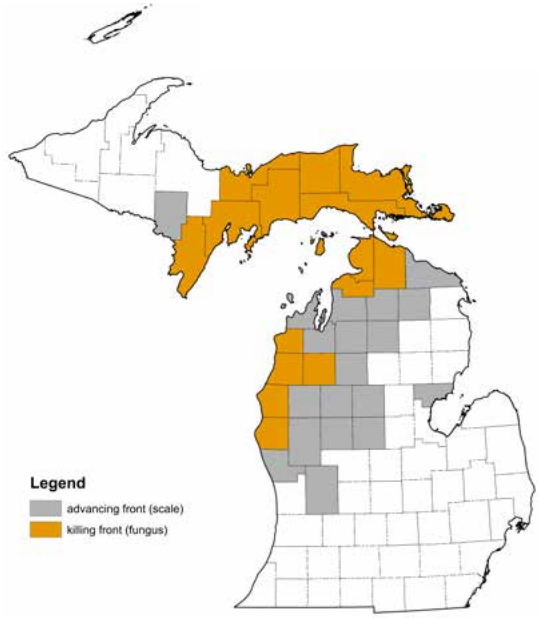
Resistant American Beech Project

Since 2002, the DNR has been working with Dr. Jennifer Koch at the Northern Research Station (NRS) of the USDA Forest Service to select and breed American beech trees for resistance to BBD. Beech trees that are resistant to BBD are resistant to the beech scale. Cuttings from potentially resistant beech are sent to the NRS where they are grown and tested for scale resistance.

Techniques to propagate resistant trees through grafting have been developed, and genetic tests of full- and half-sibling families have demonstrated that BBD resistance is heritable, and we can breed parents that are resistant; approximately 50 percent of the progeny can be expected to be resistant.

Project efforts are now focused on identifying, selecting and propagating resistant beech for establishing seed orchards. These orchards will provide seed to generate resistant seedlings for restoration plantings so that healthy American

Exhibit 23. Counties with Beech Bark Disease



beech trees will persist in Michigan forests. Planting of the first resistant American beech seed orchard began in 2011 at the DNR's Tree Improvement Center (TIC).

The root stock used for grafting to date is from southern Ohio. Forest health specialists believe that this has resulted in poor performance and survival in Michigan. Beech seed from northern Michigan has been collected, and Michigan State University is germinating the seed to produce root stock for grafting Michigan destined resistant seedlings. In the meantime, the TIC seed orchard site has been provided with irrigation and is enclosed.

Resistant Michigan beech will be used with the existing Ohio rootstock to establish a seed orchard at Purdue University's Hardwood Tree Improvement and Restoration Center. Seed from Purdue's seed orchard will be available for Michigan's American beech restoration efforts.

So far, five different beech bark disease-resistant parent combinations have produced an average of 52 percent resistant progeny. Subsets of seedlings from these families were out-planted in November 2011 in the Upper Peninsula in an area heavily impacted by BBD. These trees are within an exclosure and will be monitored annually for growth characteristics and continued scale resistance.

Oak Wilt (Red Oak Group)

Oak wilt is an aggressive disease that affects many species of oak (Quercus spp). It is one of the most serious tree diseases in the eastern United States, killing thousands of oaks each year in forests, woodlots and home landscapes. Once introduced to an oak area, oak wilt spreads through root connections to adjacent oaks. Oak wilt was first identified in 1944. The fungal pathogen that causes the disease, Ceratocystis fagacearum, is an exotic pathogen. Difficulty in isolating and identifying the fungus delayed recognition of the extent of its impact until the 1980s. Oak species vary in their susceptibility to oak wilt. Species in the red oak group (leaves with pointed lobes) are the most susceptible. White oaks (leaves with rounded lobes) are the least susceptible.

The oak wilt fungus moves from tree to tree in two ways: transported underground through roots, or overland by sap beetles. New oak wilt areas are created when the fungus is carried by sap beetles from infected wood (e.g., a tree, log or firewood) to a fresh wound on a healthy oak. Trees killed by oak wilt produce spore pads the following

year only. Sap beetles are attracted to these pads where they feed and pick up spores. They are also attracted to fresh wounds. Oak wilt is introduced to a wounded oak when visited by spore carrying sap beetles between April 15 and July 15. Most new oak wilt outbreaks can be traced to damage from pruning, construction, various human-caused tree-wounding activities, and damaging storms in areas with oak wilt or in areas where wood from infected trees has been moved.

Once an oak is infected, oak wilt moves to adjacent oaks through grafted roots. When roots of oaks of the same species come into contact, they often grow together, a process known as grafting. This allows neighboring oaks to exchange food and water, as well as infectious oak wilt spores.

Oak wilt is established widely in the southern Lower Peninsula with spotty distribution in the northern Lower and Upper peninsulas. It is found primarily on private lands. As the public moves northward into forested areas, the risk of spreading this disease grows. People often harvest dead oaks

for firewood. This wood is often taken to camps or on camping trips where it serves as a source of inoculum to infect nearby oaks that are wounded in the spring or early summer.

Exhibit 24. Oak Wilt in Michigan

Michigan's Oak Resource

The USDA Forest Service FIA reports a Michigan forest resource of 149 million oak trees greater than 5 inches in diameter in the oak wilt susceptible red oak group. There are 68 million red oaks with a diameter greater than 11 inches. This equates to a volume of 11.9 billion board feet growing on 3.9 million acres of Michigan forest land. Ownership of this oak forestland is 67 percent private, 22 percent state and local government, and 11 percent federal.

Detecting, Confirming and Reporting Oak Wilt

Knowing the number and distribution of oak wilt pockets is crucial to understanding the potential short- and long-term impacts of oak wilt on Michigan's oak resource. However, confirming oak wilt as the cause of oak mortality is not always easy. Not all oak mortality is oak wilt-caused. Oak mortality and decline in the last decade is the result of drought, late-spring frosts, two-lined chestnut borer and a mature to over-mature northern pin oak resource. In addition, new infections started by movement of firewood are difficult to document. Most often, a newly killed tree is felled and cut into firewood. This firewood can serve as a source of new infections in this area, or if moved to areas near oaks. Removing the tree does not stop the disease. Neighboring oaks will start dying in a year or two. Generally, it isn't until more oaks start dying that people begin seeking answers as to the cause.

The Michigan DNR and Michigan State University, Department of Plant, Soil and Microbial Sciences have stepped up efforts in the last three years to detect and confirm oak wilt in Michigan **(Exhibit 24)**. A grant from the USDA Forest Service has funded an effort to detect, confirm and record oak wilt occurrence. Once oak wilt is confirmed, data is entered into a national oak wilt database housed in Fort Collins, Colorado, at the USDA Forest Service Forest Health Technology Enterprise Team facility. The oak wilt database is available to any state with oak wilt problems. As we populate this database, we can begin to understand the distribution and scale of the problem. It also provides operational guidance for prevention and suppression efforts.

If anyone suspects they have oak wilt, review the signs and symptoms of oak wilt by visiting: http://na.fs.fed.us/pubs/howtos/ht_oakwilt/identify_prevent_and_control_oak_wilt_print.pdf.

Managing Oak Wilt

Oak wilt can be removed from an infected oak resource. Oak wilt requires a living oak to survive. Thus, if infected trees are isolated by breaking root-grafts and all oaks within the area are removed, oak wilt is effectively removed. The only caveat is that trees that were killed the previous year will produce pressure pads, so they must be

destroyed via burning, chipping, or cutting into lumber before the following April.

If oak wilt is detected the year it infects a new area via overland spread by sap beetles, removing the infected oak and its stump will remove the disease before spreading to adjacent oaks. If the stump remains in the ground the year following infection, many neighboring oaks will become infected. Management recommendations include:

- Prevent wounding of oaks from April 15 to July 15. If pruning is necessary, or if wounded by accident, paint wounds with tree wound dressings or latex paints immediately to prevent transmission of oak wilt.
- Have a forest health professional confirm the presence of oak wilt. If confirmed, hire an experienced professional to isolate the oak wilt pocket by breaking root-grafts to a depth of 5 feet. This is done by using a vibratory plow or backhoe. Only after root-grafts are disrupted, remove all red oaks within the isolated area. Wood larger than two inches in diameter from oaks killed by oak wilt in the current year are debarked, chipped, sawn into lumber, burned and/or tightly tarped to the ground before the following April. If tarped, the tarps can be removed after July 15.

Upper Peninsula - Oak Wilt Supression

The USDA Forest Service has provided Oak Wilt Suppression funds to help remove oak wilt from the Upper Peninsula. The Michigan DNR and Michigan Technological University worked together in 2013 to:

- Remove oak wilt from the Upper Peninsula by detecting and treating all infection centers;
- Educate affected communities to prevent the reintroduction of oak wilt; and
- Demonstrate an approach that can be used for detecting and effectively treating oak wilt infection epicenters throughout Michigan.

This year's project focus was the Shakey Lakes area of Menominee County. Thirty-three oak wilt pockets totaling 116.5 acres were isolated by creating 36,160 feet of root-graft barriers with a vibratory plow. All red oaks within these pockets were removed via timber sales before April 2014. All sites were reviewed and treatments approved by the USDA Fish and Wildlife Service, Native Tribes, and the State Historic Preservation Office.

Michigan State University Extension continued to evaluate past oak wilt suppression efforts in 2013. Many treated areas in Menominee and Dickinson counties remain free of oak wilt. Although much has been achieved, untreated oak wilt pockets remain. Diligence will be needed if we are to succeed in removing this threat to the Upper Peninsula's oak resources.

Lower Peninsula - Oak Wilt Supression

In the Lower Peninsula during October and November 2013, approximately 10,000 feet of root graft barrier was created using a vibratory plow. All red oaks within the plow lines were removed and chipped or otherwise processed before April 2014.

Forest Resource Division's Forest Health Program participated by operating the vibratory plow to create several hundred feet of root graft barrier in the Huron National Forest to treat an oak wilt infection in the Sand Lake Campground, Oscoda County. Huron National Forest personnel oversaw the removal and treatment of all red oaks from within the root graft barriers before April 2014.

Oak wilt detection and confirmation efforts continue across all ownerships in Michigan's Lower Peninsula.

Michigan DNR, Parks and Recreation Division, treated oak wilt infection centers in two state parks and in four state recreation areas in 2013.

Drought Effects on Short-lived Oak Species on Light Soils

Droughts can trigger significant declines in tree health. Hardest hit are trees that grow in light, sandy soils or on lowlands exposed to significant water table fluctuations. Drought-stressed trees are susceptible to a host of insect pests and diseases. As a result of a series of droughts in the last decade and dry conditions in 2010, tree mortality on these drought-prone sites increased.

Oak was especially affected by the two-lined chestnut borer (Agrilus bilineatus) and Armellaria root rot. Some areas were also impacted by multi-year defoliation by the forest tent caterpillar (Malacosoma disstria) and the gypsy moth (Lymantria dispar). It will take a few years of normal or higher amounts of precipitation for trees to return to normal growth patterns.

Feral Swine

The World Conservation Union has included feral swine in its list of "100 of the World's Worst Invasive Alien Species." In Michigan, the vast majority of feral swine are Russian boar. Russian boar (Sus scrofa) were added to the list of Michigan Invasive Species in 2011. It is illegal to possess Sus scrofa (or hybrids of Sus scrofa) in Michigan. The DNR is currently involved in five legal cases in an effort to bring people into compliance with the Invasive Species Order of 2011 prohibiting the possession of Sus scrofa in Michigan.

Feral swine pose a major threat to Michigan's citizens, natural areas, wildlife, agriculture and livestock. They are voracious and opportunistic feeders that can directly (through consumption of eggs or young) and indirectly (competing for natural foods) impact a variety of wildlife, including ground nesting birds (i.e., wild turkey, ruffed grouse, etc.), reptiles and amphibians, small mammals, and even white-tailed deer. They also consume agricultural crops and cause damage to crops, wildlife food plots, gardens, golf courses and lawns through rooting activity. Rooting and wallowing behavior can lead to soil erosion destroying river banks and changing water quality through the introduction of sediment and bacteria. Additionally, feral swine pose health risks to humans, livestock, and other animals, because they are known carriers of at least 30 diseases and 37 different parasites. One of the most significant diseases for the domestic swine industry is pseudorabies, a reportable disease to the USDA's National Animal Health Reporting System. Pseudorabies has been documented in 7 percent of feral swine tested (N = 144) in Michigan.

Feral swine have been introduced into other states and when emerging populations are not addressed, they rapidly expand in numbers and range. Hunting alone has continually proven ineffective at slowing population growth. Aggressive, targeted lethal control has proven effective at reducing numbers in some western states where feral swine are observable in open rangelands. Michigan may have an opportunity to eradicate feral swine if we take swift action. Feral swine are social animals tending to live in large groups. Understanding their behavior (daily and seasonal movements, evasion of lethal control activities, etc.) is an essential step to design effective control strategies. Professional organizations such as The Wildlife Society and American Veterinary Medical Association support the scientific removal of free-ranging feral swine and research on effective methods of control. The DNR, MDARD, USDA-WS and several Michigan universities are partnering through research to inform Michigan's strategy for feral swine eradication. Partners are developing effective internal communication strategies to gather and exchange information about feral swine sightings and activity. Partners also are

increasing education and communication about feral swine to stakeholders (i.e., hunting and agricultural organizations, non-governmental organizations (NGO), and the general public). USDA-WS provides assistance to private, state, federal, tribal and NGO land managers to lethally remove feral swine.

Aquatic Invasive Species

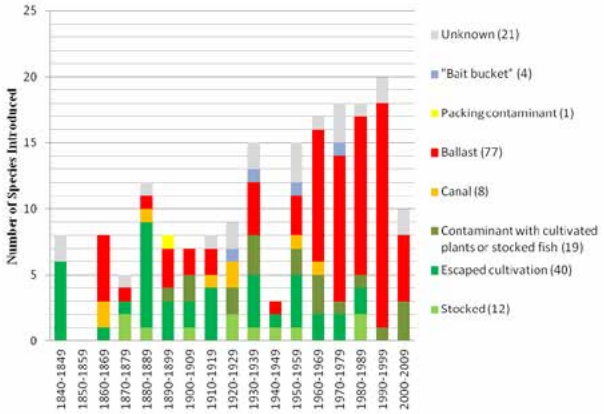
Michigan's aquatic ecosystems and its economy are experiencing significant negative effects from aquatic invasive species (AIS) already present, and the state's waters are continually threatened by new invasions. The introduction of AIS into the Great Lakes and inland state waters is a source of biological pollution that threatens not only the ecology and water resources but also the economic and public health conditions of the region and states. AIS may compete with native species for food and habitat and can directly or indirectly harm or displace native species, degrade habitat, and alter food webs and energy flow. AIS can also have significant economic effects on waterfront property values, tourism, utilities and other industries (Lovell et al. 2005).

Currently, 184 non-native aquatic plant and animal species are known to be established in the Great Lakes Basin. The list of non-native aquatic species is maintained by the National Oceanic and Atmospheric Administration's (NOAA) National Center for Research on Aquatic Invasive Species.

AIS enter and disperse in Michigan waters through various human-assisted vectors, including maritime commerce, fishing and boating, aquaculture, canals and diversions, the trade of live organisms, and tourism and development activities. Actions taken to date to prevent the introduction of new AIS include regulatory and voluntary efforts, educational programs to increase awareness, monitoring and surveillance efforts, and management/control efforts by a variety of partners. However, much work remains to protect Michigan waters from new introductions of AIS from around the world, other waters across the country and adjacent areas of the Great Lakes watershed, as well as to minimize the harmful effects of AIS already in Michigan waters.

The largest number of exotic aquatic species introduced into the Great Lakes Basin coincides with the expansion of the St. Lawrence Seaway in 1959, which allowed greater transoceanic shipping traffic. More than one-third of the known aquatic invasive species were introduced into the Great Lakes during the last half of the 20th century **(Exhibit 25).**

Exhibit 25. Distribution of Nonnative Aquatic Species Introduced to the Great Lakes by Various Pathways (Source GLANSIS).



Not all non-native species become invasive and cause economic or environmental harm, but a few cause major damage. Some of the more problematic introductions in recent decades have been the sea lamprey, Eurasian watermilfoil, and zebra/quagga mussel. Eurasian watermilfoil and zebra mussels have propagated not only throughout the Great Lakes but also throughout many of the state's inland lakes at an alarming rate. Limited progress has been made to control Eurasian watermilfoil and zebra mussels, although research is under way to develop and test biocontrol agents.

Aquatic Invasive Species State Management Plan

In 2013, Michigan released a second update to its Aquatic Invasive Species State Management Plan, which was first approved in 1996 under the auspices of the federal National Nuisance Species Act. A team of experts from the Michigan departments of Environmental Quality, Natural Resources, Agriculture and Rural Development, and Transportation developed the plan with public input. The comprehensive AIS State Management Plan outlines new actions for implementation, in addition to maintaining and enhancing existing efforts, to address four overarching goals:

- Prevent new introductions of AIS into Michigan waters.
- Limit the dispersal of established populations of AIS throughout Michigan waters.
- Develop a statewide interagency Early Detection and Rapid Response Program to address new invasions of AIS.
- Manage and control AIS to minimize the harmful environmental, economic and public health effects resulting from established populations.

Strategic actions to address the four goals target work on legislation and policy, regulation (including compliance, enforcement and inspection), information and education, and research and monitoring. Overarching recommendations highlighted in the AIS State Management Plan include:

- Promote public/private collaboration to leverage expertise and resources as a mechanism to address Michigan's AIS priorities.
- Continue and enhance state agency communication and coordination.
- Continue and enhance information and education efforts.
- Secure sustainable long-term funding for Michigan's AIS program to ensure implementation of this state management plan.

Michigan's Tier 1 AIS priorities focus on blocking key pathways for invasion, since prevention is the most cost-effective means of dealing with AIS:

- Prevent the introduction of AIS through canals and waterways, specifically Asian carp through the Chicago Area Waterways System.
- Prevent the introduction of AIS through ballast water discharges.
- Prevent the introduction of AIS through organisms in trade.

Michigan's Tier 2 and Tier 3 AIS priorities focus on developing capacity for early detection and response activities, including monitoring and detailed response planning coordinated at regional and state scales and supporting AIS management and control efforts, especially through technical assistance and the development of best management practices.

Asian Carp

Asian carps, specifically bighead and silver carps, pose an imminent threat to Michigan's waterways. Currently bighead and silver carps are not established in Michigan waters; however, in response to this threat, Michigan has deemed the issue of Asian carps a top priority. As such, the DNR Fisheries Division has developed Asian carps management documents and educational materials and has collaborated with regional partners throughout the Great Lakes Basin to prevent the spread of these species into Michigan waters.

The DNR has taken multiple steps to increase public awareness of Asian carps and to ensure

that, if prevention is not achieved, the division is trained and prepared for response efforts for Asian carps in Michigan waters. Initial planning included the development of the following management documents: *Proposed 2010 Plan for the Prevention, Detection, Assessment, and Management of Asian Carps in Michigan Waters* and *Status Report for the Proposed 2010 Plan for the Prevention, Detection, Assessment, and Management of Asian Carps in*

Michigan Waters, April 2012. These documents, along with the communications operational plan, *Communication Protocol Guidance for Positive eDNA Findings or Live Asian Carps in Great Lakes Waters*, provide guidance to the DNR Fisheries Division for responding to a credible report of live Asian carps in Michigan waters.

The DNR acknowledges the importance of being prepared to implement actions described in these plans and to evaluate the awareness and readiness to respond appropriately. Therefore, in 2013, the DNR Fisheries Division conducted an Early Detection Prudent Response (EDPR) exercise that mimicked potential field sampling efforts that would occur in the event of an actual invasion of bighead or silver carps. Furthermore, in 2014, the Fisheries Division collaborated with the Ohio Department of Natural Resources to conduct the Lake Erie Asian Carps response exercise to implement the Mutual Aid Agreement and bolster regional partnerships for AIS response efforts. The Michigan and Ohio DNRs benefited during the Lake Erie Response Exercise from assistance provided by multiple state, provincial and federal agencies from throughout the Great Lakes Basin. These two field exercises were complemented with tabletop exercises that allowed discussion of policies regarding response actions internally, and with other resource agencies throughout the Great Lakes Basin, to ensure that policies regarding field response efforts and communications were analyzed and practiced. These exercises were made possible through funding provided by the Great Lakes Restoration Initiative (GLRI).

Increasing public awareness of issues related to Asian carps is an approach the Fisheries Division has utilized as an early detection tool. The division has developed Asian carps identification brochures and other printed materials as well as an identification video to assist stakeholders with identification of these high-priority invasive fish species. As part of these education and outreach materials, the division directs the public to its Asian carps website page (www.Michigan.gov/asiancarp) for additional information and a place to report suspected Asian carps findings.

State, Federal, and International Ballast Water Action

Ballast water is taken on board large vessels to provide stability and balance during a voyage and during the loading/unloading of cargo. Oceangoing vessels (also known as Salties) that transit the Great Lakes through the St. Lawrence Seaway have the potential to introduce new AIS to the Great Lakes Basin when ballast water contaminated with AIS taken on board from another region is discharged. Conservatively, 55 percent of the non-native species

that established populations in the Great Lakes during the period following expansion of the St. Lawrence Seaway (from 1959 onward) are attributed to ballast water release, although this number could be as high as 70 percent.

Considerable regulatory activity at the international, national and state levels is under way to require treatment of ballast water prior to discharge to prevent the introduction of aquatic invasive species. The International Maritime Organization (IMO) developed and adopted the International

Convention for the Control and Management of Ships' Ballast Water and Sediments. This convention includes standards on the concentration of live organisms in ballast water discharge. The convention will enter into force 12 months after it has been ratified by 30 member states, representing at least 35 percent of the world's merchant shipping tonnage. As of Feb. 28, 2014, 38 states representing 30.38 percent of the world's merchant shipping tonnage had ratified the convention. The United States has not ratified the convention. Canada ratified the convention in 2010, but the treatment requirements will not go into effect until the convention enters force (i.e., until enough states ratify to reach the tonnage requirement).

The United States Coast Guard, United States Environmental Protection Agency and several Great Lakes states have included the IMO discharge standard under various regulatory frameworks to be phased in over the next few years. Several federal and state agencies have determined the IMO discharge standard to be a technologically achievable and practicable standard.

In June 2005, Michigan legislation was signed establishing the requirement for a ballast water discharge permit for oceangoing vessels operating in Michigan ports. This legislation does not address non-oceangoing vessels (Lakers). Michigan's Ballast Water Control General Permit for Port Operations and Ballast Water Discharge became effective January 1, 2007, and requires oceangoing vessels to use one of four approved ballast water treatment methods, or an alternative treatment based on an effectiveness demonstration to the DEQ, to prevent the discharge of AIS during port operations or to certify that they are not discharging ballast water.

Organisms In Trade

Aquatic plants and animals introduced through channels of trade pose a significant threat to Michigan waters. For the most part, these organisms have been obtained deliberately, such as plants and animals popular for the aquarium or ornamental pond trade or as culinary products. Channels of trade include traditional sales to and through retail stores or markets, as well as increasing sales through the global internet marketplace.

AIS obtained through trade find their way into lakes and streams through a variety of pathways. Although well-intentioned, uneducated consumers may purposefully release unwanted pets or plant species and associated pathogens, believing it is a humane action, without knowing the damaging consequences to the environment. Release may be through direct disposal of organisms in lakes and streams or through aquarium water disposal into the storm sewer system.

Live bait may be imported into Michigan from other states and countries by either State of Michigan-licensed nonresident or resident wholesale minnow dealers. The importation, distribution, use and disposal of live bait are all possible mechanisms by which AIS can be inadvertently introduced or dispersed throughout the Great Lakes Basin. In addition, public, private and tribal agencies stock lakes in the Great Lakes Basin with fish from hatcheries in an effort to aid in species recovery; meet fisheries management objectives; and sustain, improve or enhance sport fishing opportunities. Hatchery practices are not without potential risk, and AIS may be inadvertently introduced into an ecosystem if preventative measures are not efficiently employed. AIS may reside on contaminated gear, in water used during transportation, and in or on the fish. Fish also may be infected with diseases, viruses, pathogens and parasites.

Regulation of these industries by the DNR and MDARD is a key component to block trade pathways by which AIS may be released. However, education and outreach is equally as important at the wholesale, retail and consumer levels to raise awareness of AIS and preventative actions that can be taken to protect Michigan waters.

Physical and Chemical Indicators

Ambient Levels of Criteria Air Pollutants

Pollutants, both man-made and naturally occurring, affect the quality of Michigan's air. Air quality can vary depending upon location, time and weather conditions. The air quality in Michigan has shown marked improvement over the past 40 years, as sources of air pollution have been identified and corrective solutions implemented. However, with new scientific information leading to more stringent national health standards, challenges remain.

National Ambient Air Quality Standards (NAAQS) have been established for six pollutants, referred to as criteria pollutants. The criteria pollutants include carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter and sulfur dioxide. The DEQ and its tribal partners operate air-monitoring stations in 27 counties. Currently (2013), all of these monitored areas are reporting levels well below the USEPA criteria pollutant standards for carbon monoxide, nitrogen dioxide and particulate matter. However, for sulfur dioxide, ozone and lead, parts of Michigan are not attaining the health standards.

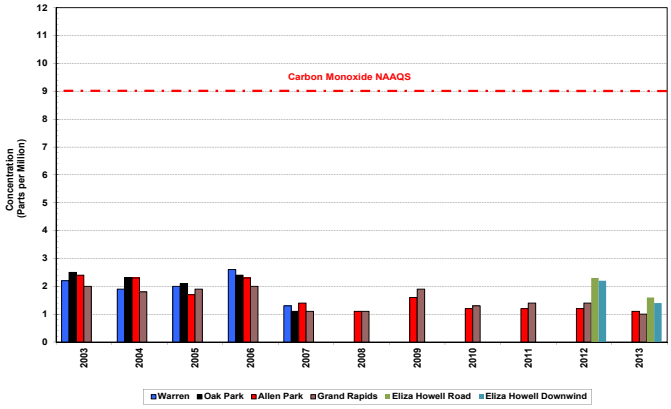
Additional information on Michigan's air quality is available on the DEQ's Air Quality website at www.deqmiair.org. A brief summary for each of the six criteria pollutants is presented below.

Carbon Monoxide

Carbon monoxide is produced primarily from transportation, fuel-burning for space heating and electrical generation. Industrial processes, as well as wood, agricultural and refuse burning, also contribute to carbon monoxide emissions. Carbon monoxide can exert toxic effects on humans by limiting oxygen distribution to organs and tissues. People with impaired circulatory systems are vulnerable at lower levels than healthy individuals. Exposure to carbon monoxide can impair visual perception, work capacity, manual dexterity, learning ability and the performance of complex tasks.

Michigan's on-road motor vehicles account for 50.7 percent of the state's carbon monoxide

Exhibit 26. Ambient Carbon Monoxide Trends (Annual Maximum 8-hour Carbon Monoxide Levels) 2003-2013



emissions. Michigan's non-road transportation sources contribute 26.8 percent of the state's carbon monoxide emissions. These sources include aircraft, marine vessels, non-road two- and four-stroke engines, and railroads. Carbon monoxide emissions from Michigan's industries (point sources) account for only 3.6 percent.

The USEPA first established health standards for carbon monoxide in 1971, and in 2011 proposed to retain these standards. Since 1984 there have been no exceedances of the carbon monoxide standard in Michigan. **Exhibit 26** indicates a clear downward trend, representing a 50-percent decrease in average carbon monoxide levels over 10 years. The decline of carbon monoxide follows a national trend.

