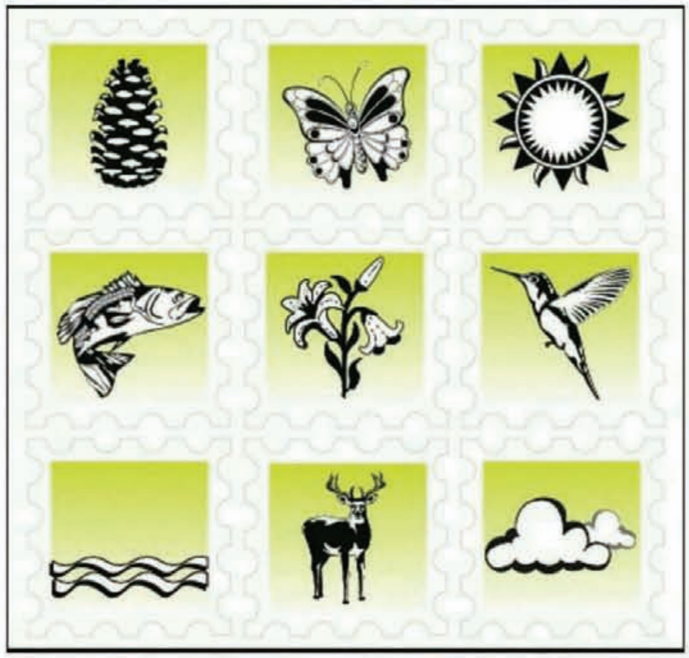

STATE OF MICHIGAN'S ENVIRONMENT 2008

First Triennial Report

State of Michigan's Environment 2008

(First Triennial Report)

Michigan Department of Environmental Quality
Steven E. Chester, Director

Michigan Department of Natural Resources
Rebecca A. Humphries, Director

Jennifer M. Granholm, Governor

Message from the Governor

Michigan is one of the most recognizable places on Earth. The Great Lakes vividly outline both of our majestic peninsulas. Michigan's more than 37 million acres of land are dotted by some of the most unique and varying landforms in the United States, and are marked and crossed by more than 11,000 inland lakes and over 36,000 miles of streams.

In 1999, the Michigan Departments of Environmental Quality (MDEQ) and Natural Resources (MDNR) were legislatively mandated with the task of developing a program for tracking and reporting changes in environmental trends in the state using scientifically sound environmental indicators. Environmental indicators are scientifically measurable components that reflect biological, chemical, and physical attributes of the environment. By tracking changes that occur over time in land cover, fish populations, ambient air pollutant levels, and stream flows, to name a few, the direction and rate of environmental change can be determined and corrective programmatic measures developed to ensure optimal resource preservation and protection.

In 2000, the Michigan Environmental Science Board (MESB) reviewed the scientific validity of the MDEQ and MDNR proposed program. The MESB report, *Recommended Environmental Indicators Program for the State of Michigan*, was published in July 2001. Using this resource as a guide, the first comprehensive environmental indicators report for Michigan was published in December 2001. A second and third report was completed in December 2003 and December 2005, respectively. In December 2005, the state's Environmental Indicators Act was amended changing the frequency of the report's preparation from a biennial to a triennial basis. I am pleased to present you with the first triennial *State of Michigan's Environment Report* (Triennial Report).

The 2008 Triennial Report continues to follow important trends in environmental indicators such as land use and cover, mammal, bird, and fish populations, ambient air pollutant levels, and surface and ground water quality, among many others. The 2008 Triennial Report also addresses several other issues of importance including the impact of the many exotic species that have invaded Michigan's waters and land, and the progress the state has made to help control the existing exotics and to prevent new ones. Finally, the 2008 Triennial Report discusses the status of Michigan's endangered and threatened plants and animals, urban sprawl, numerous environmental programmatic measures, current energy concerns, and several emerging contaminants of concern in Michigan's environment.

These Triennial Reports will help us to scientifically measure our progress and define future environmental policy in our continuing efforts to preserve and better Michigan for its current and future generations. The continued protection and enhancement of Michigan's environmental legacy will require the active participation of not only its governmental officials, but also of its individual citizens if we are to succeed in this endeavor.

Jennifer M. Granholm
Governor

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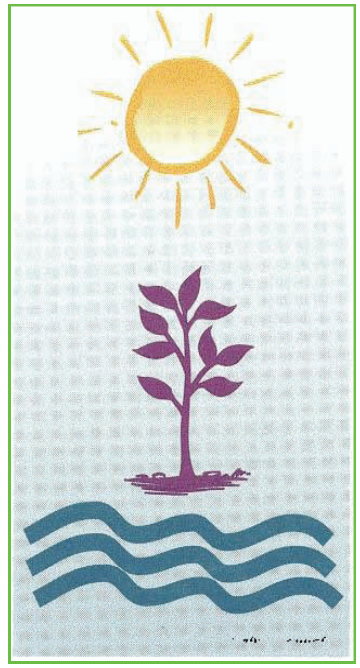
Introduction



Beginning in the late 1960s and early 1970s, concerns regarding the health of the nation's environment and how well it was being protected by state and federal agencies heightened amid numerous reports of contaminated drinking water, rivers, and streams resulting from open dumps and polluting industries, and of reports of sick and dying song, predatory, and shore birds resulting from the misuse and overuse of pesticides. These and other environmental consciousness-raising concerns ultimately led to the passage of a series of state and federal environmental regulations during the 1970s that were designed to identify and reverse the often long-standing contamination practices that lead to the environmental degradation.