Starting with the Clean Air Act of 1970, catalytic converters, fuel-economy standards, national standards for tailpipe emissions, new vehicle technologies, clean-fuels programs, and state and local emissions-reduction measures are credited with the decrease in emissions of carbon monoxide.

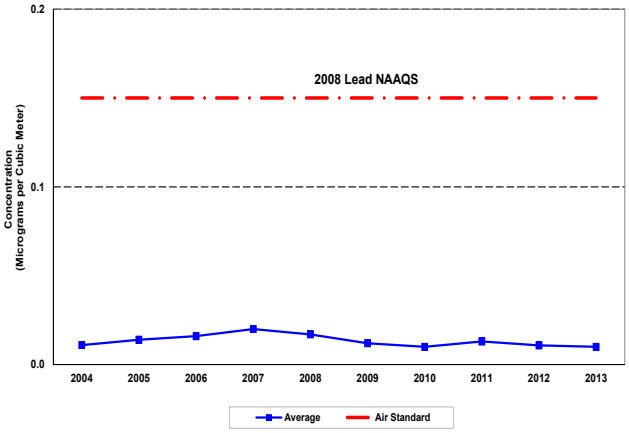
When the DEQ's funding for air monitoring was cut in April 2007, all but two carbon monoxide monitors were shut down. These are operated in Grand Rapids and Allen Park as part of the National Core Monitoring (NCORE) Program. In

2011, the DEQ also began monitoring carbon monoxide along I-96 and Telegraph in Detroit to characterize pollutant levels in the near-road environment.

Lead

The most common sources of lead emissions are gasoline additives, non-ferrous smelting plants and battery manufacturing. Historically, lead was added to gasoline to prevent engine knocking. The lead content of gasoline began to be controlled in the 1970s, when legislation was passed to gradually reduce lead levels. Currently, smelters, foundries, boilers, waste incinerators, glass manufacturers, cement producers and piston-driven aircraft engines using leaded fuel are the major sources of lead.

Exhibit 27. Ambient Lead Trends (Statewide 3-month Average of Monitored Lead Levels) 2004-2013

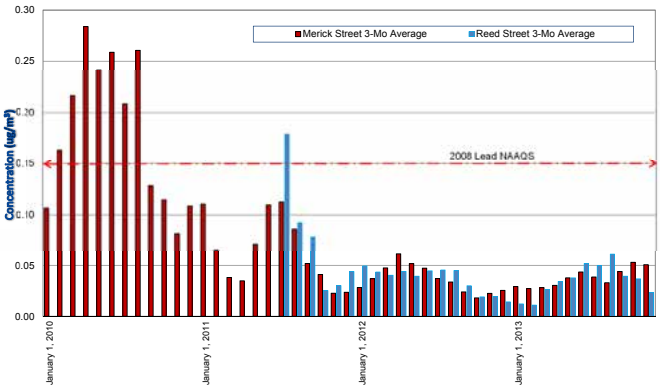


Human exposure to lead can occur through ingestion or inhalation. The nervous system is most sensitive to the effects of lead, and high exposures to lead can result in behavioral and learning disorders. Lead also may be a contributing factor in high blood pressure and heart disease.

Concentrations of lead in the air decreased steadily in the 1980s after the removal of lead from gasoline, and have remained low over the past ten years **(Exhibit 27)**. The DEQ has routinely monitored lead in Dearborn. Lead has also been measured in Grand Rapids and Allen Park as part of the NCORE program since 2010.

In November 2008, the USEPA lowered the NAAQS limits from 1.5 micrograms per cubic meter to 0.15 micrograms per cubic meter. As part of the new standard, the DEQ was required to monitor near-stationary lead sources emitting greater than 0.5 ton per year. Michigan Air Emissions Reporting System data and further evaluation

Exhibit 28. Belding Air Lead Levels 2010-2013



and computer modeling showed that an industrial source located in Belding was likely to exceed the new protective health standard. A monitor was installed in Belding on Merrick Street, which recorded a violation of the new health standard. Due to stack-height modifications at the facility, a second site was added on Reed Street in Belding. This site also reported a violation of the new NAAQS in 2011 **(Exhibit 28)**. Since that time, the DEQ has worked with the industrial facility to lower ambient lead impacts. Both DEQ's Merrick Street and Reed Street monitors have reported lead levels below the standard during 2012 and 2013. Monitoring will continue in Belding until the DEQ has collected three consecutive years of data that shows the health standard is being met.

Nitrogen Dioxide

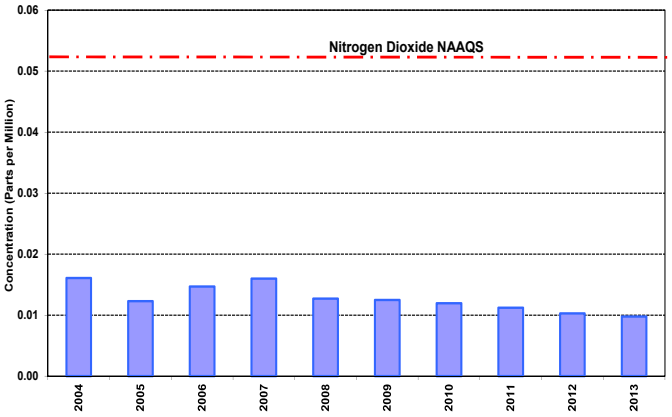
Nitrogen dioxide is formed during high-temperature combustion processes, such as those from power plants burning fossil fuels and from burning fuels in motor vehicle engines. In Michigan, 37.1 percent of nitrogen dioxide-producing compounds are emitted from motor vehicles, and 26.3 percent come from point sources such as industrial, commercial, institutional and residential fossil-fuel combustion.

The human respiratory system is susceptible to effects caused by exposure to nitrogen dioxide. Asthmatics are particularly sensitive to these effects. Nitrogen oxides contribute to

the formation of ground-level ozone and can contribute to acid rain. It sometimes can be seen as a reddish-brown layer.

Regulations on vehicle emissions over the past few decades, and reductions in emissions from power plants due to stricter regulations and new technologies, have contributed to a decreasing

Exhibit 29. Ambient Nitrogen Dioxide Trends (Statewide Average of Monitored Annual Average Nitrogen Dioxide Levels)



trend. In 2010, the USEPA strengthened the form of the nitrogen dioxide ambient air-quality standard, changing it from an annual to a one-hour standard. Statewide monitoring results show that annual average nitrogen dioxide levels have remained less than 40 percent of the NAAQS **(Exhibit 29)**.

The DEQ operates nitrogen dioxide monitors in Detroit and Lansing and near Houghton Lake. In addition, the DEQ has operated nitrogen dioxide monitors at its NCORE sites in Grand Rapids and Allen Park since December 2007. As with carbon monoxide, the DEQ also has been measuring nitrogen dioxide along I-96 in Detroit since 2011.

Ozone

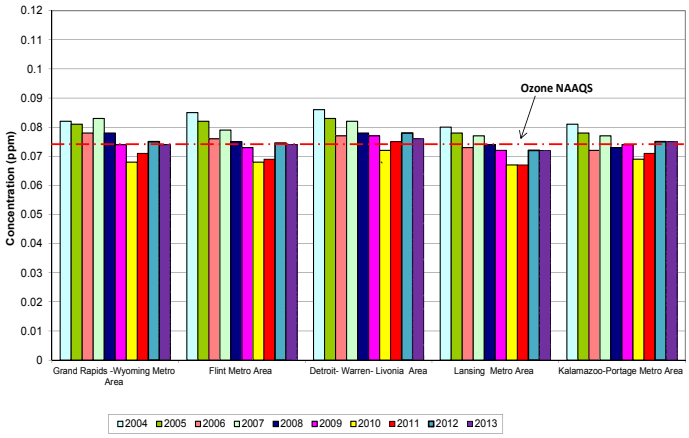
Ground-level ozone is created through photochemical reactions involving nitrogen oxides and volatile organic compounds (VOCs) in the presence of sunlight. These reactions usually occur during the hot summer months, when ultraviolet radiation from the sun initiates the sequence of photochemical reactions. Ozone, a key component of urban smog, is capable of being transported hundreds of miles under favorable meteorological conditions. Ozone levels are often higher in downwind rural areas than in urban areas. This is why shoreline monitors in western Michigan often measure high ozone levels, due to transport from upwind areas such as Gary, Chicago and Milwaukee.

Major sources of nitrogen oxides and VOCs include engine exhaust, gasoline vapors, chemical solvents, industrial facilities, power plants and biogenic emissions from natural sources.

Elevated, long-term ozone exposure irritates the respiratory system, reducing lung function and aggravating asthma, emphysema and bronchitis-like chronic conditions. Ozone also impacts vegetation and the surrounding ecosystem, resulting in reduced crop yields and diminished resistance to diseases.

Within Michigan, 22.8 percent of the ozone-producing VOCs is emitted by vehicles. The remaining 77.3 percent is emitted from the

Exhibit 30. Ambient Ozone Trends (3-year Average of the 4th Highest Daily Maximum 8-hour Average Concentration) 2004-2013



combustion of fuels; chemical and petroleum product manufacturing, storage and distribution loss; solvent utilization in coatings and adhesives; and waste disposal and recycling.

Exhibit 30 shows a comparison between the eight-hour standard and trends in urban areas. The DEQ and its partners measure ozone at 27 different locations throughout Michigan. In 2011, all sites in Michigan came into attainment with the eight-hour ozone NAAQS. However, many monitors are now violating the 0.075 ppm standard.

Particulate Matter

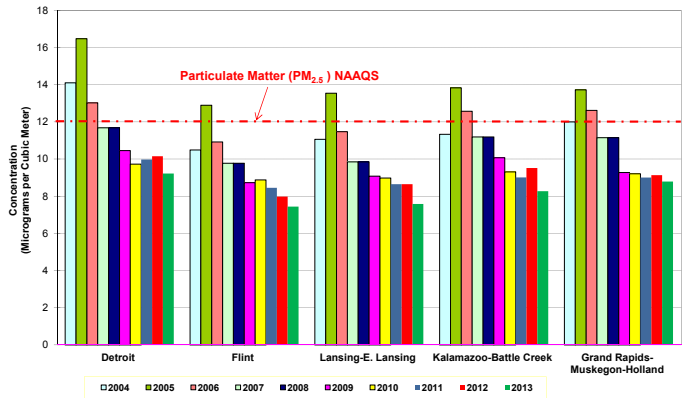
Particulate matter is a broad classification of material that consists of solid particles, fine liquid droplets or condensed liquids adsorbed onto solid particles. Large particles with diameters of less than 50 micrometers (µm) are classified as total suspended particulates (TSP). PM10 are particles less than 10 µm in diameter (about one seventh the diameter of a human hair) and PM2.5 are much smaller "fine particles" equal to or less than 2.5 µm in diameter.

Particulate matter can be emitted directly (primary) or may form in the atmosphere (secondary). Most manmade particulate emissions are classified as TSP. PM10 consists of primary particles that can originate from power plants,

various manufacturing processes, wood stoves and fireplaces, agriculture and forestry practices, fugitive dust sources (road dust and windblown soil) and forest fires. PM2.5 can come directly from primary particle emissions or through secondary reactions that include VOCs, sulfur dioxide and nitrogen oxides emissions originating from power plants, motor vehicles, industrial facilities and other types of combustion sources.

Human exposure to particulate matter can affect breathing and aggravate existing respiratory and cardiovascular disease. More serious effects may occur depending on the length of exposure, the concentration and the chemical nature of the particulate matter. Asthmatics and individuals with chronic lung and/or cardiovascular disease, people with influenza, the elderly and children are most susceptible. Particle size is the major factor that determines which particles will enter the lungs and how deeply the particles will penetrate. It is the major cause of reduced visibility in many parts of the U.S. PM2.5 is considered a primary visibility-reducing component of urban and regional haze.

Exhibit 31. Ambient Particulate Matter Trends ($PM_{2.5}$) (Annual Average) 2004-2013



Airborne particles impact vegetation ecosystems and damage paints, building materials and surfaces. Deposition of acid aerosols and salts increases corrosion of metals and impacts plant tissue.

The USEPA has set particulate air-quality standards for PM10 (24-hour average) and PM2.5 (24-hour and annual averages). As of 2013, Michigan is attaining the PM10 standard and the 24-hour and annual PM2.5 standards statewide. The DEQ currently runs 27 filter-based and 13 continuous PM2.5 monitors across the state. **Exhibit 31** shows the PM2.5 levels monitored in five urban areas relative to the annual PM2.5 standard.

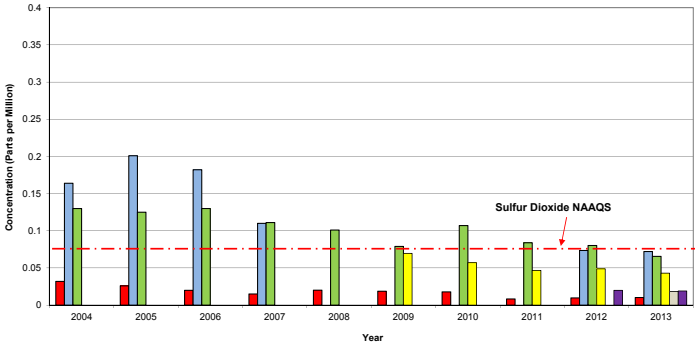
Sulfur Dioxide

Nationwide, the largest source of sulfur dioxide is coal-burning power plants. State regulations now require that most of the coal burned in Michigan contain only low amounts of sulfur. Sulfur dioxide also is emitted from smelters, petroleum refineries, pulp and paper mills, transportation sources and steel mills. Other sources include residential, commercial and industrial space-heating. Sulfur dioxide and particulate matter often are emitted together.

Human exposure to sulfur dioxide aggravates existing respiratory and cardiovascular diseases.

Asthmatics and individuals with chronic lung and/or cardiovascular disease, children and the elderly are most susceptible. Sulfur dioxide and nitrogen oxide together are the major precursors to acid rain, which can potentially acidify lakes, streams and soils and corrode building surfaces.

Exhibit 32. Ambient Sulfer Dioxide 1-hour Values (99th percentile of the Daily Maximum 1-hour Average) 2004-2013



Levels of sulfur dioxide have fallen dramatically. This is due to tougher state and federal emission limits on power plants.

The DEQ operates sulfur dioxide monitors at its Detroit-Fort Street station and as part of its NCORE network in Allen Park and Grand Rapids. In 2011, two additional sulfur dioxide monitors were added to the Port Huron and Jenison sites. In 2012, a new monitoring station was established at Sterling State Park to monitor for sulfur dioxide. When a new one-hour sulfur dioxide NAAQS was implemented in 2010, the Detroit-Fort Street monitor fell out of attainment, failing to meet the new standard in 2011and 2012 **(Exhibit 32)**.

Air Quality Index

The USEPA developed the Air Quality Index (AQI) in 1998 to provide a simple and uniform way to report daily air quality. The AQI provides advice to the public about the health effects associated with various levels of air pollution, including recommended precautionary steps if conditions warrant.

Over the last several years, AQI values have been mostly good and moderate air quality levels. However, some metropolitan areas in Michigan have experienced days that were categorized as unhealthy for the general population or unhealthy for sensitive groups **(Exhibits 33 and 34,** respectively, for the years 2004-2013).

While based on actual measurements, caution should be exercised with the use of the AQI, since the health-classification labels are quite general

Exhibit 33. Air Quality Index: Number of Unhealthy Days for the General Population (Excluding Sensitive Groups) 2004-2013

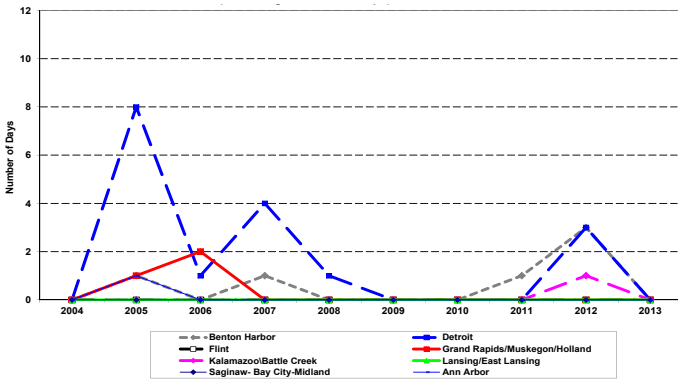
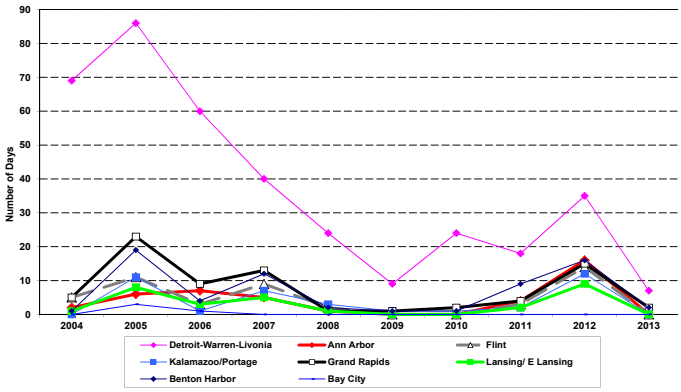


Exhibit 34. Air Quality Index: Number of Unhealthy Days to Sensitive Groups 2004-2013



and are therefore subject to interpretation. Additional information on the AQI, including the daily AQI values for Michigan monitoring sites, is available on the DEQ's Air Quality website www.deqmiair.org/. MIair also displays air-quality forecasts, continuous air-monitoring data, and animated ozone and PM2.5 maps.

Ambient Levels of Air Toxics Contaminants

There are many more air contaminants than just the six criteria pollutants. The additional air pollutants are referred to as air toxics. While there are no NAAQS for air toxics, many do have health reference levels. The available air toxics monitoring data are less extensive than the criteria pollutants data.

The DEQ's air toxics monitoring program was established in January 1990. Since the program's

inception, approximately 50 organic compounds and 13 trace metals have been monitored at various urban locations in the state. Detailed information on which air toxics are currently being monitored is available on the DEQ's website at www.michigan.gov/deqair.

The USEPA has developed a nationwide air toxics monitoring network (www.epa.gov/ttn/amtic/natts.html). This network is measuring ambient concentrations of air toxics at monitoring sites throughout the U.S. that can be used in the estimation of human and environmental exposures to air toxics. Dearborn, Michigan, is one of those sites. **(Exhibit 35 and 36)**

Exhibit 35. National Air Toxics Trend Site (NATTS) Dearborn, Michigan

In December 2010, DEQ completed a study called the "Detroit Air Toxics Initiative (DATI-2) Risk Assessment Update." This study provided a risk characterization for air toxics based on air concentrations monitored in the Detroit area (www.michigan.gov/deq/0,4561,7-135-3310_4105-139044--,00.html). This study evaluated monitoring data from February 2006 to February 2007, including VOCs, carbonyls, and metals monitored at six sites in the Detroit area. Air concentrations during DATI-2 were also compared to other published studies in the U.S., indicating that similar levels occur in other large cities. The report provides estimates of health risks that may be associated with breathing the measured levels over time.

Exhibit 36. National Air Toxics Trend Site (NATTS) Dearborn, Michigan

The DATI-2 study found that air concentrations and associated cancer and non-cancer risk estimates had declined since the first DATI study, including compounds producing the greatest potential health risks. Three reasons are suggested for the decline in air toxics health risks: improved regulatory compliance by industries, decreased vehicle emissions and reduced industrial emissions due to the economic downturn. Two cancer-causing compounds, formaldehyde and benzene, continued to show elevated health concerns even though concentrations had decreased since the first DATI study (DATI-1).

The DATI-2 Risk Assessment Report provides useful information. However, it should be noted that the risk estimates in this type of study represent a "snapshot" in time and do not reflect individual risks from past or future exposures to air toxics. Furthermore, there are uncertainties in the estimation of exposure levels, and there is limited information available on potential health effects of air toxics alone and in combination with other air pollutants. Nevertheless, this study helps identify the air toxics of greatest concern in the Detroit area and is useful for characterizing the air quality for the public and regulatory agencies.

Deposition of Persistent and Bioaccumulative Air Toxics

Some air toxics can persist and bioaccumulate in the environment. For these substances, air deposition to the ground and water is a concern because of potential ecological impacts and human exposure. Examples of persistent, bioaccumulative and toxic (PBT) pollutants include PCBs and mercury. PCBs, synthetic chlorinated organic chemicals used historically, were banned in 1979 due to their toxic properties. Exposure to PCBs has been shown to cause cancer

in animals and can impact the nervous, immune, reproductive and endocrine systems.

Mercury has been used in thousands of applications over the years, including batteries and fluorescent lights, because of its unique properties. Many uses have been banned in Michigan, including fever thermometers and thermostats, but several uses continue. Although health impacts of industrial exposure to high levels of elemental mercury have been documented, the primary environmental concern at lower ambient concentrations is with methylmercury, the most bioavailable and bioaccumulative form of mercury. Mercury is converted to methylmercury by a process known as methylation, and can occur in the water column or sediment by bacteria. Species at the high end of the food chain, such as predatory fish, can have concentrations in their tissue up to one million times the surrounding water due to bioaccumulation. Methylmercury is a potent neurotoxicant that can adversely impact humans and wildlife if exposed at elevated levels.

The DEQ, USEPA and an USEPA contractor developed a statewide PCB and mercury total maximum daily load (TMDL) for the state of Michigan that addresses atmospheric deposition of these pollutants to inland waters of the state. Section 303(d) of the federal Clean Water Act and USEPA's Water Quality Planning and Management Regulations (Title 40 of the CFR Part 130) requires states to develop TMDLS for all water bodies not meeting water-quality standards (WQSs). The TMDL process establishes a maximum amount of a pollutant to the waters of Michigan that can occur without exceeding the WQS.

PCB Statewide TMDL

Thousands of miles of rivers, streams, lakes and fish have elevated levels of PCBs as a result of decades of loadings of this pollutant via atmospheric deposition. The TMDL identified all of the water bodies that have elevated PCBs in the water and/or fish. A target fish species was selected, and a goal was set for reductions in atmospheric deposition. Lake trout were selected as the target fish species for several reasons, including the fact that they are found with PCB contamination, they are a native fish species, and people catch and consume these fish.

Based on an analysis of current atmospheric levels, a 94 percent reduction from 2010 levels is needed to meet the fish target concentration. Most PCBs emitted to the air are from legacy sites (as opposed to new production) or from landfills, scrap yards and from old electrical equipment like capacitors and transformers.

Because PCBs have been banned, PCBs in the air and in fish tissue have continued to decline over the last several decades. Based on current levels, and if the decreasing temporal trend continues, it will take the state approximately 50 years to reach the TMDL atmospheric deposition PCB goal. Certain remediation actions may accelerate this rate of decline, by actively removing historical sources of PCBs that have been previously volatilizing and contributing to elevated atmospheric PCB concentrations. Such activities include cleaning up contaminated sediment and prohibiting PCB disposal at landfills.

The statewide PCB TMDL was released for public comment and was submitted to the USEPA in 2013. The PCB TMDL is considered draft until the USEPA approves the TMDL, and approval is expected in 2015.

Mercury Statewide TMDL

A statewide mercury TMDL also was developed for the inland waters of Michigan primarily impacted by atmospheric deposition of mercury. Similar to PCBs, mercury finds its way to lakes predominantly by atmospheric deposition. The widespread loading of mercury into the Great Lakes region caused mercury-related fish consumption advisories in all of the eight Great Lakes states. Hundreds of water bodies in Michigan have elevated levels of mercury in the water column and fish.

A target fish concentration was set for mercury, and the target species selected was northern pike. Northern pike were selected because this species represents a top-predator species, has the

highest mercury concentrations of fish species evaluated, and is widely distributed throughout the state. Based on the target fish-tissue mercury concentration, the TMDL established a goal for reducing atmospheric mercury loadings relative to a baseline. Anthropogenic atmospheric sources of mercury in Michigan must be reduced by approximately 80 percent from 2001 levels to meet the goal set in the TMDL. Mercury fish-tissue concentrations and mercury air emissions will be monitored to track progress.

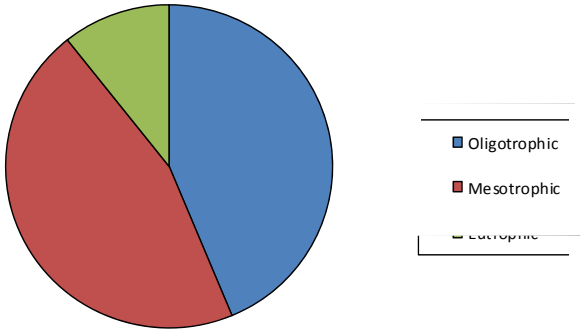
Reductions in mercury atmospheric deposition and fish levels are not yet showing similar reductions to PCBs. While many uses and releases of mercury have stopped, thousands of pounds of mercury continue to be emitted from Michigan sources, and most of the mercury deposited within the state comes from outside Michigan's state boundaries. Michigan will continue to work on voluntary and regulatory efforts within the state, regionally as well as nationally. The statewide mercury TMDL was released for public comment in 2014 and will be submitted to the USEPA in 2015 for approval. The mercury TMDL is considered draft until the USEPA approves the document.

Inland Lake Water Quality

The federal Clean Water Act requires states to assess lake water quality and to categorize lakes according to their trophic status, an indicator of biological productivity. Lake trophic status is commonly inferred as the level of growth of algae and higher plants, or primary productivity, as measured by phosphorus content, algae abundance based on chlorophyll content and depth of light penetration in the lake. Low-productive lakes are generally deep and clear with little aquatic plant growth. These lakes are generally very desirable for boating and swimming and may support cold-water fish, such as trout and whitefish. By contrast, highly productive lakes are generally shallow, turbid and support abundant aquatic plant growth. These lakes commonly support warm-water fish, such as bass and pike. Historically, over 700 public lakes in Michigan have been assessed and classified. The majority (67 percent) were categorized as moderately productive or low-productive lakes. Only 5 percent of the lakes evaluated were categorized as excessively productive lakes.

Currently, the Cooperative Lakes Monitoring Program, a Michigan Clean Water Corps (MiCorps) program (www.micorps.net), provides for long-term water-quality measurement and continues the lake classification process. The MiCorps program enlists citizen volunteers from public and limited-access lakes across the state to monitor lake primary productivity indicators, including water clarity, total phosphorus and chlorophyll a, from which the lakes can be categorized in terms of trophic status. During 2011-2013, volunteers monitored these primary lake productivity indicators on 273 lakes. For these lakes, the majority exhibited moderate (46 percent) to low (44 percent) productivity. Eleven percent of the monitored lakes were categorized as having high productivity. (**Exhibit 37**).

Exhibit 37. Trophic Status of the 273 Cooperative Lakes Monitoring Program 2011-2013



The Cooperative Lakes Monitoring Program (CLMP) is a cost-effective volunteer program for increasing baseline water-quality data and lake-productivity classifications for select Michigan inland lakes. The long-term monitoring program can provide information to evaluate water-quality variability and trends in these lakes. However, because results from the volunteer program only provide information on lakes where volunteers choose to participate in the program, the CLMP trophic-status breakdown is not expected to characterize statewide inland-lake trophic status.

The CLMP is also engaging volunteers in the Exotic Plant Watch program, monitoring for invasive

aquatic plant species not native to Michigan. These plants can be extremely disruptive to lake ecosystems and recreational activities. Volunteer monitoring for the plants facilitates preventive management, early detection and rapid response, providing the best chance of stopping invasive species before they become established. For populations that have become established, continued monitoring helps guide continuing maintenance control efforts to keep plant populations at low, manageable levels. During 2011-2013, 27 lakes were enrolled in the Exotic Plant Watch program.

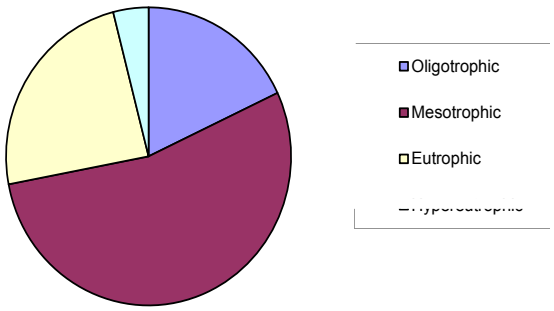
The DEQ, in partnership with the United States Geological Survey (USGS), re-established a Lake Water Quality Assessment Monitoring Program for public-access lakes in Michigan (http://mi.water.usgs.gov/splan1/sp00301/cmiinland.php). Baseline data for conventional water-quality parameters such as plant nutrients (i.e., total phosphorus and nitrogen), chlorophyll a, dissolved oxygen, temperature, water clarity and dissolved ions (i.e., chloride, sulfate, sodium, potassium and calcium) were collected, and the trophic status classification updated, for 729 public access lakes through 2010. Of the 729 lakes sampled, 18 percent were characterized as low-productive (oligotrophic) lakes, 54 percent as moderately productive (mesotrophic) lakes, 24 percent as highly productive (eutrophic) lakes, and 4 percent as excessively productive (hypereutrophic) lakes. This project was completed in 2010 **(Exhibit 38)**.

Clean Michigan Inintiative funds also continue to support work by the USGS using remote sensing satellite imagery for lake water-quality assessments that enable the DEQ to cost-effectively estimate productivity in inland lakes statewide. Statistical models for predicting lake water clarity have been developed and tested with data collected from the Cooperative Lakes Monitoring and Lake Water Quality Assessment Monitoring Programs. To date, there are five data sets from 2002, 2003-05, 2007-08, 2009-10 and 2011 that include an average of 3,000 inland lakes greater than 20 acres with predicted water clarity and corresponding trophic-status values.

An online interactive map viewer allows users to access the predicted water clarity of inland lakes throughout Michigan during the different time frames (http://miwebmapper.er.usgs.gov/CMILakesRS/). The partnership with USGS was extended in 2014, with plans to produce water-clarity data sets for 1999-2000 and 2013. The additional data sets will provide 15 years of data, allowing for a more thorough analysis of status and trends of water clarity for Michigan's inland lake resources.

In 2007, Michigan participated in the USEPA supported National Lakes Assessment Survey (http://water.epa.gov/type/lakes/upload/nla_newlowres_fullrpt.pdf). The DEQ coordinated Michigan's involvement in the survey, in which 50 Michigan inland lakes were monitored. The survey was designed to help the EPA provide regional and national estimates of the condition of lakes, as well as statewide assessments for those states who participated in the survey. A final report comparing the sampling results in Michigan to the national and ecoregion results was issued in 2010

Exhibit 38. Trophic Status of the 729 Lake Water Quality Assessment Lakes 2001-2010



(www.michigan.gov/documents/deq/wrd-swas-nla2007_405400_7.pdf). In summary, key findings of the 2007 survey were: only 3-4 percent of Michigan lakes are in poor condition for nutrients and turbidity stressors; 86 percent of Michigan lakes are in good biological condition; Michigan lakes are currently at low risk for algal toxin (microcystin) exposure; and shoreline habitat alteration is a major stressor for Michigan lakes.

In 2012, DEQ staff once again participated in the National Lake Assessment effort, sampling 53 randomly selected Michigan lakes. Comparable data was collected by the USEPA and its state and tribal partners at 1,133 lakes across the nation to

assess the current condition of the nation's lakes, establish a baseline to compare future surveys and evaluate change in condition since the 2007 survey. The results of the 2012 NLA survey are scheduled to be reported in 2014.

Surface-Water Chemistry

Consistent with a Water Chemistry Trend Monitoring Plan developed by the DEQ and the USGS, water samples have been collected from major Michigan rivers since 2000. Water samples also are collected from Saginaw Bay, Grand Traverse Bay and the Great Lakes connecting channels. Samples are analyzed for nutrients, heavy metals and other selected parameters. These data are used to measure spatial and temporal trends in inland rivers, connecting channels and bays.

Exhibit 39 compares mean annual total phosphorus concentrations from downstream stations of 26 tributaries from 2010 to 2012. Phosphorus is a key nutrient that affects algal growth and regulates productivity in surface waters. Phosphorus concentrations tend to be generally higher in rivers that drain urban or heavily agricultural areas, and lower in relatively

Exhibit 39. Surface Water Chemistry. Mean Annual Total Phosphorus at Select Tributary Stations, 2010-2012

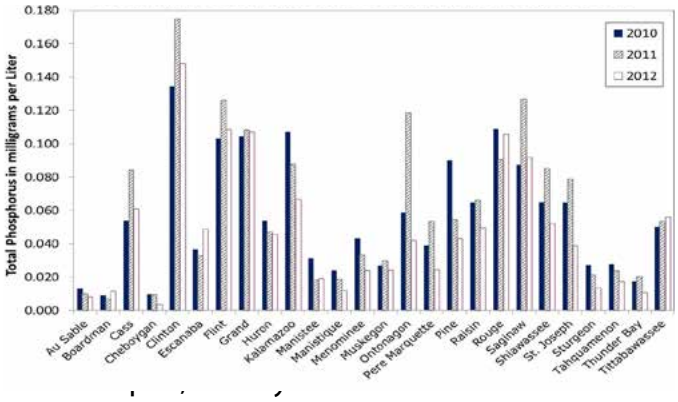
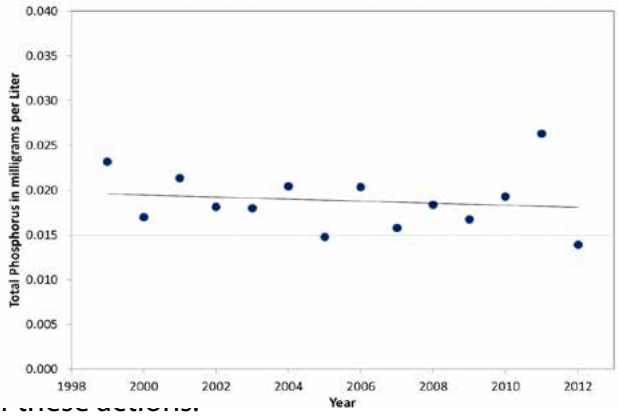


Exhibit 40 presents the mean annual total phosphorus concentrations from seven locations throughout the inner Saginaw Bay. Between 1998 and 2012, average phosphorus levels were lowest in 2012 (0.014 milligrams per liter (mg/L)) and highest in 1998 (0.036 mg/L). Mean total phosphorus appears to be decreasing over time; however, variation in the data precludes detecting a significant trend at this time. The DEQ has taken a number of actions to reduce phosphorus levels in the Saginaw Bay watershed and will continue to monitor Saginaw Bay to evaluate the effectiveness

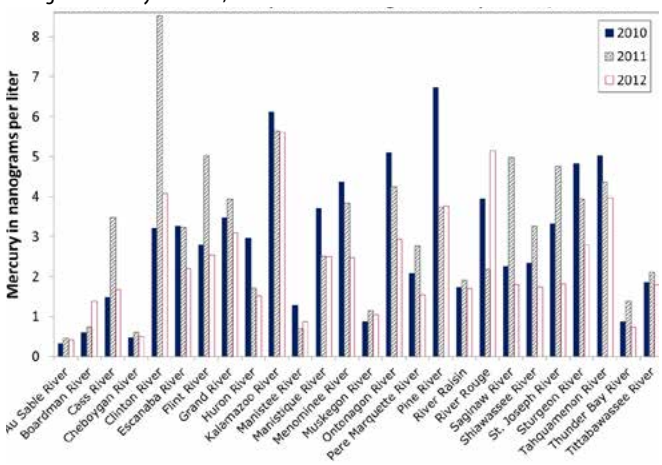
Exhibit 40. Surface Water Chemistry. Average Annual Total Phosphorus Concentrations in Saginaw Bay 1998-2012



of these actions.

Exhibit 41 shows mean total mercury concentrations from downstream stations of 26 tributaries from 2010 to 2012. The highest average annual mercury concentration occurred in the Clinton River in 2011 (8.5 nanograms per liter (ng/L)). The lowest concentration was found in the Au Sable River in 2010 (0.32 ng/L). In the previous Triennial Report, the Ontonagon and Cheboygan rivers had the highest and lowest mean mercury levels, respectively. Mean mercury levels exceeded the Michigan water-quality standard (1.3 ng/L) in 20 (2010) and 21 (2011 and 2012) of these 26 tributary stations. Similar to the phosphorus river data, no clear trend in water quality can be discerned from the mercury river data at this time.

Exhibit 41. Surface Water Chemistry. Mean Annual Total Mercury in Select Michigan Tributary Stations, 2010-2012



Inland Lakes Sediment

A joint initiative between the DEQ and Michigan State University (MSU) to assess chemical trends in inland lake sediments was initiated in 1999. The objectives of the project are to:

1. Use sediment records in selected inland lakes across the state of Michigan to understand current exposure to toxic chemicals; and
2. Identify historical trends that can be used to anticipate future changes in exposure, including new threats.

Since 1999, vertical sediment core samples have been collected from 47 lakes; 11 of these lakes have been sampled twice. Sediment slices are analyzed for mercury, other selected metals (e.g., lead, arsenic, cadmium, copper and nickel), and selected persistent organic pollutants (POPs – e.g., PCBs, PAHs and pesticides). ^{210}Pb (a naturally occurring unstable isotope) and ^{137}Cs (peak activities from the Chernobyl incident) are used to establish sediment rates and consequently the ages of each of the sediment slices. The following exhibits build on those presented in the 2011 Triennial Report. Graphs that indicate "normalized" concentrations on the x-axis mean that, instead of absolute concentrations, concentrations of chemicals in each core are normalized to the highest concentrations. Thus, the highest value will be one. Normalization does not change the shape of the data, but does allow for easy comparisons of patterns among lakes.

Inland Lakes Sediment **Exhibit 42 - A, B, C, D** includes example data used to address the goals of the project. The data also exemplify the complexities of understanding contaminant loadings in the environment. **Exhibit A** shows changes in lead concentration over time. All of the lakes across the state show a similar pattern (caused by a regional atmospheric source) with peak concentrations around 1974, the time when lead was banned in gasoline. Prior to this time, the pattern of the increase in lead concentrations was similar among lakes. After banning, the patterns differ, and many lakes have not returned to concentrations reflective on uncontaminated systems, some lakes remain elevated and some have increasing concentrations. **Exhibit B** shows that copper does not peak at the same time in all lake sediments, indicating individual watershed influences. Similar to lead, some lakes remain elevated and some have increasing concentrations. **Exhibit C** shows that, although the record for arsenic indicates human influences (elevated concentrations), it is very complicated. The record is highly influenced by processes that make arsenic mobile in the sediments after burial, which might have implications to the benthic communities. **Exhibit D** shows mercury concentrations are highly influenced by human activities and vary widely among lakes, suggesting the possible influence of local watershed sources. Similarities in some episodic high concentrations indicate the influence of regional, and perhaps global, sources. Some of the events can be attributed to historical increases in mercury deposition (e.g., World War II).

Inland Lakes Sediment **Exhibit 43** summarize some aspects of the PCB and PAH analyses. For each, **Exhibit A** is the inventory analysis.

Exhibit 42. A. Changes in Lead Over Time

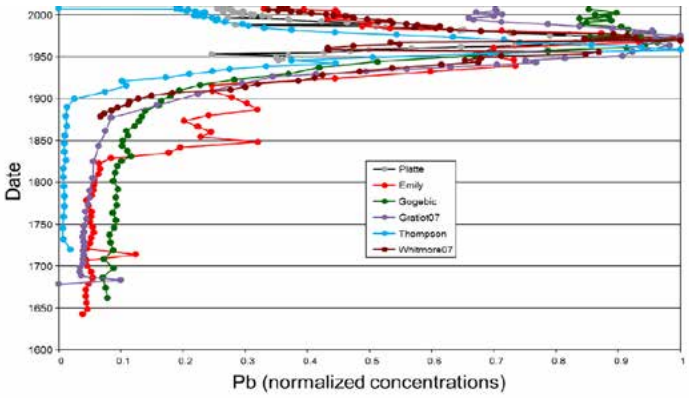


Exhibit 42. B. Copper Does not Peak at the same time in all lake sediment

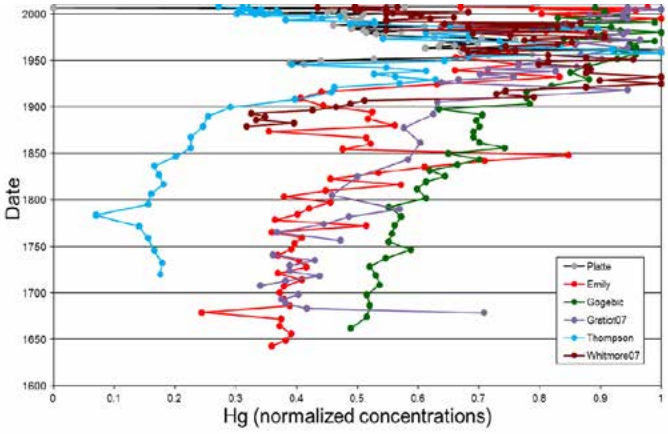


Exhibit 42. C. Changes in Arsenic Levels

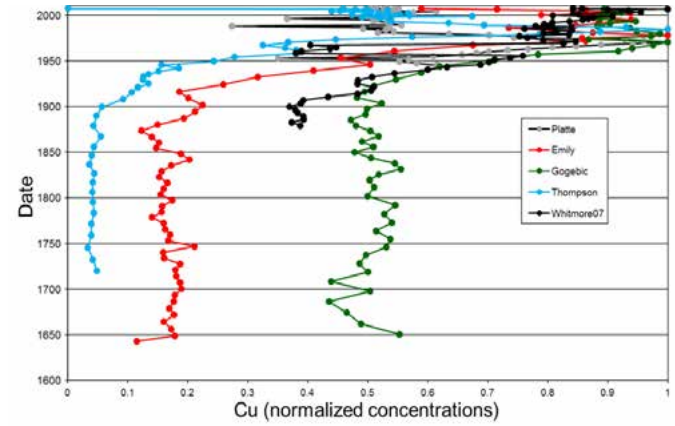
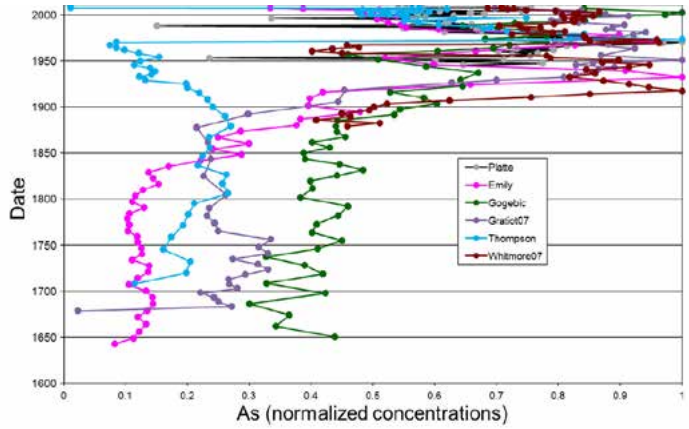


Exhibit 42. D. Changes in Mercury Levels



Uncorrected inventory is the total mass of POPs in the sediments. Focusing corrected inventory adjusts the values to account for sediment washed into the depositional basin from the lake and watershed. If atmospheric deposition of the POPs were equal across Michigan, then the corrected inventories for each lake should be the same. The results show that for many lakes (and the Great Lakes), the PCB values are similar and there is no apparent north-south trend. Some lakes (e.g., Thompson, White) have high inventories, suggesting sources within the watersheds. Results for PAHs are similar, but only Lake Campau has unusually high values. A cluster analysis of the congeners at a particular time horizon was conducted, indicating which lakes are similar in the relative abundance or fingerprint of the congeners and which congeners are similar. Examining these relationships might help to identify common sources. The results of the lake clusters are shown in **Exhibit B**, where similar colors mean similar fingerprints. Preliminary results are beginning to show areas across Michigan in which lakes have similar fingerprints that might be related to source.

Exhibit 43. A. Trends in Polychlorinated Biphenyls

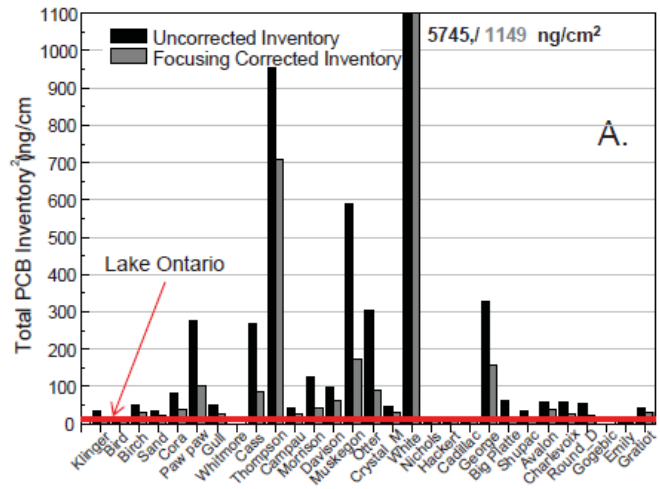


Exhibit 43. B.

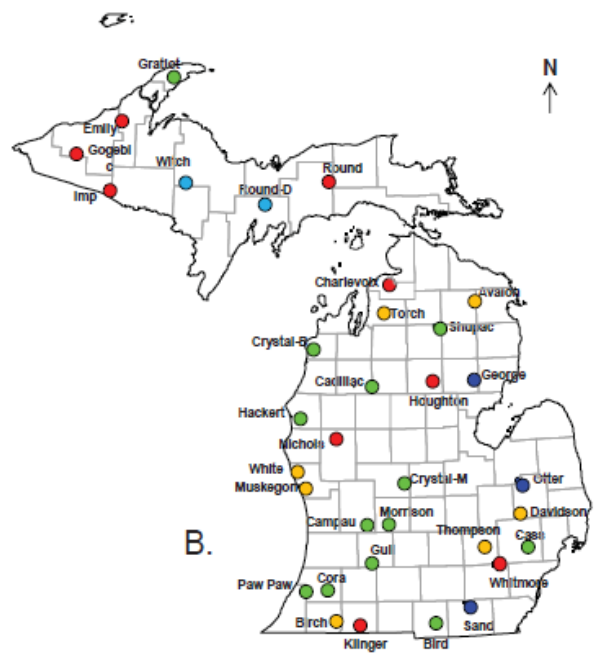


Exhibit 44 shows examples for two new types of knowledge gained: understanding the fate of DDT in the environment and the influence of land-use change on ecosystems. **Exhibit A** shows DDT can be a mixture of the breakdown products DDE and DDD. Total DDT (DDT + DDD + DDE) peaks in Thompson Lake (Howell, Michigan) around 1960, which is the peak in DDT consumption. Total DDT concentrations have not reached zero, and thus DDT is still flushing off of the landscape. **Exhibit B** shows how we can use the data to determine the rate (slope of the line) of DDT breakdown, which in Thompson Lake DDT has a 15-year half-life.

Exhibit C shows that aluminum concentrations (Elk Lake) increase dramatically as a result of

Exhibit 43. C. Inventory Analysis for PAH

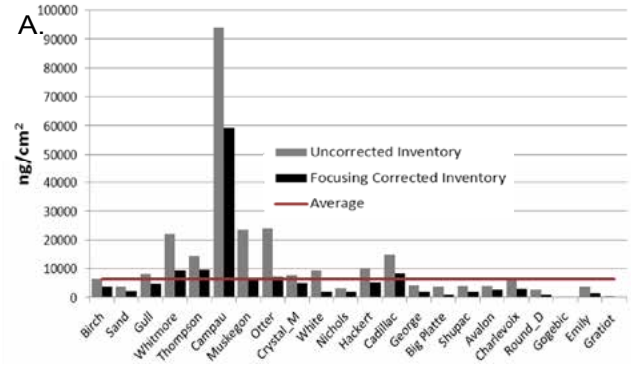
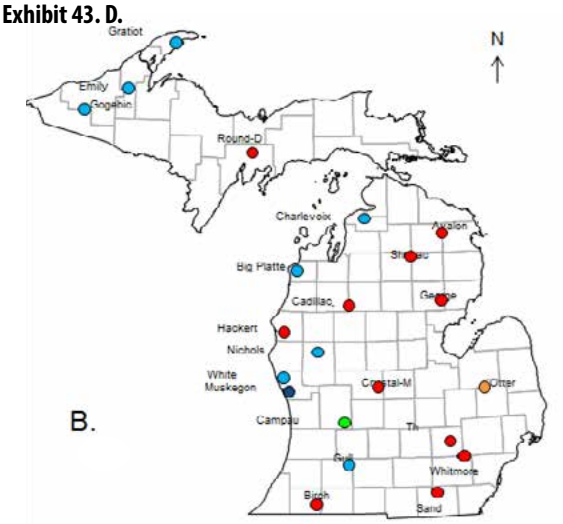


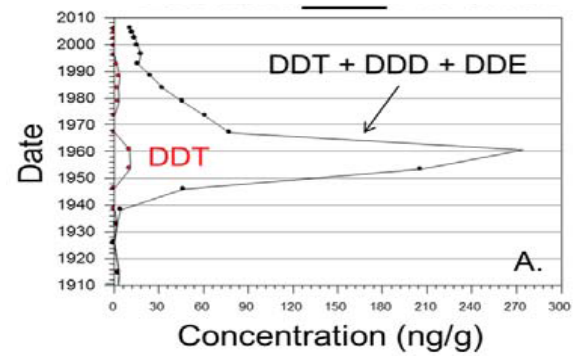
Exhibit 43. D.

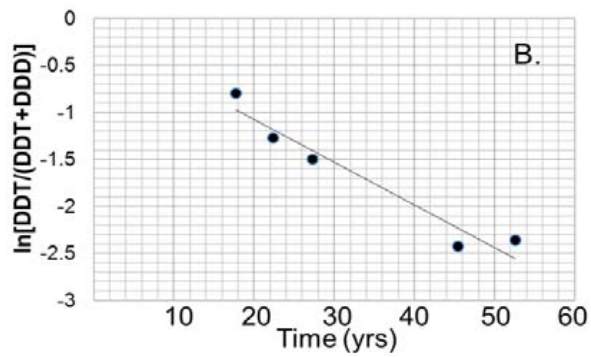


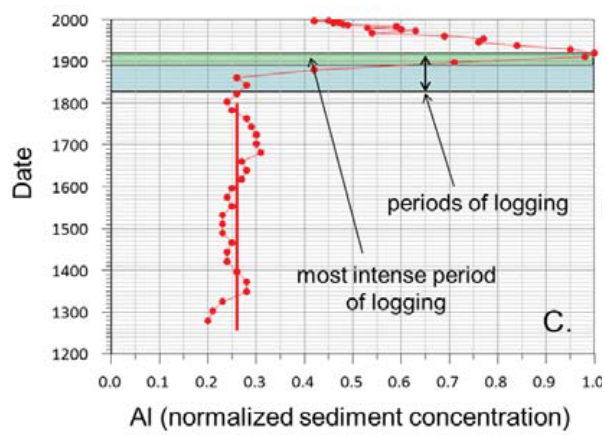
logging. Concentrations reflect the increase in landscape erosion, and indicate that the watershed has not recovered from this activity after 100 years. **Exhibits C & D** shows the influence of logging (Thompson Lake) on calcium and nitrogen concentrations. Higher productivity is related to higher calcium levels in the sediment. As is the case for Elk Lake, aluminum concentrations increase during clear-cutting. Phosphorous concentrations dramatically decrease, and calcium concentrations increase, after logging. Prior to logging, decreasing calcium levels possibly indicated oligotrophication. Such trends in calcium and phosphorous concentrations are not necessarily similar among lakes. On the other hand, nitrogen concentrations show a decline after logging, followed by an increase, a pattern observed in many lakes. Logging and recent human activities have clearly changed lake productivities from historic conditions.

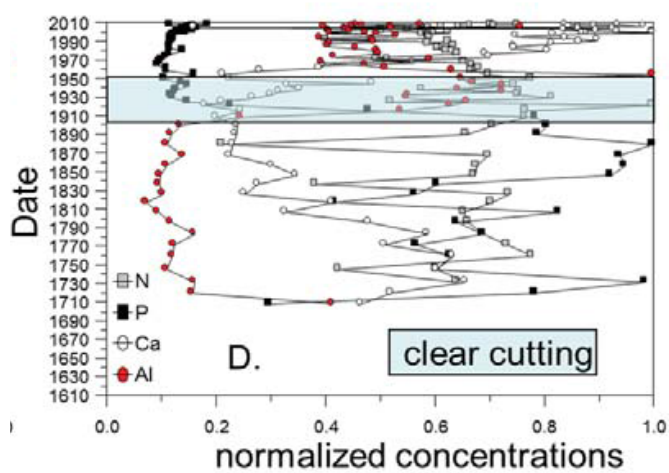
In addition to the lake sediment assessment program, the DEQ also participates in the

Exhibit 44. A, B, C, D - Concentrations of DDT in the sediments of Thompson Lake that show the fate of DDR in the environment and the influences of land-use changes.



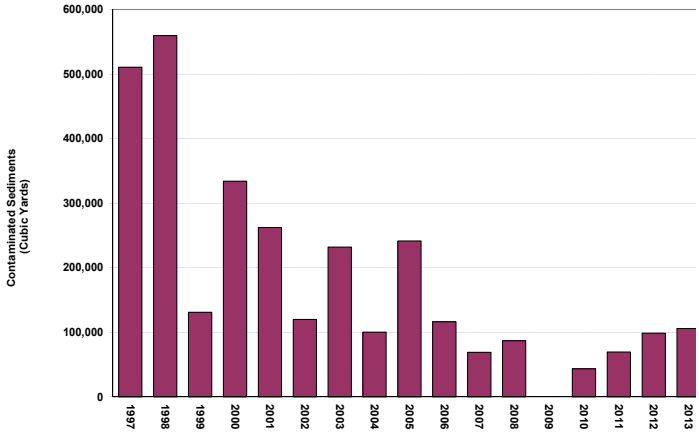






removal of contaminated sediments from lakes and streams. Inland Lakes Sediment **Exhibit 45** shows the cubic yards of sediment removed from Michigan waters since 1997. Approximately 69,500 cubic yards of contaminated sediment was removed in 2011 from the Muskegon Lake Great Lakes Area of Concern (AOC) and the St. Marys River AOC. In 2011, approximately 98,700 cubic yards of material were removed from the River Raisin AOC and the Kalamazoo River Super Fund site. The Muskegon Lake project, the St. Marys River project and the River Raisin project were all completed with Great Lakes Legacy Act funds. In 2013 approximately 106,000 cubic yards of contaminated sediment were removed from the Kalamazoo River Super Fund site, a Manufactured Gas Plant site in Ripley, the White Hall Leather site in the White Lake AOC and the Ceresco Dam site on the Kalamazoo River.

Exhibit 45. Cubic Yards of Contaminated Sediments Removed from Surface Waters 1997-2013



Stream Flow

Natural flow regimes play a significant role in maintaining stream channel configuration, wetland and riparian vegetation, and stream-dependent biological communities. Stream flow is an indicator of the amount and type of habitat available for fish and other aquatic organisms. It also is an indirect measure of water quality in streams, lakes and reservoirs occurring in stream systems.

Changes in flow patterns reflect changes in runoff from land, groundwater level, water extraction, discharge from upstream reservoirs (if present) and climatic variability. Several common stream flow measures are used to monitor and assess status of flow patterns. These include measures of high (10-percent exceedance frequency), median (50-percent exceedance frequency) and low (90-percent exceedance frequency) flows. High and low flow measures can be standardized by the median flow to facilitate comparisons among different rivers. An additional measure of runoff (mean annual discharge/mean annual precipitation) also is evaluated.

The status of flow is determined by comparing recent flow patterns to a benchmark. This benchmark can be based on presettlement flows or from the earliest period of record. Models have been developed that predict stream flow as a function of geology, stream size and current land-cover characteristics. These models can be used to estimate baseline flow patterns by substituting current land-cover data with presettlement land cover data.

The primary source of flow data comes from USGS gauging stations. At present, the USGS maintains approximately 186 stations statewide.

Great Lakes Water Level Trends

The Great Lakes Basin lies within eight U.S. states and two Canadian provinces and comprises the lakes, connecting channels, tributaries and groundwater that drain through the international section of the St. Lawrence River. The combined influence of precipitation (the primary source of natural water supply to the Great Lakes), upstream inflow, groundwater, surface-water runoff, evaporation, diversions into and out of the system, consumptive water uses, dredging and water-level regulation determine lake levels.

The hydraulic characteristics of the Great Lakes are the result of both natural fluctuation and, to a lesser extent, human intervention. Despite this, human activities such as water-control structures, dredging and diversions still can have an impact on lake levels. Out-of-basin diversions or other large removals and consumptive uses can reduce water levels both above and below the point of withdrawal and can reduce flows within the system. However, climatic conditions are the most

significant factor influencing the lake levels of the Great Lakes.

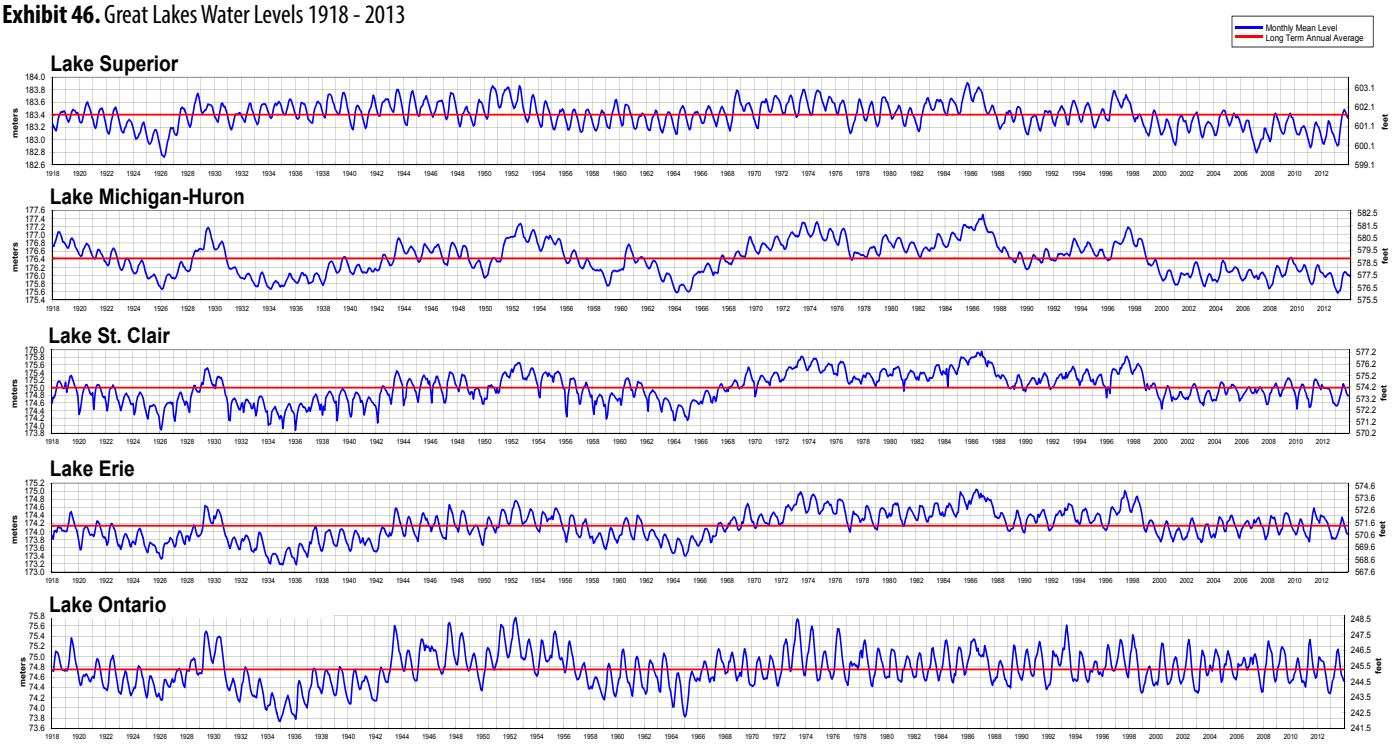
Climatic conditions control precipitation, groundwater recharge, runoff, ice cover and the rate of evaporation. During dry, hot weather periods, flows into the Great Lakes system decrease and evaporation increases, resulting in lower lake levels and reduced flows within the Great Lakes. During wet, colder periods, higher water levels and increased flows occur. An example of how quickly water levels can change in response to climatic conditions occurred during 1998-99, when the water levels of Lakes Michigan and Huron dropped 22 inches in 12 months.

Historical water-level data for the Great Lakes provide a picture of a dynamic system with seasonal and yearly water-level fluctuations. **Exhibit 46** shows the monthly mean (blue line) and long-term annual average (red line) water levels of the Great Lakes for the period 1918–2013. Over this time period, there have been several periods of extremely high and extremely low water levels and flows. High water levels occurred in 1929–1930, 1952, 1973, 1985–1986 and 1997–1998. Exceptionally low water levels were experienced in the mid-1920s, mid-1930s and early 1960s. Additionally, from 1999–2013 the Great Lakes were in an extended period of low lake levels, and an all-time record low was set for Lakes Michigan and Huron in January 2013.

Since setting this record low, water levels across the Great Lakes have significantly increased. According to the U.S. Army Corps of Engineers' June 2014 Great Lakes Water Level Summary, water levels across the Great Lakes have increased 3–13 inches from the previous year. As detailed in the report, water-level increases by lake are as follows:

- Lake Superior: The monthly mean for June 2014 was up 13 inches from the previous year and was 6 inches above long-term average for the lake.
- Lake Michigan-Huron: The monthly mean for June 2014 was up 13 inches from the previous year and was 6 inches below long-term average for the lake.
- Lake Erie: The monthly mean for June 2014 was up 7 inches from the previous year and was 3 inches above long-term average for the lake.
- Lake Ontario: The monthly mean for June 2014 was up 3 inches from the previous year

Exhibit 46. Great Lakes Water Levels 1918 - 2013



The monthly average levels are based on a network of water level gages located around the lakes.

Elevations are referenced to the International Great Lakes Datum (1985).

and was 5 inches above long-term average for the lake.

A copy of the U.S. Army Corps of Engineers' June 2014 Great Lakes Water Level Summary is available at: www.lre.usace.army.mil/Portals/69/docs/GreatLakesInfo/docs/NewsAndInformation/JUN14summary.pdf.

In 2012, the International Joint Commission (IJC) completed a 5-year International Upper Great Lakes Study to evaluate options to improve the existing St. Marys River regulation plans and to investigate potential hydraulic changes in the St. Clair River that may be impacting water levels in the upper Great Lakes. The key findings from the IJC's study are as follows:

- Most of the key interests have demonstrated their capacity to adapt to changes in water-level conditions that have been within historical upper or lower ranges. However, future water levels that are outside these ranges would require some interests to carry out more comprehensive and costly adaptive responses than any undertaken to date.
- Changes in the levels of the upper Great Lakes may not be as extreme in the near future as previous studies have predicted. Lake levels are likely to continue to fluctuate, but still remain within the relatively narrow historical range–while lower levels are likely, the possibility of higher levels cannot be dismissed. Both possibilities must be considered in the development of a new regulation plan.
- The Study Board identified a regulation plan that will be more robust than the existing plan and that will provide important benefits related to the maintenance of Lake Superior levels, environmental impacts, economic benefits and ease of regulation.
- Restoration structures designed to raise Lake Michigan-Huron water levels would result in adverse effects on certain key interests served by the upper Great Lakes system.
- The potential for multi-lake regulation to address extreme water levels is limited by the uncertainty regarding future climatic conditions and net basin supply, very high costs, environmental concerns and institutional requirements.
- Adaptive management has an important role to play in addressing the risks of future extremes in water levels in the upper Great Lakes, though it requires leadership and strengthened coordination among institutions on both sides of the international border.
- Public concerns about water levels in the upper Great Lakes differ strongly depending on geographical location.

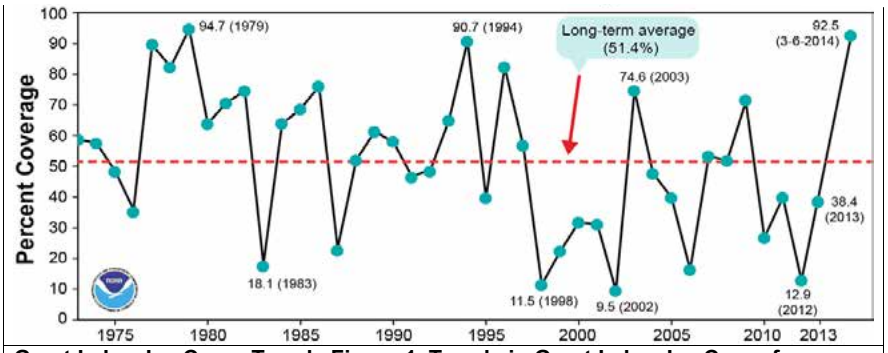
Additional information about the IJC's study, its findings and a copy of the full report are available at www.ijc.org/iuglsreport/.

Great Lakes Ice Cover Trends

For over 40 years, federal agencies have been studying, monitoring and predicting ice coverage on the Great Lakes, as it has an influence on ecosystems and regional economies that depend on the lakes. The amount and duration of ice cover in the Great Lakes varies from year to year, as do the types of positive and negative impacts that can occur in any given year.

In a significant divergence from recent winters, the 2013-2014 winter developed into one of the most severe ice seasons on the Great Lakes in the past 40 years. The ice season started early, in late November 2013, and resulted in the second-highest amount of ice cover on the Great Lakes, at 92.5 percent, following the 94.7 percent observed in 1979 (Figure 1). Four of the Great Lakes surrounding Michigan (Superior, Michigan, Huron and Erie) became 90 percent or more ice-covered

Exhibit 47. Great Lakes Annual Maximum Ice Coverage 1973-2014



Great Lakes Ice Cover Trends Figure 1. Trends in Great Lakes Ice Cover from 1973-2014. (Source: NOAA – Great Lakes Environmental Research Laboratory)

for the first time since 1994 **(Exhibit 47)**. Lake Michigan reached 93.3 percent ice cover on March 8, 2014, setting a new record for that lake.

The freezing and thawing of lakes is an important characteristic of aquatic ecosystems in northern latitudes. For example, in the bays and other shallow waters where lake whitefish spawn, ice cover protects their eggs from harsh wind and wave action as well as predators. These near-shore areas also provide opportunities for winter recreational activity such as ice fishing. With a year-round $4 billion commercial and sport fishing industry in the Great Lakes region, ice cover is a significant factor affecting the region's economy.

Great Lakes ice cover influences terrestrial systems as well as aquatic ecosystems. For example, fruit-growing areas along the West Michigan lakeshore benefit from cooler air temperatures lasting long into the spring, reducing the possibility of a killing frost on blossoms that may otherwise have bloomed earlier in the spring. Other benefits ice cover provides include protecting the shoreline from erosion during the winter months and reducing non-native pest species that have not evolved to cope with Michigan's severe winter conditions.

Not all ice cover impacts are positive, however. The thick and extensive ice cover on the lakes during the 2013-2014 winter season caused delays in the shipping of fuel oil and raw materials that in turn affected industries, including the steel-producing industry. The Great Lakes shipping industry also suffered vessel damage due to thick ice and a delay in the start of the shipping season. However, according to the National Oceanic and Atmospheric Administration ice-cover forecasting system, the extensive and prolonged ice cover reduced evaporation from the lakes and will likely have a positive effect on water levels and thus recreation and commercial shipping in 2014. Early projections called for increased water levels on Lakes Michigan and Huron and slight increases on Lakes Superior and Erie.

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2014. NOAA, Great Lakes Ice Cover 2014 Highlights. Accessed on 7/18/14 at: www.glerl.noaa.gov.

2014. NOAA, Ice Cover on the Great Lakes. Accessed on 7/18/14 at: www.glerl.noaa.gov.

Climate and Weather Trends

Michigan's current climate may be broadly characterized as being dominated by three general weather patterns. The two most dominant patterns originate from west to north and from west to south, influencing weather in northern Michigan and southern Michigan, respectively. The approximate boundary or tension line between these areas runs along an east-west line at about the latitude of Bay City. In general, the southern Lower Peninsula is warmer with a long frost-free season, has more rain in the springtime, less rain in the fall, and more thunderstorms, tornadoes, hail, and freezing rain

than the north. The climate of the northern Lower Peninsula and eastern Upper Peninsula tends to be cooler with a shorter frost-free period, greater snowfall and influenced more by the presence of the bordering Great Lakes.

A third weather pattern occurs in the western portion of the Upper Peninsula. Due in part to the generally higher elevations and more northerly location, cooler temperatures, severe thunderstorms, and high winds are common.

Knowledge of the state's climate and weather is important to help interpret observed changes in air and water quality environmental indicators, but also in many of the programmatic measures. Michigan's climate has fluctuated for thousands of years and will continue to fluctuate with time. The change from glacial conditions occurred about 11,300 years ago when warm dry Pacific air masses became more frequent. Warm air masses dominated from 9,500 to 4,700 years ago. The tendency since then has been toward cooler and wetter conditions with a brief warming period from 1200 to 1400. Cooler temperatures and greater precipitation dominated again from around 1550 to 1850.

While annual variation exists, Michigan's mean temperature trend between the mid-1890s to the period of record through the mid- to late 2000s is similar to global patterns - cooling from approximately 1940 through the 1970s, followed by warming from the early 1980s that continues to the present (Exhibit 54A). Across the period of record, the overall change is about +0.6ºC. This compares favorably to overall global trends and temporal patterns which include an increase in mean temperature of approximately +0.8ºC since 1850 (IPCC, 2007).

Much of Michigan's increase in average temperature over the past 30-40 years is attributed primarily to increasing minimum temperatures. For example, mean winter minimum temperatures from the mid-1980s through the present have increased approximately 4ºC. Similarly, both Michigan and regional warming correlates well with warmer nighttime temperatures (i.e. minimum temperatures), especially during the winter months. It may be surprising to note that relatively little shows that the number of years per decade that Grand Traverse Bay has been frozen over has rapidly decreased since the early 1970s. This is supported by additional studies of data collected in western Lake Superior where the most dramatic changes in ice cover have occurred since 1975. During this period the ice season has begun an average of 11.7 days later and ended 3.0 days earlier every decade.

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Howk, F. 2009. Changes in Lake Superior ice cover at Bayfield, Wisconsin. Journal of Great Lakes Research. Volume 35, Issue 1, March 2009, Pages 159-162

Intergovernmental Panel on Climate Change (IPCC). 2001. Observed Climate Variability and Change. C.K. Folland, and T.R. Karl, co-ordinating lead authors. In: Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Dia, X.,Maskell, K. and C.A. Johnson (eds), Climate Change 2001: The Scientific Basis. Cambridge University Press, Cambridge, UK. Pages 99–181.

Programmatic Measures

Programmatic Measures

Air Quality

Air Emissions Estimates

The federal Clean Air Act requires states to prepare and maintain inventories of emissions from large stationary sources. Emissions from large "point" sources are calculated for particulates, sulfur dioxide, nitrogen oxides, carbon monoxide, volatile organic compounds (VOCs) and lead. The DEQ compiles information from over 1,600 facilities. **Exhibit 48** presents a summary of point source emissions for six contaminants; emissions of these contaminants have decreased substantially over the past 20 years.

Air-pollutant emission sources are categorized as point sources, area sources, mobile on-road sources, and mobile non-road sources. Point sources are the primary contributors to sulfur dioxide and lead, while mobile sources are the primary contributors to nitrogen oxides, carbon monoxide and VOCs. **Exhibits 49, 50 and 51** indicate the contribution of these source categories to VOCs, nitrogen oxides and carbon monoxide. Photochemical reactions between nitrogen oxides and VOCs form ground-level ozone.

Exhibit 48. Stationary Source Emission Trends (TPY)

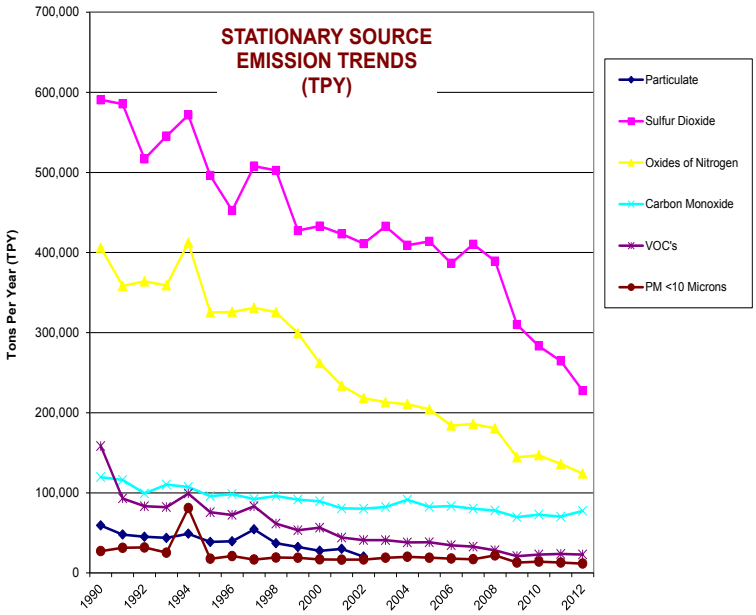


Exhibit 49. Estimated Levels of Volatile Organic Compound Emissions by Source Category 2011

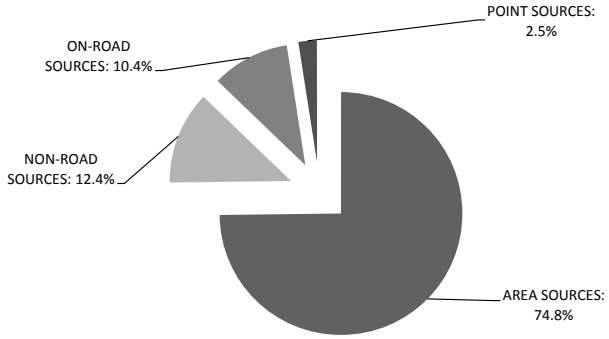


Exhibit 50. Estimated Levels of Nitrogen Oxide Emissions by Source Category 2011

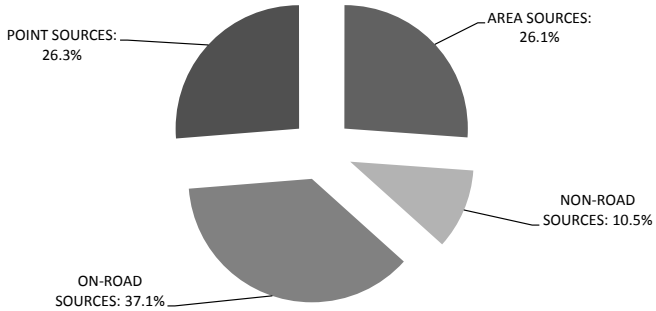
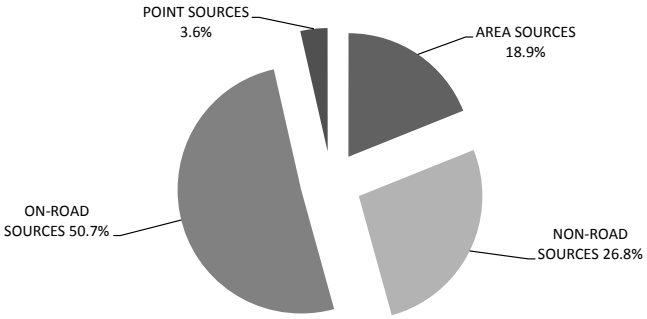


Exhibit 51. Estimated Levels of Carbon Monoxide Emisssions by Source Category 2011



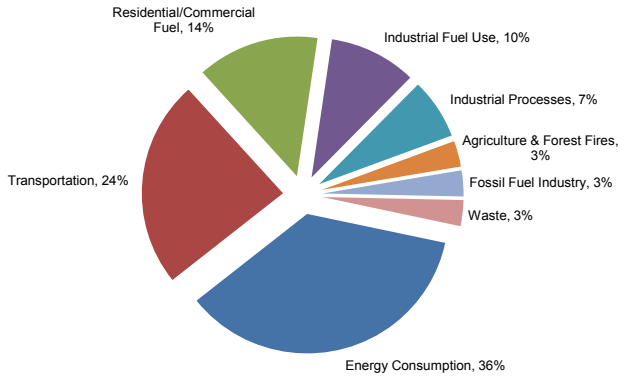
Greenhouse Gas Emissions Inventory

Greenhouse gases allow sunlight to enter the atmosphere and then prevent heat from leaving. These gases are both naturally occurring and emitted by human activities such as burning of fossil fuels, industrial processes, agriculture and deforestation. Changes in the atmospheric concentrations of greenhouse gases can alter the balance of energy transfers between the atmosphere, space, land and the oceans (IPCC, 2001). The current concern is that, since the

Industrial Revolution, the global-average surface temperature of the Earth has been rising due to an amplification of greenhouse gases emitted by human activities.

In March 2009, the Michigan Climate Action Council issued the Climate Action Plan. This comprehensive report included a greenhouse gas inventory and forecast (prepared by the Center for Climate Strategies) and recommended reduction goals and potential actions to mitigate climate change in various sectors of the Michigan economy. The inventory for 2005 and projections out to 2025 cover six types of gases: carbon dioxide (CO2), methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride. Emissions are reported using a common metric, CO2 equivalent (CO2e), which adjusts for the different global-warming potential of the various gases.

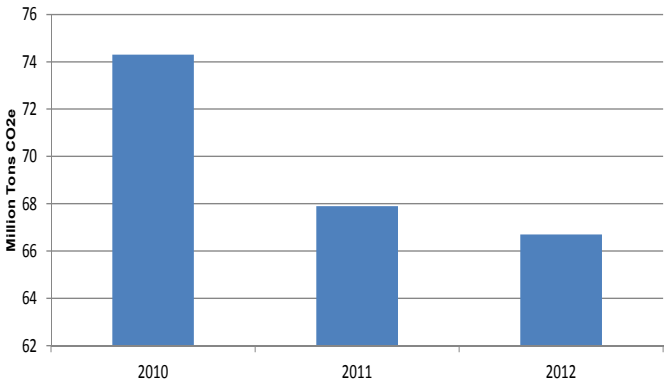
Exhibit 52. Distribution of Michigan Greenhouse Gas Emissions by Economic Sector, 2005



Activities in Michigan accounted for approximately 248 million metric tons (MMt) of gross CO2e emissions, an amount equal to about 3.5 percent of total U.S. gross greenhouse gas emissions. From 1990 to 2005, Michigan's gross emissions increased about 12 percent, while national emissions rose by 16 percent. The principle sources of Michigan's greenhouse gas emissions are electricity consumption (36 percent), residential, commercial and industrial fuel use (24 percent), and transportation (24 percent). (**Exhibit 52)**.

In October 2009, the USEPA promulgated the Mandatory Reporting of Greenhouse Gases rule (GHGRR), requiring the reporting of greenhouse gas emissions from all sectors of the U.S. economy, starting with emissions in 2010. The GHGRR established reporting thresholds that account for 85-90 percent of the nationwide GHG emissions and was further refined for reporting of emissions starting in 2011.

Exhibit 53 Michigan Power Plant Greenhouse Gas Emissions



Source: USEPA Flight (http://ghgdata.epa.gov/ghgp/main.do)

The data compiled by the GHGRR indicates a greater than 10 percent reduction in GHG emissions from Michigan power plants (the largest emitting sector) since 2010. **(Exhibit 53)**. There are several forces driving this large reduction in GHG emissions. The reduction in natural gas prices is compelling greater use of natural gas instead of coal. The burning of natural gas emits substantially less greenhouse gases than coal. Also driving the reductions in greenhouse gas emission from Michigan power plants is the retirement of some of the older, coal-fired electric generating units, which – at least in part – is due to recently promulgated and proposed federal regulations.

Air Radiation Monitoring

The DEQ is responsible for monitoring the potential for environmental impact from the operation of nuclear power plants in Michigan. Baseline radiological data for the four nuclear power plant sites that operated in Michigan (Enrico Fermi, Big Rock Point, Palisades and D.C. Cook) were established a minimum of one to three years prior to plant operation, which dates back to 1958 for the Enrico Fermi Nuclear Plant site. To date, off-site environmental impacts attributable to the operation of nuclear power plants in

Michigan have not been detected. The data monitored by the DEQ includes radioactivity in air particulates, radioactivity in milk and, as discussed later in this report, radioactivity in surface waters. Annual reports on the overall quality of the radiological environment are available by contacting the DEQ.

Since the inception of the program in the early 1960s, a general trend of decreasing levels of radioactive fallout from atmospheric testing of nuclear weapons has been observed, with the radioactivity associated with air particulates. A brief exception to this downward trend was observed in 1986 as a result of radioactive fallout from the Chernobyl Nuclear Power Plant accident in the former Soviet Union. Since 1986, the radioactivity levels associated with air particulates have returned to natural radiation background levels of 0.01 to 0.03 picocuries per cubic meter. A level of concern would be a three-month average exceeding one picocurie per cubic meter or several consecutive quarters exceeding 0.1 picocurie per cubic meter. A total of four sites are monitored throughout the state. **Exhibits 54 and 55** present measurements for the Lansing Background Reference and the Enrico Fermi Nuclear Power Plant sites, respectively, and may be considered representative for the other two monitoring locations. Data through 2013 from the monitoring locations demonstrate that radioactivity levels have continued to remain at natural background levels.

The DEQ also monitors the level of radioactivity found in milk in order to assess the potential

Exhibit 54. Quarterly Average Air Particulate Radioactivity 1960-2013 (Lansing Background Reference Site)

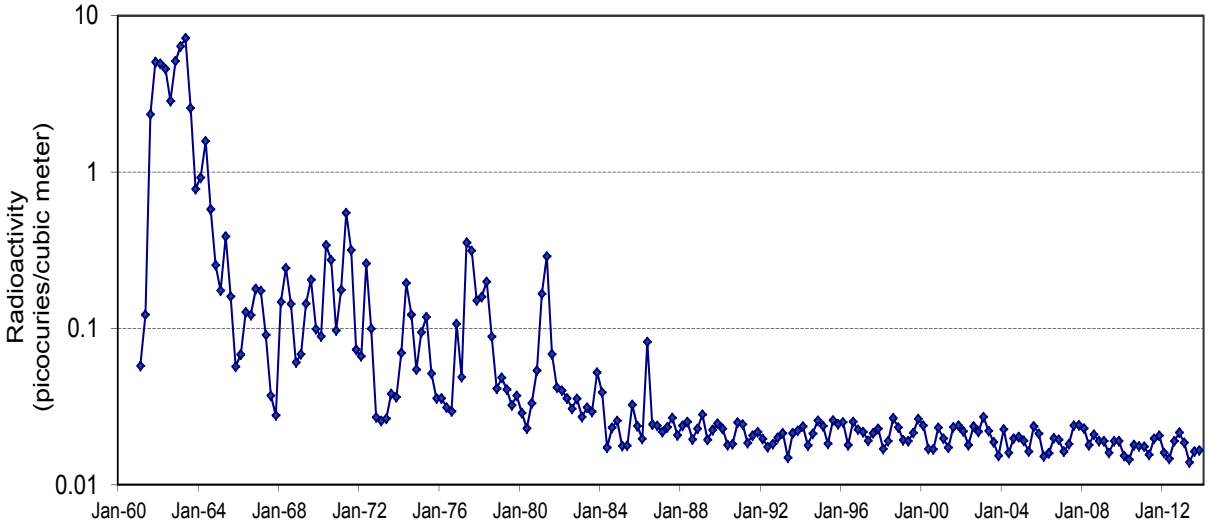
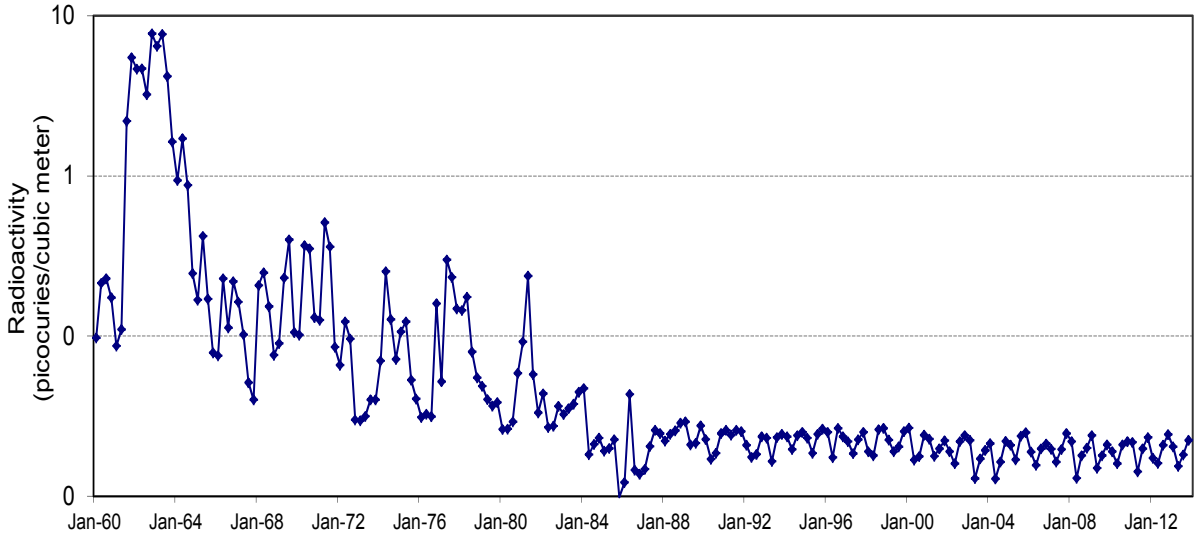


Exhibit 55. Quarterly Average Air Particulate Radioactivity 1960 - 2013 (Enrico Fermi Nuclear Power Plant Site)



impact of radioactivity on the environment and human food chain. The radioactivity is characterized by determining the level of cesium-137, a radionuclide resulting from nuclear fission. It is highly suitable for this measurement, since its chemical behavior is similar to that of potassium.

Exhibits 56 and 57 present radioactivity measurements taken from the Monroe and Lansing Milk Stations, respectively, which are representative of other milk-monitoring locations in the state. Over the past 20 to 25 years, cesium-137 annual averages have remained below minimum detectable activity levels. Prior to 1980, but especially during the early 1960s, radioactivity levels in milk were significantly higher due to atmospheric nuclear testing. A level of concern would be an annual average exceeding 20 picocuries per liter.

Water Quality

Combined, Sanitary and Storm-Water Sewer Systems

Over the years, the DEQ has worked closely with municipalities to eliminate untreated sewage discharges from combined, sanitary and storm-water sewer systems. As a result, all cities have either corrected their combined sewer overflow problems (by replacement of the combined sewer system with separate storm and sanitary sewers or by providing retention and treatment of the overflow) or have an approved program in place that will lead to adequate control. Additionally, the DEQ has worked with municipalities and industrial facilities to minimize the discharge of pollutants to surface water from storm-water discharges. Both of these efforts have resulted in a continued reduction of nutrients, biological, heavy metal and industrial pollutants to the waters of the state.

Exhibit 56. Annual Average Cesium 137 Radioactivity in Milk 1963-2013 (Monroe Milk Station)

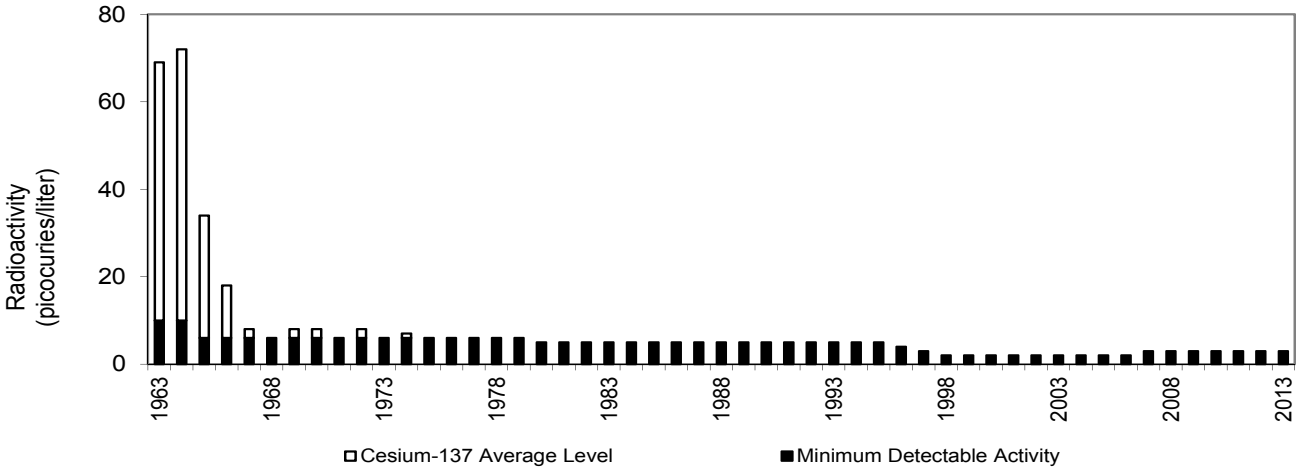
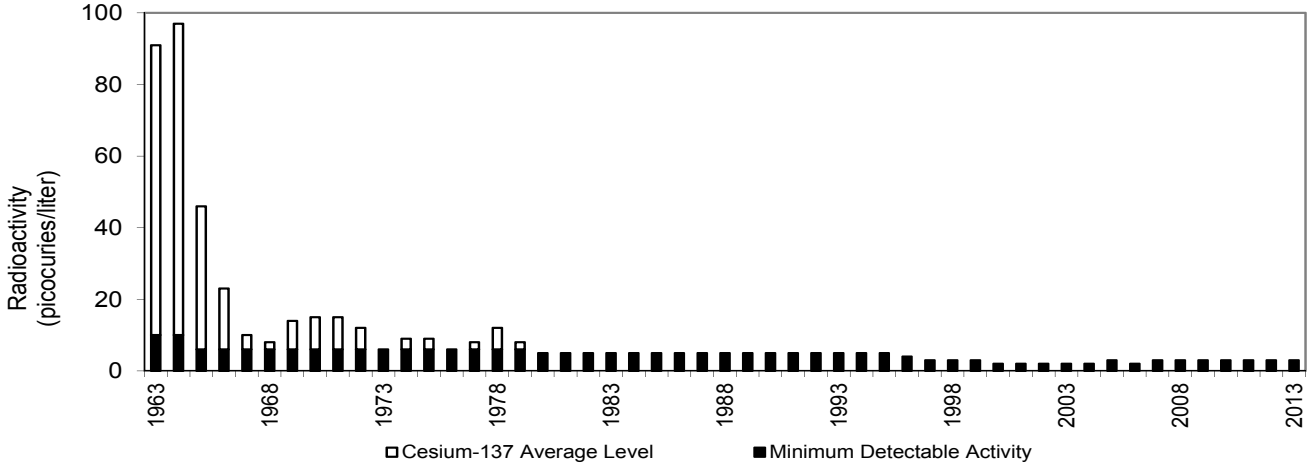


Exhibit 57. Annual Average Cesium 137 Radioactivity in Milk 1963-2013 (Lansing Milk Station)



Sanitary sewer overflows generally are discharges of untreated sewage from municipal separate sanitary sewer systems, but they can occur from non-municipal systems as well. These systems are designed to carry domestic sewage, but not storm water. When a sanitary sewer overflow occurs, untreated sewage is released into city streets and low areas – including, in some cases, parks and other areas of public contact and surface waters, such as drainage ways, streams and lakes – rather than being transported to a treatment facility. Sanitary sewer overflows are illegal and can constitute a serious environmental and public health threat.

Additional health threats occur when sewage from a public sewer system backs up into structures, such as residential basements, as a result of excess wet-weather flow in the sewer system. Other sewer-system deficiencies, such as mechanical or electrical failures at pump stations or structural failure of sewers due to age or accidents, also can result in discharges threatening the environment and public health.

In 1999 and early 2000, the DEQ identified municipalities throughout the state that experienced discharges of sanitary sewage into waters of the state. In May 2000, the DEQ announced a statewide strategy to identify and correct the discharge of untreated or inadequately treated sanitary sewage. The strategy emphasized the implementation of corrective action programs for those municipalities identified as a sanitary sewer overflow community, with the goals of eliminating illegal sanitary sewer overflows and preventing new ones from occurring. In December 2002, the DEQ adopted a statewide sanitary sewer overflow policy statement for implementation to accomplish these goals.

The DEQ is keeping the public informed of the identified overflows in their communities by posting on the Internet a listing of untreated or partially treated sewage discharges and the waters to which the discharge occurs as the reports are received. State statute requires the reporting of the discharge of untreated or partially treated sewage and the public posting.

Dischargers also are required to promptly notify local county health departments, potentially impacted neighboring municipalities and the local media of such incidents. The DEQ is taking actions to establish immediate control measures, where necessary, and require corrective action programs to eliminate illegal sewer discharges. An annual report of the discharge of untreated or partially treated sewage, identifying the quantity of sewage discharge reported and the corrective programs being undertaken, is available on the DEQ's website (www.michigan.gov/deq).

In 2013, the DEQ began an initiative to promote programs aimed at pursuing and achieving sustainable wastewater infrastructure. Such programs are referred to as asset management programs. Generally, asset management programs include the practice of managing infrastructure capital assets to minimize the total cost of owning and operating them, while delivering a desired level of service. Many municipalities throughout Michigan will be required to develop asset management programs over the coming years. Such programs will aid in both addressing existing wet-weather discharges and preventing future occurrences.

Surface Water and Beach Monitoring

All of Michigan's surface waters are designated and protected for total-body-contact recreation (swimming) from May 1 to Oct. 31. In Michigan, a water body is considered suitable for total-body-contact recreation when the number of the indicator bacteria, *E. coli*, per 100 milliliters of water is less than or equal to 130, as a 30-day geometric mean. At no time should waters protected for total-body-contact recreation contain more than 300 *E. coli* per 100 milliliters of water in any individual sample. The DEQ works in partnership with county health departments and other local entities to ensure that Michigan's surface waters are monitored for *E. coli* and protected for total-body-contact recreation.

The DEQ awards federal funds from the BEACH Act to local health departments to support *E. coli* monitoring at public beaches located

Exhibit 58. 10-Year Summary of Great Lakes Beach Monitoring

Year	Number of grants awarded	Total award amounts	Number of counties that monitored	Number of beaches monitored
2014	23	$152,000	To be determined	To be determined
2013	23	$404,124	37	239
2012	23	$180,377	38	260
2011	23	$207,539	38	262
2010	23	$204,807	38	224
2009	23	$437,986	37	225
2008	23	$ 245,719	37	208
2007	23	$ 212,766	38	205
2006	23	$ 212,766	37	207
2005	21	$ 278,157	36	197
2004	19	$ 244,873	33	204

along the Great Lakes shorelines. A summary of grant awards and monitoring information for Great Lakes beaches is shown in Surface Water and Beach Monitoring **Exhibit 58**. The number of counties that monitored beaches, and the number of monitored beaches, were supported with federal and local funds. In 2009, the DEQ supplemented the BEACH Act funds with approximately $210,000 to increase the duration of monitoring to at least 16 weeks for the majority of Great Lakes beaches. In 2013, the DEQ received $102,000 in additional federal funds that were allocated to health departments for monitoring. In 2014, $100,000 was provided for real-time beach-monitoring equipment for a new lab at the Lake St. Clair Metropark Beach.

The DEQ awards state funds from the Clean Michigan Initiative (CMI) and Clean Water Fund (CWF) to local health departments to support *E. coli* monitoring at public beaches located on inland lakes. A summary of grant awards and monitoring information for inland lake beaches is shown in Surface Water and Beach Monitoring **Exhibit 59**. The number of counties that monitored beaches, and the number of monitored beaches, were supported with CMI-CWF and local funds. From 2009, the grants were extended for a two year period, with funding availability adjusted accordingly.

The DEQ received $3.2 million in eight Great Lakes Restoration Initiative (GLRI) grants in 2010 from the USEPA, Great Lakes National Program Office, to increase monitoring frequency, conduct beach sanitary surveys and investigate potential sources of contamination at 224 Great Lakes public beaches. Several additional GLRI grants were awarded to local municipalities in 2010, 2011 and 2012 for green infrastructure improvements at beaches. The DEQ received one of these

Exhibit 59. 10-Year Summary of Inland Lake Beach Monitoring

Year	Number of grants awarded	Total award amounts	Number of counties that monitored	Number of beaches monitored
2014	15	$200,000	To be determined	To be determined
2013			35	174
2012	12	$189,938	33	163
2011			34	153
2010	14	$187,423	42	206
2009			37	189
2008	13	$ 111,500	37	259
2007	13	$ 100,000	38	269
2006	10	$ 117,576	40	233
2005	11	$ 100,000	33	209
2004	9	$ 100,000	41	290

GLRI grants in 2012 to improve two beaches in Chippewa County.

E. coli monitoring, notification and location data for beaches are reported by local health departments to BeachGuard, the DEQ's beach-monitoring website. Annually, 3 to 4 percent of the daily samples exceed daily standards at 24 percent of the monitored beaches. Increases or decreases in these percentages over the years tend to be a reflection of the monitoring strategies and beach-remediation projects. The percentage of beaches open in 2003 was 90 percent, but fell to 72 percent in 2011 and went back up to 80 percent in 2013. The increased exceedances were due in part to improved monitoring efforts, especially at beaches with historical contamination. The GLRI funds in 2011 supported intensive monitoring to identify sources of contamination at Great Lakes beaches with known or suspected water-quality problems. In 2013, sources of contamination were identified, corrected and eliminated for at least 10 beaches with historical pollution. The Water Resources Division (WRD) will continue working with local communities to identify sources of contamination and implement corrective actions to restore water quality. As mentioned, the WRD provided funds in 2014 for real-time beach-monitoring equipment for a lab at the Lake St. Clair Metropark Beach. The DEQ budget for 2015 included $500,000 for the WRD's effort to expand the use of real-time beach-monitoring equipment for more communities in Michigan. A summary of the beach-monitoring data is shown in Surface Water and Beach Monitoring **Exhibit 60**.

Conservation Reserve Enhancement Program

The DEQ has been working closely with the MDARD to implement a federal/state/local conservation partnership program, referred to as the Conservation Reserve Enhancement Program (CREP), to reduce significant environmental effects related to agriculture. Michigan is implementing conservation practices under the CREP in four critical watersheds (Saginaw Bay, Macatawa, River Raisin and Western Lake Erie Basin) that have intense agricultural land use. The objectives of the program are to improve and protect water quality and to promote and enhance wildlife habitat by providing incentives to Michigan citizens for implementing conservation practices for a period of 15 years. Eligible conservation practices include filter strips, riparian buffer strips, field windbreaks and wetland restorations. The DEQ has agreed to supply CMI-CWF monies and CMI-Nonpoint Source (NPS) Pollution Control funds for the establishment of a livestock exclusion program, cost share for the implementation of Natural Resources Conservation Service-approved conservation practices, technical assistance from conservation districts in the CREP watersheds and permanent conservation easements.

CREP conservation practices are currently being applied on over 74,700 acres that are either under contract or pending in Michigan. The goal for Michigan is to implement CREP practices on 85,000 acres in the four watersheds.

Over $7.5 million in CMI funds were awarded and utilized to acquire permanent conservation

Exhibit 60. Summary of *E. coli* data for Beach Monitoring Program

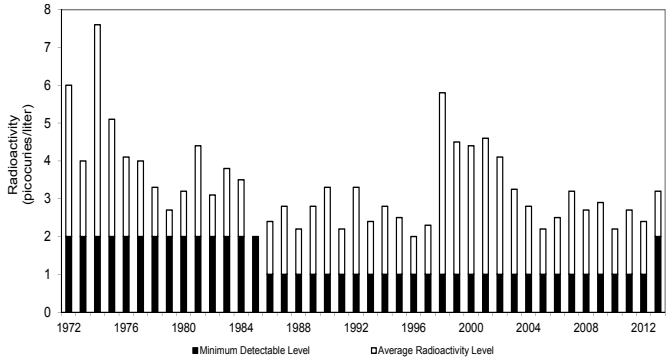
Description	2008	2009	2010	2011	2012	2013
Counties with beach monitoring programs	57	57	59	55	56	51
No. of daily mean *E. coli* samples collected	5,435	5,921	5,194	6,128	5,801	4,958
No. of samples exceeding the daily standard	154	212	209	266	224	162
% of samples exceeding the daily standard	2.8%	3.6%	4.0%	4.3%	3.9%	3.3%
Beaches with *E. coli* samples collected	467	414	430	415	423	413
No. of beaches exceeding the daily standard	75	83	108	124	114	98
% of beaches exceeding the daily standard	16%	20%	25%	30%	27%	24%

easements on 5,473 acres for CREP practices. The funds resulted in 72 permanent conservation easements, covering 460 acres of filter strips, 3,062 acres of restored wetlands and 1,951 acres of riparian buffers protected.

Surface Water Radiation Monitoring

The DEQ is responsible for monitoring the potential for environmental impact from the operation of nuclear power plants in Michigan. One of the factors monitored is the level of radiation associated with nearby surface water. Surface-water radioactivity averages have remained in the natural background range of one to six picocuries per liter since the inception of the monitoring program in 1972. A level of concern would be an annual average exceeding 50 picocuries per liter. **Exhibit 61** shows the annual radioactivity measurements for the monitoring stations near the Fermi Nuclear Power Plant. These results are representative of what has been measured at the other nuclear power-plant locations in Michigan. Annual reports on the overall quality of the radiological environment may be obtained by contacting the DEQ.

Exhibit 61. Annual Average Surface Water Radioactivity 1972-2013 Fermi Reactor Site



The DEQ oversees approximately 11,000 community and noncommunity public water systems by emphasizing prevention, early detection and correction of sanitary defects. Community water systems are those systems furnishing drinking water year-round to residential populations of 25 or more. Noncommunity water systems are public water systems serving 25 or more people (non-residents), 60 days or more per year and include campgrounds, restaurants, schools, churches, child care centers and businesses with their own water supply.

In Michigan, there are approximately 1,400 community public water systems serving over 7.6 million residents, or approximately 76 percent of the state's population. The remaining residents rely upon household wells. Of the 1,400 community public water systems, almost 1,100 rely solely upon groundwater as their source. Although the majority of community systems rely upon groundwater, these systems only serve 1.8 million residents, or about 20 percent of the state's total population. The remaining 5.8 million people served by a community public water system receive their drinking water from the Great Lakes and connecting channels or from inland rivers and lakes. Approximately 60 community systems have one or more intakes in one of these surface waters, with the remaining systems purchasing water from one or more of these surface-water systems.

The Public Water Supply Supervision (PWSS) Program provides regulatory oversight for public water systems to assure that drinking water meets the standards established in the federal and Michigan Safe Drinking Water Acts (SDWA). This assurance is provided primarily through a technical assistance program of conducting frequent on-site visits and periodic sanitary surveys, performing plan review to assure proper design and operation, training and certifying operators and managers, establishing monitoring and reporting requirements, and implementing emergency response activities. In addition, the PWSS Program promotes wellhead and source-water protection activities to protect drinking water supplies from potential contamination; implements a capacity-development program to assure public water systems have adequate technical, financial and managerial capabilities; and more recently, ensures adequate security measures, including response plans, are in place.

In addition to conducting routine visits, DEQ completes a comprehensive sanitary survey of each public water system every three years for

community systems and every five years for noncommunity systems. These surveys assess the ability of the water supply system to produce, treat and distribute adequate quantities of water meeting the drinking water standards. They are an in-depth analysis of the water system's physical facilities, operational condition, capacity to reliably supply customer demands, maintenance programs, monitoring programs, staffing levels, compliance record, condition of the distribution system and storage tanks, security measures and source-water protection program. Upon completion, conclusions and recommendations are provided to the system, and mutually acceptable schedules to complete necessary improvements are developed and implemented.

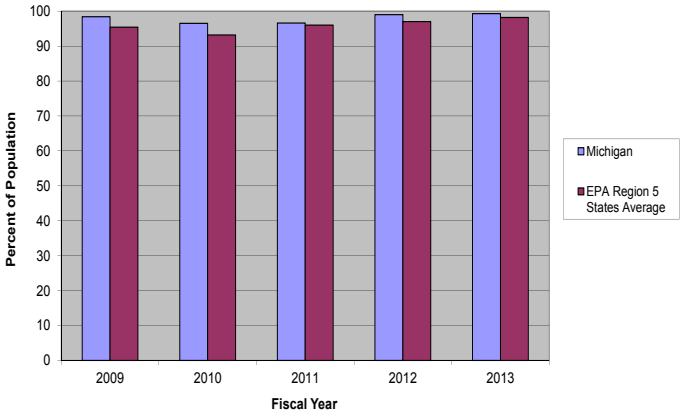
Public water systems are also required to have trained and certified operators in accordance with state law. The DEQ recognizes that competent operators are critical to identifying potential problems and making corrections before public health problems develop. The DEQ also establishes monitoring requirements for community drinking water systems based on vulnerability and source-water assessments.

All of these proactive practices have proven successful in minimizing public health threats originating from public water systems in Michigan, and for the most part, allowed any threats that do occur to be minimized, the impacts on the customers to be mitigated and the problem to be promptly resolved.

Nevertheless, microbiological, chemical and radiological contaminants can and do enter water supplies. These contaminants may be produced by human activity or occur naturally. For instance, chemicals can migrate from disposal sites or underground storage systems and contaminate sources of drinking water. Animal wastes, pesticides and fertilizers may be carried to lakes and streams by rainfall runoff or snow melt. Nitrates from fertilizers also can be carried by runoff to streams and lakes or percolate through soil to contaminate groundwater. Arsenic and radon are examples of naturally occurring chemical contaminants that may be released into groundwater as it travels through rock and soil formations.

The health effects of exposure to contaminants in drinking water vary depending on many factors, including the type of contaminant, its concentration in drinking water and how much contaminated water is consumed over what period of time. As of 2014, more than 90 contaminants are regulated in drinking water under the federal and state SDWA. Additional contaminants also are regulated by requiring certain treatment techniques to be applied if monitoring of the source water indicates potential for contamination. For example, if a surface-*water source is deemed vulnerable to Giardia or Cryptosporidium cysts that may originate f*rom animal activity within a watershed, treatment methods such as disinfection and filtration become mandatory. These treatment

Exhibit 62. Percent of Population Served by Community Water Supplies Meeting Health-Based Standards



techniques also remove a wide number of other microbiological parameters that could impact public health.

The DEQ maintains data on community and noncommunity water supplies that receive drinking water meeting all health-based standards. These data are derived from state reports of drinking-water violations to the USEPA's national data system. Since the first quarter of 2009, the percentage of the population served by community water systems meeting all health-based standards over the most recent five-year period ranged from a low of 96.5 percent to as high as 99.3 percent **(Exhibit 62)**. The DEQ

delegates inspection, monitoring, oversight, permitting and enforcement of the more than 9,500 noncommunity water systems to the local health departments.

Source Water Protection

In recent times, water-quality concerns have shifted largely from a focus on waterborne illnesses to a focus on prevention and management of contamination of drinking water sources and impairment of recreational waters, coastal and beach pollution, and the cleanup of legacy contaminated sites. County and local health departments, as well as the state and federal government, vigilantly focus on safe drinking water; these systems are well-established, and programs are practiced with diligence and effectiveness. However, there are still new challenges arising every day – new toxins are identified, new treatment technologies must be evaluated, new threats to drinking water sources are discovered, new regulatory standards need to be developed and aging infrastructure needs to be replaced.

The 1986 amendments to the federal SDWA recognized the benefit of protecting drinking water sources and directed states to develop Source Water Protection Programs (SWPP). Since then, the DEQ has made a concerted effort to promote SWPP for public water systems. In Michigan, SWPP are voluntary programs implemented on a local level through the coordination of activities by local, county, regional and state agencies.

SWPP are separated into programs for surface-water sources, called Surface Water Intake Protection Programs (SWIPP) and those for groundwater systems, called Wellhead Protection Programs (WHPP). For drinking-water systems that rely upon surface-water sources like the Great Lakes or inland rivers, the source-water protection area is referred to as the Critical Assessment Zone (CAZ). The CAZ is established using the Great Lakes Protocol that factors in a number of criteria, such as the distance from shore and the depth of water above the intake. For a groundwater system, protection is provided by identifying the area that contributes groundwater to the public water supply wells, identifying sources of contamination within that area, and developing methods to manage the area and minimize the threat to the PWSS. The area that contributes groundwater to the well(s) is referred to as the wellhead protection area (WHPA), which is the capture zone established using pumping capacity, hydraulic characteristics of the aquifer and a 10-year time of travel.

Both SWIPP and WHPP consist of essentially the same fundamental elements. For publicly owned water systems, a SWPP is expected to address the following concepts:

- Defining roles and duties of government units and water-supply agencies.
- Designating a source-water protection area for each water-supply source based on the state's defined source-water area (CAZ for surface waters, WHPA for groundwater sources).

Identifying potential contaminant sources within each source-water protection area.

- Utilizing management approaches for protection of source water, including but not limited to education and regulatory approaches.
- Creating contingency plans for public water-supply sources, including the location of alternate drinking-water sources.
- Assuring proper siting on new water sources to minimize potential contamination.
- Encouraging public participation.

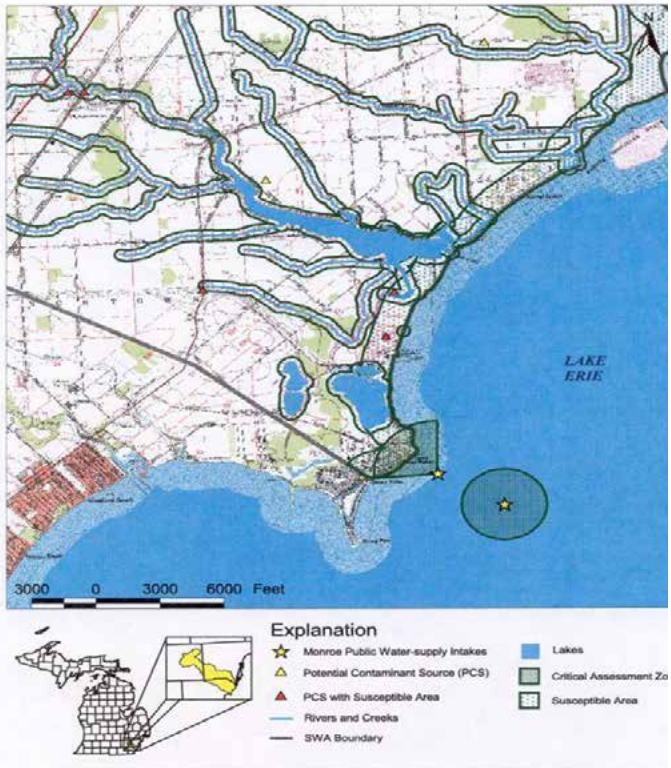
Once a source-water protection area has been established, the water system may focus attention and prioritize protection/prevention activities on this area. The water system may apply various strategies to minimize adverse impacts on the drinking-water source through zoning, permitting, inspections and land-use planning in an attempt to prevent new sources of possible contamination from being located in this area.

Exhibit 63 depicts the CAZ for the two intakes that serve the Monroe and Frenchtown Township water treatment plants. When a CAZ intersects the shoreline, as it does for one of these intakes,

substantially more effort is required to identify the contributory area because it requires an assessment of known or expected discharges to the water body along that shoreline. It may include entire watersheds if the discharge is somewhere along that shoreline within the CAZ. Water systems then have to search for potential contaminant sources throughout that watershed to be prepared for the possibility of spills, leaks, losses and permitted discharges that could impact the water quality entering the intake.

Exhibit 64 depicts the wellhead capture zone for a typical groundwater source that illustrates the difference in the WHPA when compared to the historic approach of using a radial distance. With a scientifically based delineation or WHPA, the water system can focus attention on and prioritize protection activities on the area that actually contributes water to its well(s) instead of the full area of a circle that was established using

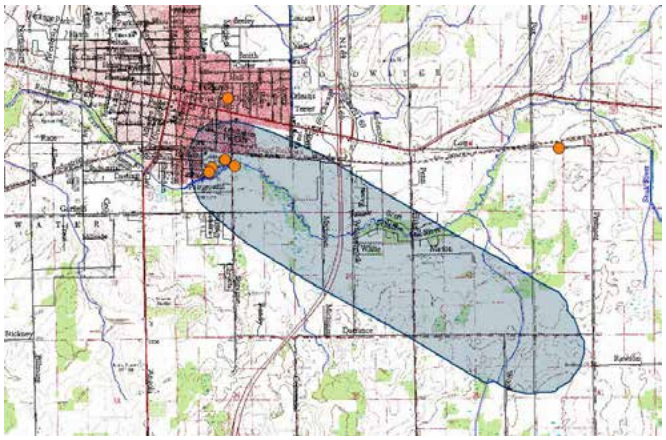
Exhibit 63. Critical Assessment Zones for Surface Water Intakes



a radial distance, where much of that area was not contributing water to the well.

To promote scientifically based WHPP, the DEQ has contracted with Michigan State University and the USGS to develop and enhance the Michigan

Exhibit 64. Typical Wellhead Protection Area



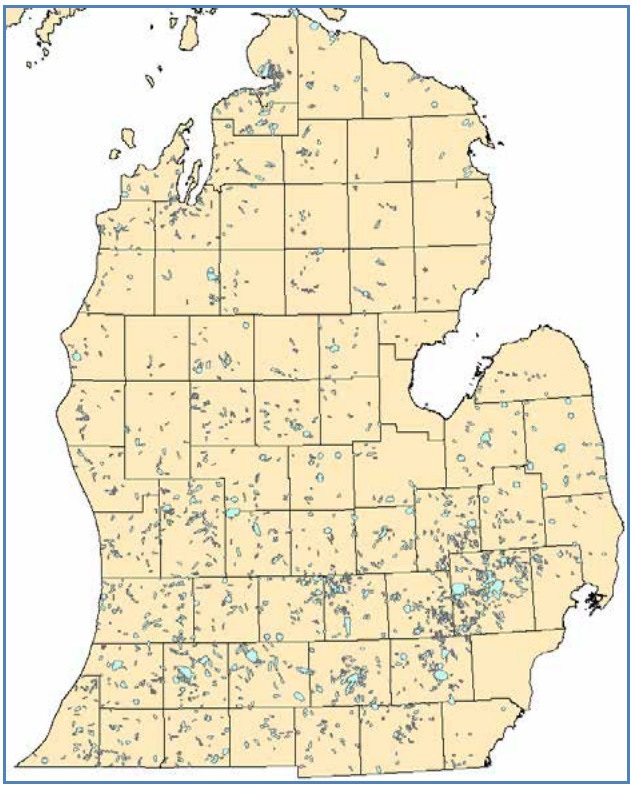
Groundwater Management Tool (MGMT). MGMT allows for the creation of "provisional" groundwater delineations, calculated by using existing information already collected and stored in state databases. They are called provisional delineations to differentiate them from traditional delineations created through field-testing and observations. The DEQ has been providing these provisional delineations to community water systems that have not initiated a WHPP, and to certain noncommunity public water systems. Municipal systems are encouraged to use this information to initiate a formal, comprehensive WHPP. Non-municipal public water systems – such as manufactured housing communities, apartment complexes, schools, etc. – have been urged to use this information to focus on surveying their provisional wellhead capture zone for potential contamination sources, to remove these sources if under their control, to educate adjacent property owners about the potential threat, and to inform local planning and zoning officials of the need to protect this area from possible future sources of contamination.

Before MGMT was capable of providing provisional delineations, less than 1 percent of Michigan's total land area had been identified as being located in a WHPA or capture zone. With the expanding functionality of MGMT, the DEQ has been able to create WHPAs for hundreds of systems that had not initiated field studies to do so. **Exhibit 65** indicates the location of wellhead protection areas for community and noncommunity public water systems throughout Michigan's Lower Peninsula, including many

delineations created by MGMT. These delineations or WHPAs now occupy 2.5 percent of the total state land area.

While 2.5 percent of the state's total land area may not seem significant, there are some counties in Michigan where there is a much larger proportion

Exhibit 65. Wellhead Protection Areas in the Lower Peninsula. Total number of Michigan WHPAs: 2664 covering 2,415.68 square miles. WHPAs as percentage of total Michigan Land Area - 2.498 percent



of land area that falls within a wellhead capture zone and for which protection activities should be a priority. **Exhibits 66 and 67** illustrate Oakland and Ingham Counties, with WHPAs that occupy 27 percent and 14 percent of the respective county's total land area. Other counties where significant land area has been identified as falling within the wellhead protection area for a public drinking water source are Livingston County (16 percent) and Kalamazoo County (13 percent). These maps can be used by local planning, zoning and land-use agencies, as well as by other regulatory programs, when decisions are being made about future uses and permitted activities that could threaten groundwater quality.

While some environmental contamination sites are being actively cleaned up to residential criteria, many are performing limited closures by putting safeguards in place, such as engineering or institutional controls. Limited closures with contamination remaining, some inside of wellhead protection areas, have the potential to impact public water systems. If limited closures are applied without consideration of WHPAs, there is an increased likelihood for contamination to impact public water supplies.

Contamination Investigation

Each year the DEQ continues to provide safe drinking water to families or businesses with

Exhibit 66. Wellhead Protection Areas - Oakland County. Total WHPAs: 238 covering 245 square miles; Total Land Area: 906.6 square miles. WHPAs as percentage of Oakland County Land Area - 27%

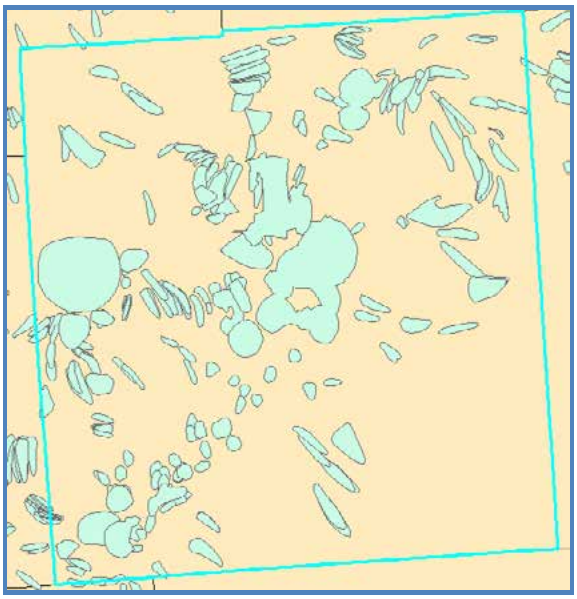
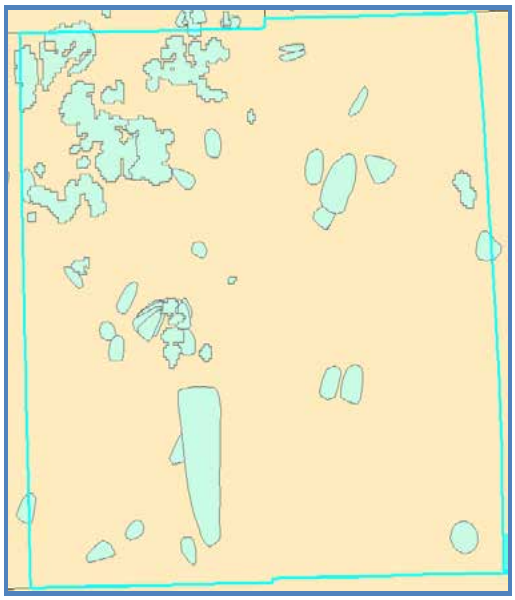


Exhibit 67. Wellhead Protection Areas - Ingham County. Total WHPAs: 53 covering 78.4 square miles; Total Land Area: 560.3 square miles. WHPAs as percentage of Ingham County Land Area - 14%



contaminated, private residential water wells when no viable, liable party is able to address the contamination. Since 1985, the department has spent about $100 million providing safe drinking water to Michigan residents whose well water is contaminated or threatened. DEQ actions at such sites have included:

- Supplying affected homes/businesses with bottled water;
- Sampling, monitoring or replacing impacted drinking-water wells;
- Providing hook-ups to municipal water when multiple private wells are tainted; and
- Helping to build new basic community water-supply systems when no feasible alternative is available.

The above corrective-action projects have ranged in cost from a few thousand dollars to as high as several millions of dollars, have taken anywhere 69 a few days to multiple years to fully address problems, and have assisted thousands of people since 1985.

There are numerous sites of environmental contamination throughout the state where drinking-water wells are contaminated, or threatened with contamination, from man-made chemicals. In many cases, the state has funded replacement wells or connections to community water. In certain circumstances when there are no readily available options, the state has provided and continues to provide bottled water to impacted residences until long-term solutions can be found to resolve the matter.

In other cases, the contaminants in drinking water are found at levels below current drinking-water standards. It is important for the state to provide regular monitoring of the contaminated, vulnerable and threatened wells, to determine changes in water quality and continue to assess the need for water-supply replacement. In fiscal year 2014, $330,000 was spent on the monitoring of private drinking-water wells near 191 sites of contamination where imminent threats exist from groundwater contamination in which the well owner did not cause the problem. Within that funding allotment is a small fund to support drinking-water sample collection to investigate potential drinking-water contamination problems not yet associated with an established site. The DEQ creates annual contracts with most Michigan local health departments where threatened drinking water wells are located within the 191 sites of known groundwater contamination.

Arsenic

One contaminant that recently has presented a significant challenge for drinking-water supplies in Michigan is arsenic. Arsenic is an element that occurs naturally and is widely distributed in the Earth's crust. It is usually found in the environment combined with other elements such as oxygen, chlorine and sulfur. Arsenic combined with these elements is referred to as inorganic arsenic. Arsenic combined with carbon and hydrogen is referred to as organic arsenic. Organic arsenic is less of a health concern than inorganic arsenic. The most common form of human exposure to arsenic is from groundwater used for drinking or cooking.

How arsenic affects humans is not fully understood. Common symptoms include thickening and discoloration of the skin, as well as stomach pain, nausea, vomiting and diarrhea. It also may cause numbness in the hands and feet. Many of the symptoms of exposure to high levels of arsenic also are seen with other common illnesses, which makes it difficult for physicians to recognize. Some people may be affected by lower levels of arsenic, while others remain unaffected. Young children, the elderly, people with long-term illnesses and unborn babies are at greater risk, since they can be more sensitive to chemical exposures. Babies are not exposed to arsenic through breast milk at levels of concern even when their mothers have been exposed.

In 2001, the USEPA promulgated a revised arsenic standard, reducing the maximum contaminant level (MCL) from 50 to 10 micrograms per liter. The effective date for this revised standard was five years later, in January of 2006. Michigan had a relatively high number of public systems impacted by this revised arsenic standard, ranking second among all states.

Approximately 120 community water systems exceeded this revised standard, with all but a few serving less than 3,300 residents. Many of these systems are non-municipal systems, such as manufactured-housing communities, apartment complexes, condominium developments, subdivisions, etc. As of June 30, 2014, all but four community systems have achieved compliance by replacing their source, consolidating with an adjacent system or constructing treatment facilities. The remaining noncompliant systems are either following a compliance schedule established in a consent order or just recently exceeded the MCL and are evaluating alternative solutions. These systems periodically provide public notice to remind customers about the health threat.

Exhibit 68. Levels of Arsenic by County

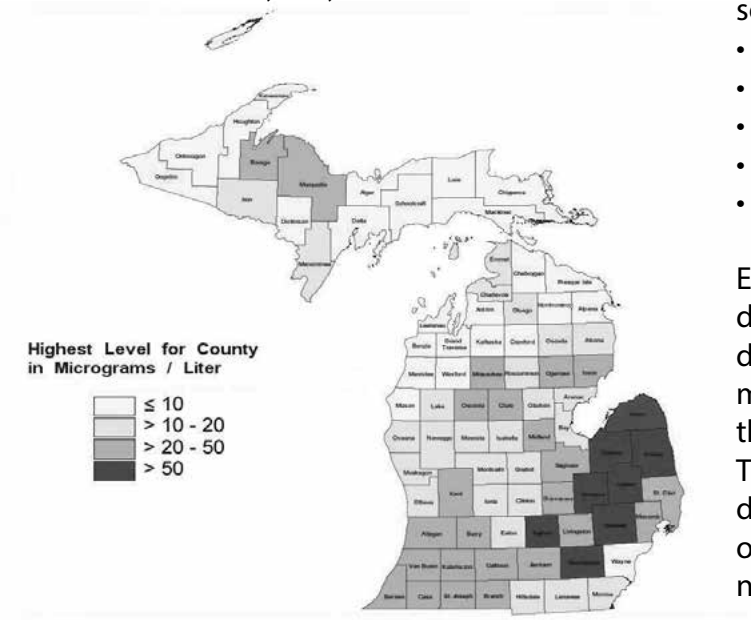


Exhibit 68 presents groundwater arsenic levels from Michigan counties that were based on results available approximately 10 years ago. Naturally occurring arsenic levels don't change much over time, so the map continues to highlight areas where elevated levels may be encountered. More precise locations of the sample locations within each county may be found on the DEQ's website (www.michigan.gov/documents/deq/deq-wd-gws-ciu-statewide-as_270812_7.pdf). Private well-owners in areas where arsenic levels are known to be elevated may contact their local health department to determine if sampling their well may be appropriate.

Nitrate

Another contaminant that continues to pose a problem for drinking-water supplies is nitrate, a form of nitrogen combined with oxygen. It can be converted in the body to nitrite. The major adult intake of nitrate is from food rather than water, but sometimes excessive amounts of nitrate get into drinking water.

Nitrate can get into drinking water if a well is improperly constructed or located where it is subject to contamination sources. Shallow water wells in sandy, unconfined aquifers are more vulnerable to nitrate contamination than deeper wells protected by overlying clay strata. Nitrate also can get into surface-water intakes in rivers and lakes that are subject to agricultural runoff and discharges of untreated sewage. Typical sources of nitrate contamination include:

- Wastes from livestock operations;
- Septic tank/drainfield effluent;
- Crop and lawn fertilizers;
- Municipal wastewater sludge application;
- Natural geologic nitrogen.

Elevated nitrate in drinking water can cause a disease called methemoglobinemia, a blood disorder primarily affecting infants under six months of age. Methemoglobinemia reduces the ability of the red blood cells to carry oxygen. The acutely poisoned person will have a blue discoloration of the skin due to the reduction of oxygen in the blood. The condition can be fatal if not immediately attended to by a physician.

The USEPA has established a drinking-water maximum contaminant level for nitrate (as nitrogen) at 10 milligrams per liter and nitrite at 1 milligram per liter. Michigan has adopted these standards.

Private homeowners who find that they have excessive nitrate or nitrite levels should contact their local health department. Although nitrate can be removed from drinking water using a complex process, it is generally recommended that an alternate source of drinking water be developed, away from any contaminating sources, and that bottled water be used for preparing

infant formula. Further consultation with the local health department may be needed to develop more permanent, longer-term alternatives.

Exhibit 69. Nitrate Location Map

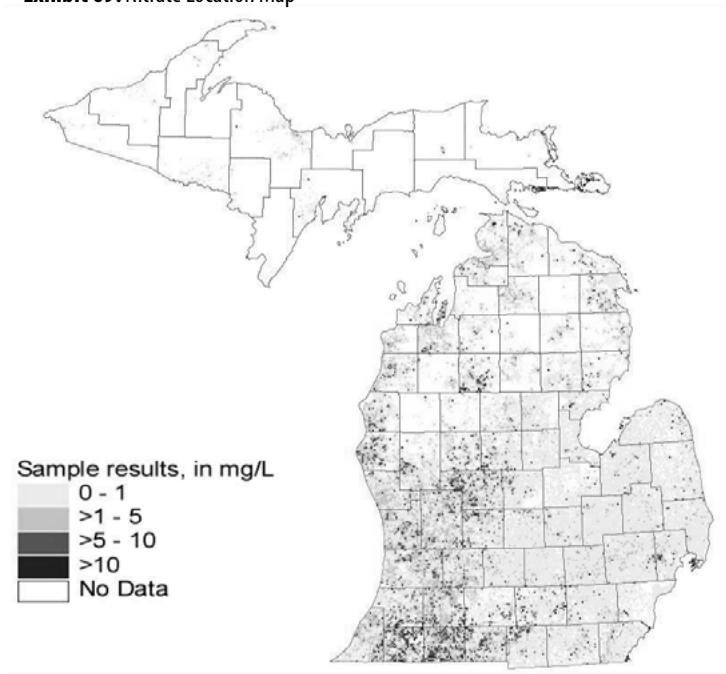


Exhibit 69 graphically presents averaged nitrate levels in groundwater from Michigan counties. Like the arsenic map, this one was also based on results available approximately 10 years ago. While nitrate levels may increase or decrease over time depending upon the source, this map continues to illustrate where elevated levels may be encountered. More precise locations of the sample locations within each county may be found on the DEQ website (www.deq.state.mi.us/documents/deq-wd-gws-ciu-no3.htm).

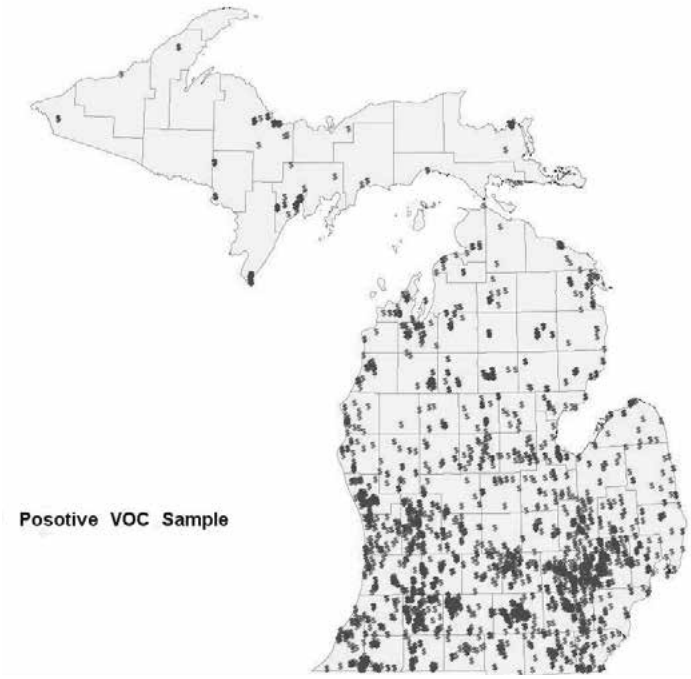
Volatile Organic Chemicals

When found in drinking water, the source of VOCs is generally associated with an industrial solvent release, a fuel spill and leak, landfill leachate, chemical transportation spill, illegal waste disposal, agricultural applications, etc. VOCs do not occur naturally in groundwater.

Twenty-one VOCs that pose a physical and/or biological risk to drinking-water resources are currently monitored by the DEQ. **Exhibit 70** presents the location of groundwater samples from Michigan counties where the volatile organic chemicals have been found. More precise locations of the sample locations within each county may be found on the DEQ website (www.deq.state.mi.us/documents/deq-wd-gws-ciu-voc.htm).

Currently, the DEQ is working with the USGS and Michigan State University to link groundwater-quality data currently held in various state databases with well-construction and -location databases to provide up-to-date mapping capabilities for a range of chemical parameters including arsenic, nitrate, and other inorganic and organic compounds. This effort should be completed in 2015.

Exhibit 70. Volatile Organic Chemical Locations



Pharmaceuticals and Personal Care Products

Another issue that has the attention of the media and some segments of the public is Pharmaceuticals and Personal Care Products (PPCPs). PPCPs have been found at trace levels in some drinking-water supplies throughout the country, including Michigan. PPCP, in general, refers to any product used by individuals for personal health or cosmetic reasons or used by agribusiness to enhance growth or health of livestock. PPCPs comprise a diverse collection of thousands of chemical substances, including prescription and over-the-counter therapeutic

drugs, veterinary drugs, fragrances and cosmetics. Detection of these compounds at very low levels (parts per trillion) have not been considered to be a human health concern, although studies are ongoing.

One of the primary routes by which PPCPs have made their way into drinking-water supplies is through discharges from wastewater-treatment plants. These waste-treatment facilities are not

designed to remove such compounds. As a result, many PPCPs that enter the wastewater system – either by normal bodily excretion or improper disposal of unused medication – show up in the plant discharge and, from there, make their way into drinking-water sources.

Drinking-water treatment plants typically do not perform these types of analyses, and the DEQ does not require drinking-water treatment plants to test for them. Current research suggests that granular activated carbon, powdered activated carbon and ozone are effective in removing many PPCPs from the water. These treatment processes are currently in use by some drinking-water treatment plants in Michigan, but not because of PPCPs. If research suggests that even these low levels of pharmaceuticals could be a health concern, these available treatment processes could be utilized more widely. However, adding treatment for PPCPs at drinking water facilities will be expensive and would only reduce, not eliminate, the concentrations of PPCPs.

USEPA has a long-standing procedure to identify and evaluate unregulated substances such as PPCPs to determine if these compounds should be regulated. The system is referred to as the Contaminant Candidate List and the Unregulated Contaminant Monitoring Regulation. The DEQ believes this existing process should be allowed to serve its function and not unnecessarily elevate PPCPs for consideration above other contaminants of concern that may have greater justification for possible regulation.

Cyanobacteria and Microcystin

Blue-green algae, otherwise known as cyanobacteria, are microscopic organisms found naturally in surface water and typically grow in lakes, ponds and slow-moving streams. In recent years, they have become a greater problem in some surface waters that serve as a source of drinking water for Michigan residents, such as Lake Erie. True algae and blue-green algae both utilize some form of chlorophyll to perform photosynthesis and produce oxygen. True algae are essentially plants, while blue-green algae are actually bacteria that exhibit a blue or green color, similar to true algae, but contain cellular structures typical of bacterial cells. True algae and blue-green algae are very different organisms and therefore should not be treated the same.

Environmental conditions that can promote the growth of blue-green algae include ample sunlight, warm weather, low turbulence and high levels of nutrient, particularly phosphorous. Once established, blue-green algae possess several traits that contribute to their success in aquatic environments, such as the ability to

regulate their buoyancy. Buoyancy regulation allows cyanobacteria to obtain ideal amounts of nutrients and sunlight, and is the reason why colonies are often observed at the water surface and as scum layers. They also possess the unique ability to utilize atmospheric nitrogen as a nutrient source when at the water surface, thus giving them a competitive advantage over other algae. Blue-green algal blooms can arise quickly and are highly visible, often appearing as a blue-green paint sheen or scum at the water surface. These blooms can be aesthetically displeasing, and wind-driven accumulations on shorelines can cause significant odors as the algae decay.

There are no known harmful toxins released by dying true algae. Blue-green algae, however, can contain harmful toxins within the cell wall that may be released as part of their natural life cycle during cell growth or death. Some species of blue-green algae can produce toxins, including neurotoxins (nervous systems), hepatotoxins (liver) and dermatotoxins (skin irritant), cytotoxins and compounds that affect the gastrointestinal tract. Ingestion of these toxins can have both acute and chronic effects and can result in illness and, in rare instances, even death of humans and animals.

In general, the most effective way to remove algal toxins is while they are still encased within the intact algal cells. Once toxins are released from the cells, they are much more difficult to remove, so the most efficient and cost-effective method for toxin removal includes optimization of current treatment processes for cell removal.

The goal of drinking-water treatment for potable use is undisruptive transport, removal and disposal of healthy, intact blue-green algal cells. Each treatment process at drinking-water treatment plants susceptible to blue-green algae is evaluated for cell-removal performance and optimized to mitigate the risk of cell breakthrough and/or release of dissolved toxins (microcystin).

Michigan water systems that rely upon surface-water sources with the greatest vulnerability to blue-green algae include those using Lake Erie and the lower Saginaw Bay. The City of Monroe and Frenchtown Township share an intake in Lake Erie. As part of a Real Time Monitoring System, the DEQ purchased and installed a blue-green algae probe at this intake that allows these two water systems to continuously monitor the concentration of this organism entering their treatment plants and apply the appropriate treatment methods when levels increase. Sampling and analysis for microcystin can be performed when blue-green algae concentrations increase, and appropriate treatment and precautions can be initiated.

The only intake in the lower Saginaw Bay vulnerable to blue-green algae serves Bay City and its customers. This intake will be replaced in 2016 by connection to the raw water supply serving the cities of Saginaw and Midland that comes from an intake located north of Whitestone Point, an area of Lake Huron that has not been susceptible to algal blooms.

Water Diversions and Consumptive Use

Under the Great Lakes Charter of 1985, the governors of the Great Lakes states and the premiers of the Canadian provinces of Ontario and Québec notify and consult with each other on proposals for diversions and consumptive uses of waters within the Great Lakes Basin of over 5 million gallons per day. Additionally, the governors have direct authority over the waters of the Great Lakes within the United States through the federal Water Resources Development Act of 1986, as amended. Under this act, no bulk export or diversions of water from the Great Lakes Basin

can take place without the unanimous approval of the Great Lakes governors.

On Dec. 13, 2005, the Great Lakes governors and premiers signed agreements that provide unprecedented protections for the Great Lakes-St. Lawrence River Basin. The agreements include the Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement, which is a good-faith agreement among the Great Lakes states, Ontario and Québec that is implemented in Ontario and Québec through provincial laws and in the states through the Great Lakes-St. Lawrence River Basin Water Resources Compact (Compact).

The Compact includes the following points:

1. Sustainable use and responsible management of Great Lakes Basin waters;
2. Banning (with some limited exceptions) of new diversions of water from the Great Lakes Basin;
3. Use of a consistent standard to review proposed uses of Great Lakes Basin water;
4. Development of regional goals and objectives among the Compact members for water conservation and efficiency;
5. Improved collection and sharing of technical data among the Compact members; and
6. Continued public involvement in the implementation of the agreements.

On July 9, 2008, the Great Lakes States completed ratification of the Compact. The president signed the legislation into law, and it came into force on Dec. 8, 2008.

Michigan's statute to implement the Compact is Part 327, Great Lakes Preservation, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. New or increased water withdrawals over 100,000 gallons per day must be authorized by an online Water Withdrawal Assessment Tool or a site-specific review by the Department of Environmental Quality before the withdrawal is placed into operation. Water withdrawals over 2 million gallons per year must be authorized by a permit issued under Part 327.

Exhibit 71 Diversions and Consumptive Use

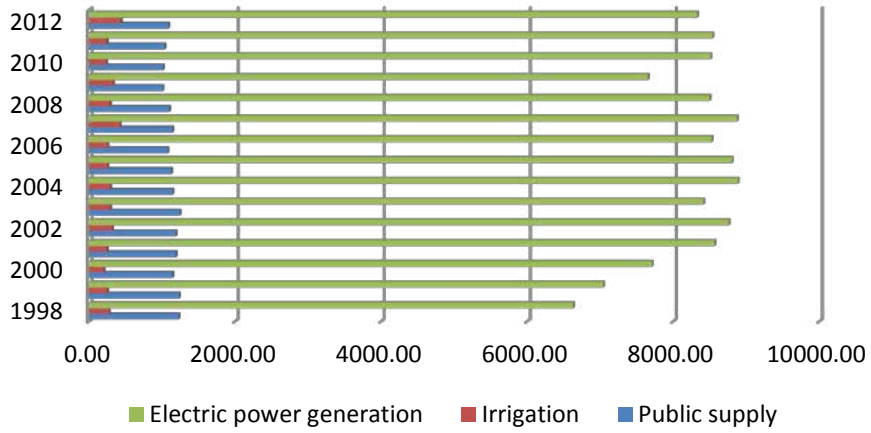
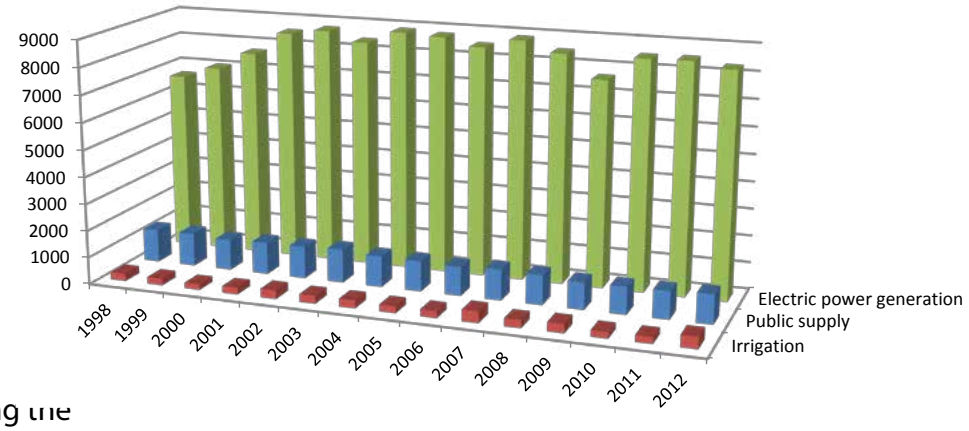


Exhibit 72 Water Withdrawals



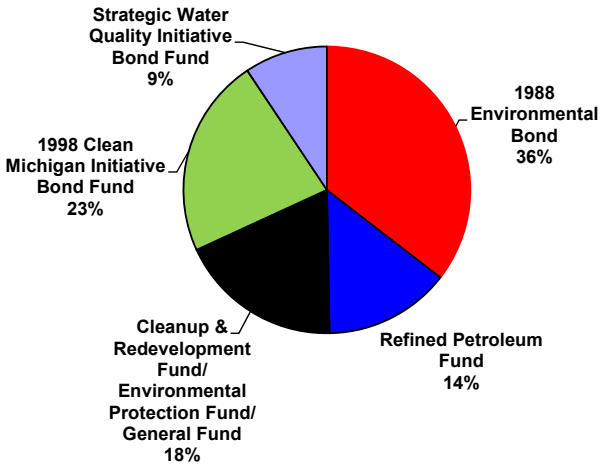
Water Diversions and Consumptive Use **Exhibit 71** is a table showing water withdrawals (in million gallons per day) between 1998 and 2012 (the most recent year available) for the electric power generation, public water supply, and agricultural irrigation sectors. Water Diversions and Consumptive Use **Exhibit 72** is a bar graph showing the water withdrawals (in million gallons per day) for these sectors between 1998 and 2012. No clear trends emerge for water use by these sectors during this time period.

Land Quality

Environmental Cleanups

Remediation (cleanup) of environmentally contaminated land is accomplished through state-funded actions and through actions conducted by liable parties and property owners. The sources of public funds that have been used for cleanup since 1989 are shown in **Exhibit 73**. Prior to passage of the CMI in November 1998, the DEQ cleanup program was funded primarily by an Environmental Bond approved in 1988. Most of the 1988 Environmental Bond money was directed

Exhibit 73. Environmental Cleanup Funding Sources 1989-2013



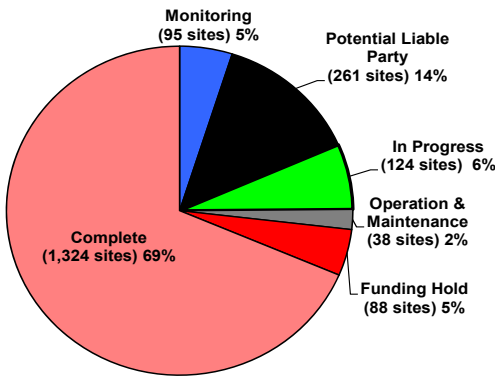
at performing cleanups to protect public health and the environment. Under the 1998 CMI, the primary focus was preparing contaminated sites for redevelopment. The Refined Petroleum Fund is used to address contamination from leaking underground storage tanks, and the Strategic Water Quality Initiatives Fund is used to address existing or imminent unacceptable water-quality risks arising from conditions that contribute to nonpoint source pollution.

A total of $335 million was earmarked from the CMI Fund for cleanup of environmentally contaminated sites, including leaking underground storage tank sites prior to 2006. To date, $320 million of the total has been appropriated as follows: $226 million for work on redevelopment-related projects and to address serious health and environmental problems at contaminated sites that lack redevelopment potential; $8 million dollars for local units of government to address municipal landfills on the federal Superfund National Priorities List (NPL); $75 for Brownfield Redevelopment grants and loans to local units of government for response activities at contaminated sites as needed to facilitate redevelopment – to date, 73 grants and 54 loans have been awarded, and $22 million is currently available for new awards; and $11 million for administrative support costs. In addition to the $335 million, another $50 million from the CMI Fund has been awarded to 72 grant projects through a competitive grant process for waterfront improvements to promote economic development and public access to the waterfront. Since 2006, $143 million has been appropriated from the RPF to address contamination caused by leaking underground storage tanks. Since 2011, $94 million has been appropriated from the SWQIF to address contamination that has contributed or, if left unaddressed, will contribute to nonpoint source pollution.

The DEQ also works with the EPA to oversee cleanups at federal Superfund sites on the NPL. Since Michigan began nominating sites for inclusion on the NPL, the state has leveraged $340 million in federal monies for investigations and cleanups.

A total of 1,930 sites have been targeted for cleanup with public funds, beginning with the 1988 Environmental Bond program. At 261 of those sites, liable parties have come forward to perform necessary cleanup actions and are currently in the process of doing so. The current status of the cleanup work at publicly funded sites is shown in **Exhibit 74.** Cleanup activities have been completed at 1,324 sites. At 95 additional

Exhibit 74. Environmental Sites Cleanup Status 2013



sites, monitoring is being conducted to assure that further state-funded actions are not required. The two categories combined represent 74 percent of the sites where work has been completed or is ongoing. Cleanup systems have been constructed, and operation and maintenance activities are ongoing, at 38 sites.

Cleanup work is in progress at 124 additional sites. Due to funding restraints, 88 projects are on hold until additional funds are secured.

Since 1995, Michigan's cleanup law has promoted redevelopment of contaminated property (referred to as brownfield sites). In an effort to reduce the serious impediment to the purchase and re-use of contaminated property that resulted in many new development projects going to undeveloped land or open space, and to put contaminated property back into productive use, liability for property owners was changed to a causation standard. The person who causes contamination, rather than the person who buys or owns the contaminated property, is responsible for conducting the cleanup. Non-liable property owners may still elect to conduct cleanups to increase their property value. They must, however, assure the safety of people who work or live at these sites.

Also, since 1995, risk-based cleanup criteria that are linked to land use have been used to determine necessary actions. The use of these criteria helps to ensure that cleanups can be conducted in a cost-effective manner. The risk-based system accounts for the fact that the use of a property dictates the type of exposures that will occur, and that risk depends on exposure. For example, industrial sites do not have children present, and workers spend only a portion of the day at the workplace. Because of these differences in exposure, different levels of cleanup may be allowed, while still providing the same degree of protection at residential, commercial and industrial sites.

In 2010, Michigan's cleanup law was significantly amended, providing private parties with new tools to promote activities to reduce risk, achieve cleanup goals and promote safe reuse of contaminated properties. Since the 2010 amendments , the DEQ has approved 360 response activity plans, 131 documentation of due care compliance, 110 No Further Action requests and issued nine certificates of completion. In addition, the DEQ has approved 227 other cleanups at spill response sites . Liable and non-liable parties have conducted cleanup work at additional sites that are not required to be reported to the DEQ.

The cleanup laws governing leaking underground storage tanks were significantly amended in May of 2012 to provide for increased tools for liable parties to close sites, and to provide for more efficient cleanups of leaking underground storage tanks. Since the 2012 amendments, the DEQ has approved 156 closure reports and 53 cleanup plans. In addition, the DEQ has closed 311 other releases.

In the 2001, 2003 and 2005 Biennial Reports, information on the amount of private investment **(Exhibit 75)** and the number of jobs created

Exhibit 75. Number of Jobs Created at Brownfield Properties 1998-2013

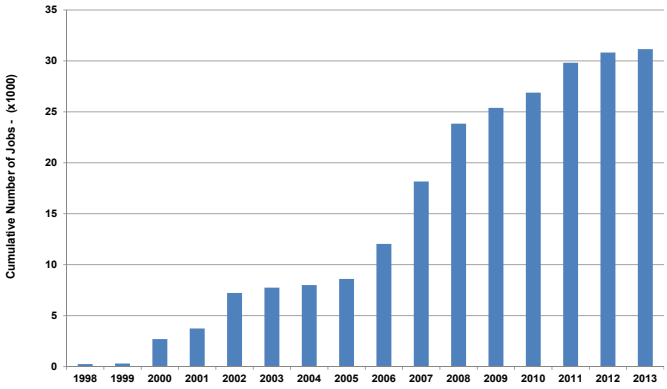
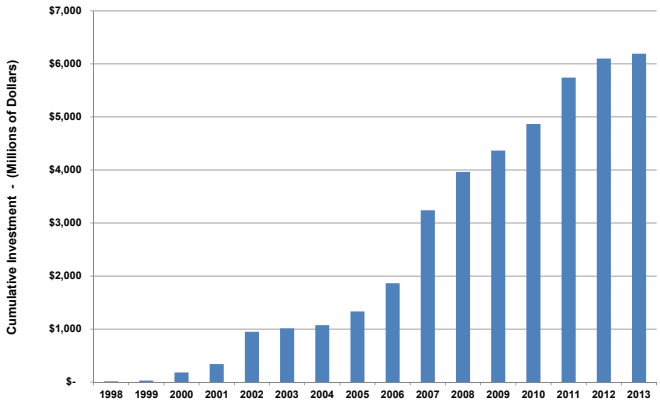


Exhibit 76. Investment in Brownfield Properties 1998-2013



(Exhibit 76) at brownfield properties was based on surveys conducted by the DEQ at 33 communities between 1996 and 2002. Beginning with the 2008 Triennial Report, the data presented are based on DEQ review of work plans submitted by local Brownfield Redevelopment Authorities in accordance with the Brownfield Redevelopment Financing Act, 1996 PA 381, as amended. These numbers are estimates provided to the DEQ prior to project construction and have not been verified post-construction. Beginning with the 2014 Triennial Report, data associated with brownfield grant and loan projects, as well as Act 381 projects, were included in the report.

Groundwater Contamination

Michigan currently has a total of 134 municipal landfills for solid waste, industrial waste, and construction and demolition waste. This total includes landfills that are closed and others that are open and accepting waste, but it does not include facilities that operated before 1979, which are addressed under the broader Environmental Cleanup Program described above. Sixty-four of these landfills have been found to be contaminating groundwater. Of these, 49 landfills (76 percent) have been cleaned up or have a corrective action ongoing. There are also eight sites where it is unknown if groundwater contamination exists. These sites are closed and no longer operating. Corrective action at the 49 landfills is, in most cases, being completed by the landfill owner. In a few cases it is necessary to use enforcement authorities to force the landfill owner/operator to address groundwater contamination. This leaves 15 sites (23 percent) at which no actions to correct known ground-water contamination are under way. All of these latter sites are closed and no longer operating.

Exhibit 77. Groundwater Contaminated Solid Waste Landfills Returned to Compliance 1990-2013

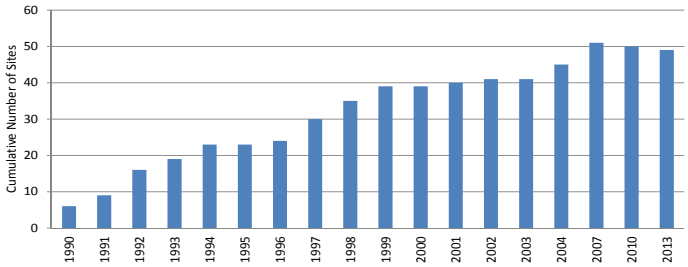


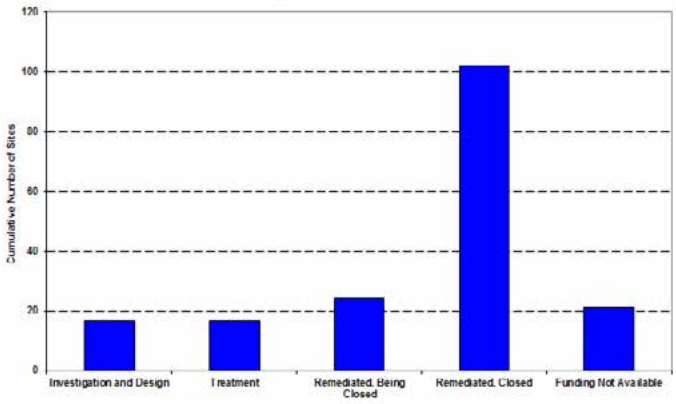
Exhibit 77 shows the cumulative number of groundwater-contaminated landfills returned to compliance since 1990.

State-Owned Sites Cleanups

In addition to ensuring the cleanup of contaminated sites by liable parties, the state is responsible for the cleanup of sites that it has contaminated as a result of its own operations. The state has identified a total of 181 such sites where it is responsible, as either the owner or operator, for environmental remediation. Of the 181 sites, 139 are underground or aboveground storage tanks; 18 are old landfills, dumps or storage pits; eight are shooting ranges; nine are surface spills; two involve either asbestos removal or radioactive license decommissioning; and five have multiple sources of contamination.

In July 1996, a States Sites Cleanup Fund was established, into which a total of $37,382,703 has been made available to help the state fulfill its own environmental-cleanup responsibilities. Of the 181 sites, 102 have been cleaned up and closed; 24 have cleanups nearly completed and are in the process of being closed; 17 are into long-term treatment to reduce the level of contamination; and 17 are being investigated or are in the process of having a treatment design developed. Since 2009, any newly listed sites have not received allocations, and 21 sites have had some work performed but are currently inactive due to lack of available funding **(Exhibit 78)**. The current unfunded need for the program is approximately $30 million.

Exhibit 78. Status of Funded Cleanups at State-Owned/Operated Sites. July 1996-2013

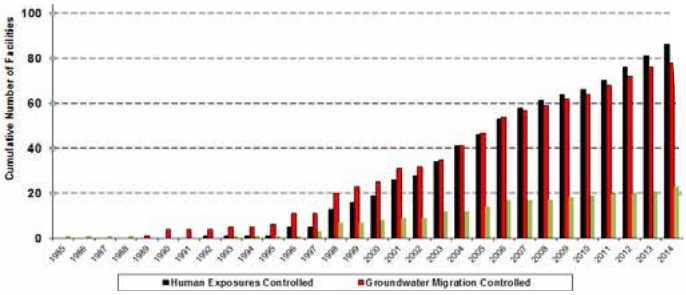


Hazardous Waste Treatment, Storage and Disposal Sites

Two hundred thirty-two hazardous waste treatment, storage and disposal sites in Michigan are subject to corrective action requirements. The corrective action requirements have been in effect under Michigan law since 1995. Similar requirements have been in effect under federal law since 1984. In 1998, the USEPA delegated to Michigan the administration of the federal corrective action requirements at licensed facilities. The DEQ has primary responsibility for overseeing the completion of corrective action at the licensed facilities.

Hazardous waste treatment, storage and disposal facilities are subject to corrective action based on an assessment of the environmental contamination present and the risks each site poses to human health and the environment. Of the 232 identified sites, 119 have been ranked by the federal government as high-priority (i.e., sites having the worst contamination or risks). The environmental contamination problems at the remaining 113 sites are not as significant as those at the 119 high-priority sites. To date, significant corrective action that has been taken at the high-priority sites includes eliminating or controlling human exposure to contaminants so that there remains no unacceptable human health risk (86 sites), eliminating or controlling groundwater contamination (78 sites), or completing the cleanup so that no further corrective action is required (23 sites). **(Exhibit 79)**.

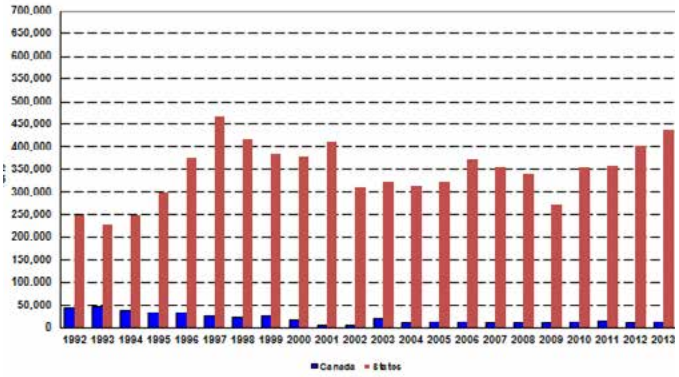
Exhibit 79. Corrective Actions Taken at High Priority Hazardous Waste Management Treatment Storage Disposal Facilities 1985-2014



Hazardous Waste Imports and Exports

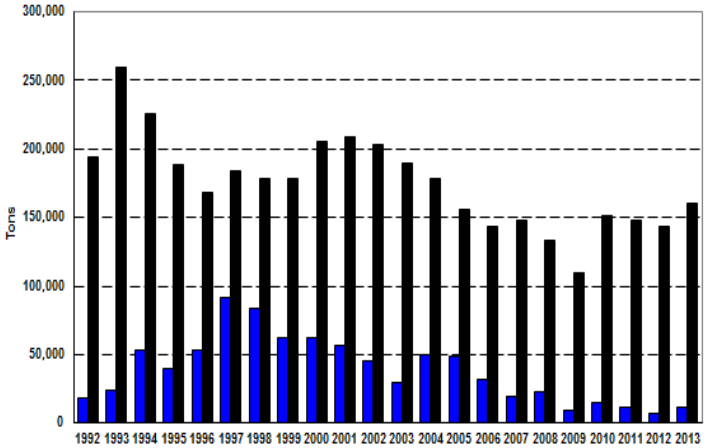
From 1992 to 2013, the importation of hazardous waste to Michigan for disposal ranged from a low of approximately 274,000 tons per year in 1993 to a high of approximately 492,000 tons per year in 1997. For the 1992 to 2013 period, Michigan imported an average 366,000 tons per year of hazardous waste **(Exhibit 80)**.

Exhibit 80. Annual Hazardous Waste Imports to Michigan 1992-2013



From 1992 to 2004, the quantity of hazardous waste exported by Michigan averaged approximately 248,000 tons per year. From 2005 to 2013, the average quantity of hazardous waste exported by Michigan declined to 163,000 tons per year **(Exhibit 81)**.

Exhibit 81. Annual Hazardous Waste Exports from Michigan 1992-2013



Comparing the import amounts to the export amounts since 1992 illustrates that the average amount of hazardous waste imported has exceeded the average amount of hazardous waste exported by approximately 140,000 tons per year. During the period from 1992 to 2013, Michigan has always been a net importer of hazardous waste.

Leaking Underground Storage Tanks

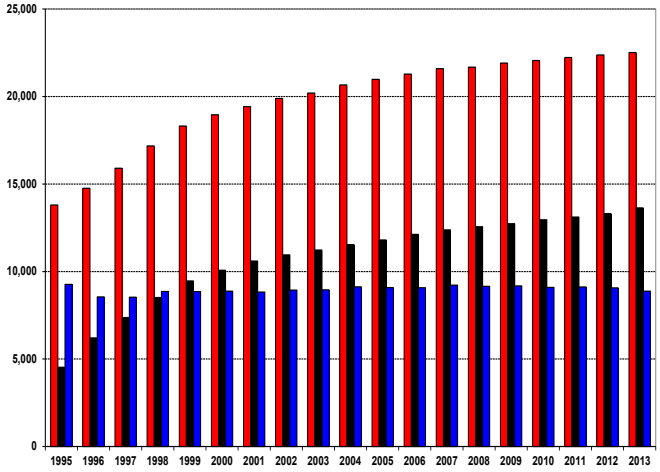
The predominant hazardous substances stored in underground storage tanks are petroleum

products (gasoline and diesel fuel) and used oil. The primary constituents of petroleum include benzene, ethylbenzene, toluene, xylenes and polynuclear aromatic hydrocarbons. These constituents can pose acute and chronic human health risks, with benzene being a known human carcinogen.

Leaking underground storage tanks can contaminate both the surrounding soil and the underlying groundwater. Of the two, groundwater contamination is much more difficult to clean up and may impact drinking-water wells. Most of the water supplies known to be affected have been replaced with alternate water supplies.

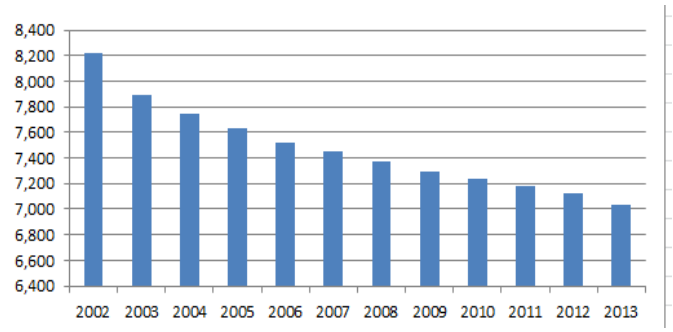
Historically, the Michigan Underground Storage Tank Financial Assurance (MUSTFA) program was created in the late 1980s to assist owners with the cleanup of releases from underground storage tanks; the legislation established a 7/8 cent fee on refined petroleum products to fund the program. The fee collection rate was found to be insufficient for the large number of release sites. The MUSTFA Fund was declared insolvent, the program stopped accepting invoices from June 29, 1995, and bonds were sold to pay off invoices at hand. The bonds were paid off in 2003 from the generated fee. Due to the large number of unaddressed releases in need of public cleanup funds, the fee was extended and the fund was renamed the Refined Petroleum Fund. The July 2006 amendments to Part 215, Refined Petroleum Fund, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, created the Refined Petroleum Fund Temporary Reimbursement Program (TRP). This program provided up to $64,000 to eligible former approved MUSTFA claimants who still had open releases that were high in risk to the public health and/or the environment. The TRP stopped accepting applications on Aug. 29, 2007. Invoices were accepted until Dec. 29, 2009, and approximately $30 million was expended. Public Act 416 of 2014 was recently enacted to assist owners and operators in conducting corrective actions by providing $20 million annually towards this effort in addition to helping them meet their federal financial responsibility requirements.

Exhibit 82. Number of Leaking Underground Storage Tank Releases 1995-2013



The cumulative closure of releases has increased from 4,530 in 1995 to 13,635 by the end of 2013 **(Exhibit 82)**. Between 1997 and 2010, the number of unaddressed releases from underground storage tanks slowly increased from about 8,531 releases to almost 9,175 releases, due to new releases being discovered at a slightly faster rate than old ones were being cleaned up. Since 2010, this number has dropped to 8,879 due to implementation of the 2012 amendments to Part 213, compliance assistance, collaboration with stakeholder groups, a triage program to gather site data by state contractors and enforcement. It is estimated that approximately 6,000 open releases will require the use of state cleanup funds due to non-viable and recalcitrant owners/operators. The cost to address only the orphan sites is estimated to exceed $1.8 billion dollars. Since 2002, the first year the statistic was counted, the number of active underground storage tank facilities (i.e. gas stations, bus garages) has decreased from 8,216 to 7,039 **(Exhibit 83)**. This is the first year that this number has been provided for this report.

Exhibit 83. Active Underground Storage Tank Facilities



State and federal rules require that owners/operators of underground storage tank systems comply with federal technical standards (the state already had these requirements in place within prescribed setback areas for drinking-water wells, and in delineated wellhead protection areas), and the state has opted to require secondary containment of all newly installed tank and piping systems.

Gasoline Additive Methyl Tertiary-butyl Ether

The gasoline additive methyl tertiary-butyl ether (MTBE) has been mandated in western and northeastern states to meet the reformulated gasoline requirements to help reduce carbon monoxide emissions and ozone formation. Since Michigan did not have as serious a problem as other states, it was never mandated by the USEPA to use reformulated gasoline. Concern about the potential health risk from groundwater being contaminated by this additive has led to reexamination of its use by the USEPA.

Within Michigan, there exist residual amounts of MTBE in some gasoline supplied by pipelines that transfer fuel to Michigan from other states. For over 16 years, the DEQ has required monitoring for MTBE at underground storage tank release sites. At sites where levels exceed safe concentrations, the DEQ has taken action to address the contamination. Michigan instituted a ban on MTBE in June 2003. The acceptable level of MTBE in groundwater used as a drinking-water source at sites of contamination is 40 parts per billion (ppb), based on aesthetic criteria for taste and odor. The aesthetic criterion is significantly lower than the health-based value of 240 ppb.

Oil and Gas Wells

Since commercial oil and gas production began in Michigan in 1925, over 58,000 oil and gas wells have been drilled. Approximately 20,000 of these wells are in use today, producing 23 percent of the natural gas and 4 percent of the oil used within the state. During the period from 2011 through 2013, 505 wells were drilled.

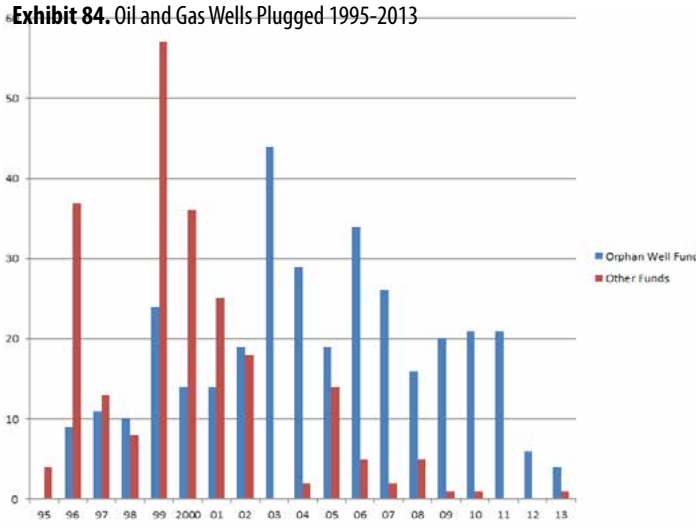
The DEQ regulates oil and gas well drilling and production to conserve natural resources and to protect the environment, public health and safety, and property. Part of that effort is directed toward establishing optimal spacing of wells. During 2011-2013, the DEQ made 212 determinations and issued 28 orders increasing the size of the tract assigned to a well. This allows fewer wells to develop an oil and gas reservoir and provides more flexibility for locating wells to protect the environment or property. In that same timeframe, the DEQ issued three orders establishing enhanced recovery projects, where gas or fluids are injected into a partially depleted reservoir, to increase the ultimate production. One of those orders provided for re-injection of produced gas, which allows for increased production while reducing the amount of potential greenhouse gas that may be flared on-site.

During the period of 2011-2013, Michigan continued to see a rise in the number of multi-stage, high-volume hydraulic fracturing completions for oil and gas wells. While hydraulic fracturing has been occurring in Michigan for decades, high-volume hydraulic fracturing completions using more than 100,000 gallons of frac fluid were increasing in frequency. On June 22, 2011 the DEQ issued Supervisor of Wells Instruction 1-2011, which set new requirements for water-withdrawal evaluation, recording and monitoring, and chemical additive disclosure for oil and gas wells that utilize high-volume hydraulic fracturing. There were 22 wells completed utilizing high-volume hydraulic fracturing from 2011 to 2013. In 2013, the DEQ initiated rule promulgation to codify portions of the Supervisor of Wells Instruction 1-2011 and added additional requirements, including baseline sampling and improved disclosure, for high-volume hydraulic fracturing operations. The rule-promulgation process was completed in 2014.

When an oil and gas well is depleted, Michigan law requires the well owner to plug the well and restore the site. Abandoned wells that are not properly plugged can pose serious threats to the environment and public health and safety because they can serve as conduits for oil, gas or brine to leak to the surface or into underground water supplies. Occasionally, a well owner dies

or becomes insolvent and leaves an inactive well unplugged. The DEQ plugs these orphan wells with funds provided from the state's Orphan Well Fund. The Orphan Well Fund was established in 1994 and is supported by taxes levied on oil and gas producers. In the case of an abandoned well that has a viable owner, the DEQ may plug the well and clean up the site with money from the state's Environmental Response Fund or other sources, and pursue recovery of costs from the owner. From 2011 to 2013 the DEQ plugged 31 abandoned wells with the Orphan Well Fund and one additional well using other funds. The DEQ has plugged 570 wells since 1995 using various funding sources **(Exhibit 84)**.

Exhibit 84. Oil and Gas Wells Plugged 1995-2013

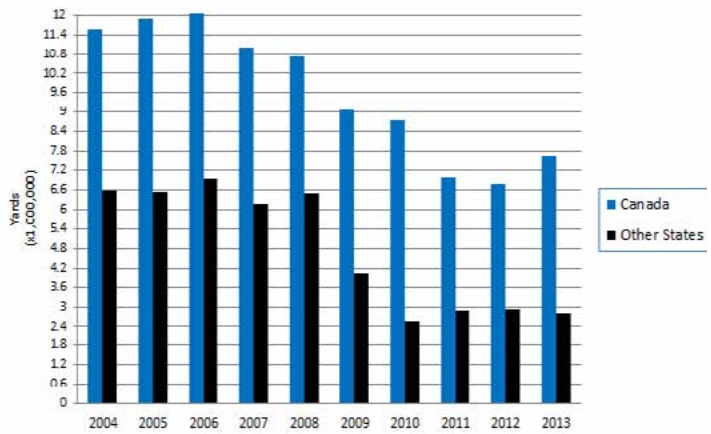


Solid Waste Imports

During the period 2004-2013, solid waste imports have ranged between 21.6 and 30.9 percent of the total amount of solid waste disposed of into Michigan landfills. During Fiscal Year 2013, the bulk of these imports, approximately 73 percent, came from Canada. Most of the remaining out-of-state waste comes into Michigan from nearby states such as Illinois, Indiana, Ohio and Wisconsin as well as more distant states such as Florida and New York.

Solid waste imports increased in 2013 **(Exhibit 85)** and made up approximately 23 percent of all waste disposed of in Michigan. (The overall amount of waste disposed in Michigan landfills from all sources also increased. However, waste generated in Michigan decreased slightly from the previous fiscal year.) Michigan continues to be one of the largest importers of waste due to the relatively close proximity of Michigan landfills to other states and Canada, low tipping fees at landfills, high volumes of remaining disposal capacity available at public landfills and the continuing inability of the state, due to federal interstate commerce rules, to restrict the import of waste from outside the state.

Exhibit 85. Annual Solid Waste Imports to Michigan 2004-2013



Scrap Tires

Over 290 million scrap tires are generated each year in the United States, with Michigan contributing 10 million scrap tires annually to that waste stream. In the past, millions of these scrap tires were abandoned or illegally stockpiled each year on vacant lands and inner-city back alleys. The illegal accumulations resulted in public health, environmental and aesthetic problems for many communities, particularly from fires and mosquitoes.

In 1990, Michigan enacted legislation, which went into effect in 1991, to address the concern of scrap tires. This legislation is now codified as Part 169, Scrap Tires, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (Part 169). The purpose of the law was to help reduce illegal scrap-tire accumulations and the public health and environmental concerns associated with these scrap-tire waste piles. In 1991, it was estimated that more than 30 million scrap tires were stockpiled and more than 7.5 million additional scrap tires were being generated annually. Each year, the DEQ discovers additional regulated collection sites and develops more accurate figures on scrap-tire stockpile inventories. Most of the newly identified sites

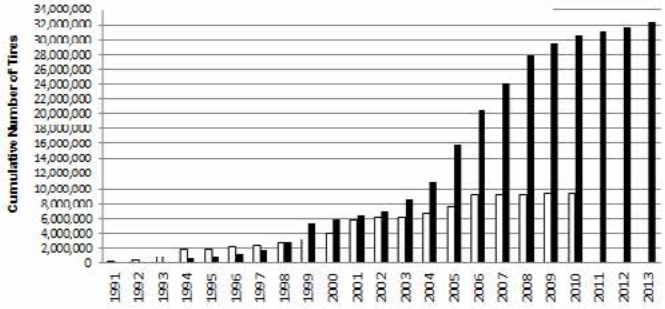
are not active and often not in a visible location. Newly identified sites are becoming less frequent, and the amount of scrap tires stored at these sites is generally smaller than sites that have been discovered historically.

Part 169 required the DEQ to ensure that all abandoned scrap tires accumulated at collection sites prior to Jan. 1, 1991, were cleaned up by Sept. 30, 2009. The DEQ has made significant progress toward this goal. It is estimated that less than a half of a percent of these pre-1991 tires remain. In addition, there were at least 5 million scrap tires accumulated after 1991 that posed an imminent threat to public health, safety, welfare or the environment that were addressed by the deadline.

Whole motor vehicle tires have been prohibited from disposal in Michigan landfills since March 2004. While portions of tires (e.g., tire shreds) still can be disposed of in a landfill, the challenge continues to be promoting other management options, such as the use of scrap tires as raw materials for products or to produce energy.

Much of the reduction in illegal stockpiles is due to Scrap Tire Cleanup Grants. Since the Legislature first appropriated funding in 1993, more than $29 million in public funds have cleaned up approximately 32.3 million passenger tire equivalents (PTEs) from the Michigan landscape. The cleanup of these public and privately owned properties has helped toward restoring the environmental quality and economic value of more than 1,000 sites across the state. **Exhibit 86** shows

Exhibit 86. Scrap Tire Cleanup Program 1991-2013



the cumulative totals of tires removed through the DEQ grant program and those removed voluntarily or through enforcement actions. In 2009, the DEQ estimated approximately 664,000 PTEs were being illegally stored in Michigan; 388,000 of these were pre-1991 and the remaining 276,000 were post-1991 scrap tires. As of June 2013, it is estimated that approximately 450,000 PTEs posing a threat to public health, safety, welfare or the environment remain in illegal accumulations throughout the state.

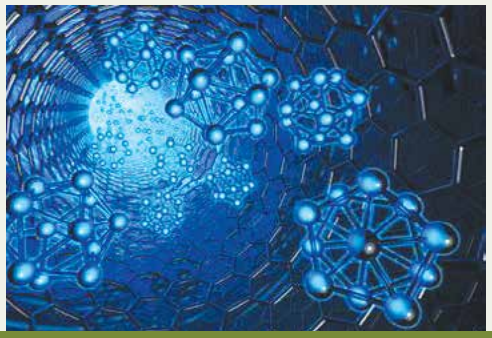
Overall, the Scrap Tire Program has been very successful. Throughout the state, many large stockpiles of tires have been eliminated, compliance rates have continued to increase, and markets for scrap tires have increased. The reasons for the program's success are:

1. continuing an appropriately funded Scrap Tire Cleanup Grant Program to address abandoned scrap tires and those collected prior to 1991, when Part 169 was enacted; and
2. consistent enforcement of Part 169, which helps to ensure a level playing field for those voluntarily meeting Part 169 requirements. It should be noted that, although markets for scrap tire material have continued to increase on their own with minimal governmental subsidies, the ongoing need for state funding for cleanup grants, compliance and enforcement is clear.

The Scrap Tire Program is funded through a fee (established in the Michigan Vehicle Code, 1949 PA 300, as amended) of $1.50 for each motor vehicle title transfer, collected by the Secretary of State. Continuation of funding supports ongoing grants to develop markets for scrap tires, clean up abandoned scrap tires and help ensure the proper disposal of the scrap tires generated annually in Michigan. Amendments to the Motor Vehicle Code in September 2011 extended the sunset for the program funding to Dec. 31, 2015.

As part of the ongoing effort to continuously improve the Scrap Tire Program, the DEQ has sought, and continues to seek, input from key stakeholders. The Scrap Tire Advisory Committee (STAC) meets periodically to advise the DEQ on implementation of the Scrap Tire Program and to address challenges and opportunities in the program as they arise.

Photo from www.greenbiz.com



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Emerging Contaminants of Concern

Emerging Contaminants of Concern

Introduction

Contaminants of Emerging Concern

According to the USEPA, contaminants of emerging concern are substances whose "risk to human health and the environment associated with their presence, frequency of occurrence, or source may not be known." Nine of these emerging contaminants are described in this section of the report; six were discussed in the 2011 Triennial Report. Ethylenediamine tetraacetic acid (EDTA) has been removed from the list because a specialized permit within the DEQ's Water Resources Division has addressed the concerns regarding discharges that contain EDTA. Three emerging contaminants were added to the list, including the plasticizer bisphenol A; triclosan, found in antibacterial soaps; and microplastics detected within the Great Lakes. When available, Michigan-specific information is included. The identification as an emerging contaminant indicates that these substances may need further evaluation to determine potential impacts in Michigan.

Identified Contaminants

Endocrine-Disrupting Chemicals

Endocrine-disrupting chemicals (EDCs) are a class of chemicals that can alter the structure and/or function of the endocrine system. The endocrine system, a network of glands that communicate with target organs via hormones, functions similarly among mammals, fish and birds. Endocrine function regulates numerous physiological processes, including reproduction, development and growth, under precise hormonal control. EDCs alter normal endocrine system function by mimicking hormones, blocking hormone receptors or disturbing hormone synthesis. Numerous environmental contaminants harm biological systems at brief high-dose exposures; however, EDCs can affect biological systems at very low doses over a long exposure period.

In 1996, the Food Quality Protection Act and amendments to the Safe Drinking Water Act (SDWA) required the USEPA to investigate whether certain chemicals are capable of altering endocrine function. As a result, the Endocrine Disruptor Screening Program (EDSP) was commissioned to determine the effects of specific chemicals on sex hormones and thyroid function. The EDSP is currently validating testing methodology for Tier I and Tier II assays. Tier I testing screens a chemical for possible initial interaction with estrogen, androgen or thyroid hormonal systems. If Tier I testing indicates a chemical has the potential to be an EDC, then more comprehensive Tier II testing will be conducted. Tier II testing identifies and characterizes adverse effects following exposure and develops dose-response information.

Currently, the majority of chemicals being screened under the EDSP Tier I testing include those that are high-production-volume chemicals, like pesticides and inert pesticide ingredients, or those that are nationally regulated under the SDWA. In June 2013, the USEPA published an updated draft list of 109 chemicals (i.e., 41 active pesticide ingredients and 68 chemicals identified under the SDWA) for Tier I screening (for details see *www.epa.gov/endo/pubs/prioritysetting/revlist2.htm*). Numerous other chemicals including pharmaceuticals (e.g., birth control pills and anti-depressants), surfactants (e.g., nonylphenol), plasticizers (e.g., bisphenol A and phthalates) and industrial chemicals (e.g., PCBs and dioxins) are known EDCs and will likely be screened in Tier I testing.

There is a limited understanding of the effects of EDCs on humans and animals at the present time. Investigation of EDC exposure pathways and outcomes for a variety of species (e.g., humans, wildlife, fish and reptiles) continues. The results of these studies are expected to improve the EDC regulatory decision-making process.

Bisphenol A

Bisphenol A (BPA) is widely used in manufacturing polycarbonate plastics and epoxy resins. It is used in nearly every industry, and its production exceeds 1 million pounds per year. In animal studies, BPA has caused reproductive and developmental effects. In response to some of the questions and concerns regarding BPA raised by these studies, the U.S. Department of Health and Human Services has made recommendations to reduce the public's exposure to BPA, and Canada is taking steps to ban BPA in baby bottles. Several manufacturers of baby products sold in the U. S. have voluntarily discontinued the use of BPA in their products.

The U. S. Geological Survey (USGS) has sampled groundwater and surface water throughout the country, keeping track of differences between waters used for drinking and waters that are not sources of drinking water. BPA was one of the most frequently detected chemicals in the samples. (http://toxics.usgs.gov/highlights/gwsw_ec.html)

Because some of the levels of BPA being detected in the environment are similar to those that caused adverse effects in studies of aquatic species, the USEPA is considering rulemaking under the Toxic Substances Control Act that would add BPA to the Concern List. Additional information is available at www.epa.gov/oppt/existingchemcals/pubs/actionplans/bpa.html.

Pharmaceuticals and Personal Care Products

Pharmaceuticals and Personal Care Products (PPCPs) comprise a diverse collection of thousands of chemical substances, including prescription and over-the-counter pharmaceutical drugs, veterinary drugs, fragrances and cosmetics. In general, PPCPs are any product used by individuals for personal health or cosmetic reasons, or used by agribusiness to enhance the growth or health of livestock. A number of PPCPs act as endocrine-disrupting chemicals (see previous section). Since the 1970s, low levels of PPCPs have been detected in our nation's surface water and groundwater, which are the sources for our drinking water.

The issue of PPCPs in the environment remains newsworthy. Ongoing studies have yet to determine whether the presence of low levels (i.e., parts-per-trillion range) of PPCPs in drinking water is a concern for human health, but nationwide, evidence is mounting that aquatic life may be impacted. Current research is focusing on prioritization of substances for assessment; pathways of exposure; bioavailability and uptake; effects characterization; risk and relative risk; antibiotic resistance; and risk management.

PPCPs enter our environment, and particularly our water systems, when drugs, fragrances and cosmetics are either disposed of or excreted after use. One of the primary pathways for PPCPs to enter our drinking-water supplies is through wastewater treatment plant discharges. Most wastewater and drinking-water treatment systems are not currently equipped with technologies such as granulated activated carbon, powdered activated carbon and ozone that effectively remove PPCPs, so it is expected that PPCPs will continue to be detected in the environment. Pharmaceutical "take-back" programs to encourage proper disposal of unwanted and expired medication continue to operate, but it is unknown how effective these initiatives are at reducing the amount of PPCPs that ultimately end up in the environment.

The USEPA and the USGS remain the best sources for up-to-date information on the issues surrounding PPCPs as environmental contaminants. Helpful websites include www.epa.gov/ppcp/ and http://toxics.usgs.gov/regional/emc/index.html.

Perfluorinated Compounds

Perfluorinated compounds (PFCs) represent a family of nearly 200 chemical compounds that are included in hundreds of commercial product formulations because of their ability to impart stain, water and flame resistance to the products. Perfluorooctanoic acid (PFOA)

and perfluorooctane sulfonate (PFOS) are the most common PFCs. Because of their widespread detection in humans, wildlife and the environment, production of PFCs in the U.S. has been phased out and alternative substances have been substituted in their place.

PFCs are highly resistant to environmental degradation and are considered persistent contaminants. PFCs have been detected in Michigan groundwater, surface water and sediment and in several species of aquatic and terrestrial wildlife. The presence of significant PFC contamination in northern Michigan led the Michigan Department of Community Health (MDCH) to issue an emergency "do not eat" fish advisory in 2012 for affected water bodies near the contaminated area. Mitigation is under way at the site.

Researchers throughout the Great Lakes region have determined a bioconcentration factor of 1,000 for PFOS and a biomagnification factor of 10 to 20, meaning that levels of PFOS can increase up the food chain. Through a grant from the USEPA's Great Lakes Restoration Initiative, the MDCH is measuring PFCs in surface water and fish collected at several locations in Michigan. Information gathered will support the development of fish consumption guidelines.

Data gaps exist for how the general population may be exposed to PFCs, although ingestion of contaminated food, such as fish, and drinking water has been suggested to be the primary route of exposure. The nomination for addition of PFCs to the USEPA's Unregulated Contaminant Monitoring Program will assist in determining their occurrence and levels in the public drinking-water supply throughout the state.

Polychlorinated Naphthalenes

Polychlorinated naphthalenes (PCNs) are a group of dioxin-like chemicals that were used as flame retardants, cutting oils, engine oil additives, insulators, water repellents and preservatives for some wood, paper and fabric products. PCNs are persistent and bioaccumulate in the environment. PCNs have been found in the Arctic, urban air, wildlife and human tissues including breast milk. Consumption of contaminated fish is considered an important route of exposure of humans to PCNs.

PCNs have been found at measurable levels in fish and sediments collected from surface water bodies in Michigan, including the Great Lakes. PCNs recently were added to the list of parameters monitored as part of the USEPA's Whole Fish Trend Monitoring Program, although further analytical method development is necessary to measure the low levels of PCNs in the fish tissues collected. Once these data are available, it may be possible to evaluate the levels of PCNs in Michigan fish and determine if they are decreasing, as has been found in Lake Ontario and other locations. A recent toxicity study also has shown that PCNs have effects on reproductive hormones in mammalian ovaries, similar to those seen in fish.

Nanomaterials

Although naturally occurring nanomaterials exist, most environmental regulatory interest is focused on engineered nanomaterials. Nanoscale technology involves engineering materials and devices from elements such as carbon, iron, silver, titanium and zinc into various structures (e.g., rods, tubes, spheres) that are scaled down to 100 nanometers or less in at least one dimension. Due to their nanoscale size, these engineered nanomaterials possess unique chemical, biological and physical properties as compared to larger particles of the same material composition. These unique properties have made engineered nanomaterials increasingly attractive for a wide range of scientific, environmental, industrial and medical applications. Currently, there are more than 1,600 manufacturer-identified, nanotechnology-based products in consumer marketplace categories that include health and fitness, home and garden, food and beverage, automotive, electronics and computers.

The public health and environmental effects of engineered nanomaterials remain mostly unknown. It is generally believed that the surface area and surface properties of nanomaterials represent a greater indicator of their potential to

cause adverse effects to living organisms than does their material composition. Human exposure to nanomaterials can occur through ingestion, inhalation and dermal contact. Ingestion of nanomaterials may occur via drinking water or food containing these materials. Occupationally, inhalation exposure is the most widely recognized route of exposure, but inhalation exposure is expected to be low among the general population because most products currently in the marketplace contain nanomaterials embedded in a solid matrix. Use of sunscreens or other skin-applied products may result in dermal exposure to nanomaterials.

Little is known about the short- or long-term effects of engineered nanomaterials on aquatic and terrestrial ecosystems. There is also very limited information regarding the environmental fate and transport of these substances, but engineered nanomaterials are expected to persist in the environment, meaning that they could be transported over great distances. It is predicted that most significant environmental releases of nanomaterials will occur during their disposal and recycling.

Nanomaterial production levels are currently estimated to be in the thousands of tons per year and are increasing. Engineered nanomaterials are regulated by a number of federal agencies, including the Food and Drug Administration and the USEPA, depending on the specific media of application or release. Environmental regulation of engineered nanomaterials is quite problematic because pollutants generally are tracked and regulated by mass, which is not a practical measure for nanomaterials. It is unclear how the introduction of engineered nanomaterials into the environment could be controlled or measured, underscoring the importance of toxicity testing and regulatory goals for engineered nanomaterials.

n-Propyl Bromide

Also known as 1-bromopropane, n-propyl bromide (nPB) is a solvent currently being used to replace ozone-depleting chlorofluorocarbons (such as trichloroethane and some Freons) and perchloroethylene. This solvent may be used where there is a need to dissolve fats, waxes or resins, and can be used in degreasers and spray adhesives.

The electronics industry uses nPB for degreasing circuit boards, and dry-cleaners can use it as a replacement for perchloroethylene. While some companies market it as a safe and "green" alternative, there are studies indicating that nPB may be more toxic than perchloroethylene. The dry-cleaners in Michigan that currently use nPB have been notified of the risks.

Humans are primarily exposed to nPB by inhalation, although it can also enter the body through the skin. Extensive animal data and limited human data have demonstrated that nPB can harm the reproductive system and the nervous system. Nationwide, two cases have been published documenting neurologic illness associated with occupational exposure to nPB, but it remains unclear how the general population may be at risk for nPB exposures.

The National Toxicology Program recently proposed to list nPB as a human carcinogen based on sufficient evidence in experimental animals. In 2013, the state of New York petitioned the USEPA to include nPB as a hazardous air pollutant regulated under the Clean Air Act; a response from EPA is expected yet this year. The USEPA has prohibited the use of nPB in adhesives and aerosols. Ongoing research will be monitored to assess the current applications of nPB.

Triclosan

Triclosan is a chlorinated aromatic compound that is widely added as an "antibacterial" or "antimicrobial" active ingredient in many personal care products. These consumer products include liquid and bar soaps, shampoos, body washes, mouthwashes, toothpastes and some cosmetics. The efficacy and safety of triclosan in many of these products is controversial and is currently under scientific and regulatory review by the Food and Drug Administration (FDA). Triclosan is also

found in many non-FDA-regulated products such as clothing, kitchenware, furniture and toys.

Given the prevalence of triclosan in so many personal care products, ingestion and dermal exposure would be expected to occur commonly among the general population. Moreover, the long-term, regular use of triclosan-containing consumer products likely represents a significant source of human exposure, rather than exposure to environmental media that is contaminated with triclosan. While triclosan has been detected in the urine of approximately 75 percent of the U.S. population, human health effects are unknown. Laboratory studies have shown that triclosan may alter the way that hormones work in the body, as well as contribute to antibiotic-resistant bacteria. There is strong evidence that fish, aquatic plants and other aquatic organisms are more sensitive to triclosan than humans.

Triclosan typically enters the environment through wastewater discharge, as conventional wastewater treatment technologies are not effective at removing 100 percent of this chemical from the effluent. Chlorine disinfection of wastewater can result in additional chlorination of the triclosan molecule, which can yield dioxins once exposed to sunlight. The environmental risk of these dioxins to aquatic ecosystems is unclear. Identification of triclosan and its dioxin products in stream and lake samples led the state of Minnesota to ban the sale of consumer care products containing triclosan, effective in 2017. While an exhaustive investigation of triclosan in the Michigan environment has not occurred, it has been detected in some surface-water and sediment samples in the state.

Microplastics

Microplastics are a newly recognized form of environmental pollution. These synthetic materials are typically made of polyethylene, polypropylene, polyethylene terephthalate, polymethyl methacrylate or nylon, and measure less than 5 millimeters in size. While some microplastics are manufactured intentionally and added to consumer and industrial products, others are formed by weathering and abrasion of larger plastic litter released into the environment. Microplastics in the environment can continue to break down into smaller fragments due to physical processes as well as exposure to sunlight; however, biodegradation does not occur at appreciable rates. Cleanup of plastic litter is considered an important and effective mitigation strategy for this source of environmental microplastics.

Plastic microbeads are an example of an intentionally manufactured microplastic product that has found its way into the environment. Microbeads are common ingredients in many widely used personal care products, such as facial cleansers and toothpaste, where they function as exfoliants or abrasive agents. The quantity of microbeads in these products can be as high as 10 percent of the total product volume. Plastic microbeads originating from personal care products are washed down the drain and enter the sanitary sewer system as a part of their normal and expected lifecycle. In 2014, in an effort to help protect the state's lakes and rivers, Illinois became the first state in the nation to ban the manufacture and sale of certain personal care products containing plastic microbeads. Several personal care product manufacturers have recently announced a voluntary phase-out of microbeads and are evaluating natural alternatives.

Watersheds surrounding the Great Lakes are heavily urbanized and represent important sources of plastic pollution of the lakes and other surface waters through use of consumer products containing plastic microbeads. Wastewater treatment facilities typically do not remove 100 percent of these plastic microbeads, as they can be too small to filter out using current treatment technologies. The plastic microbeads can then enter the environment via surface-water discharge of the treated effluent. Polyethylene microbeads, consistent in shape, size, color and elemental composition with those present in some personal care products, were collected during a 2012 study of the surface waters of Lakes Erie, Huron and Superior. Microplastic counts varied from 0 to 450,000 plastic particles per square kilometer of the lake surface, with the highest densities

reported near metropolitan areas. Microplastics also have been recently confirmed to be fairly evenly distributed throughout Lake Michigan surface waters.

Aquatic organisms could potentially be affected via ingestion of the microplastic particles themselves, as well as through persistent organic pollutants that were either originally manufactured into the plastic or that sorb onto the plastic from the environment. Transfer of microplastics and absorbed pollutants within the food chain remains under investigation. While microplastics likely represent only a small fraction of the total environmental plastic pollution burden, their overall effects in the ecosystem remain unknown.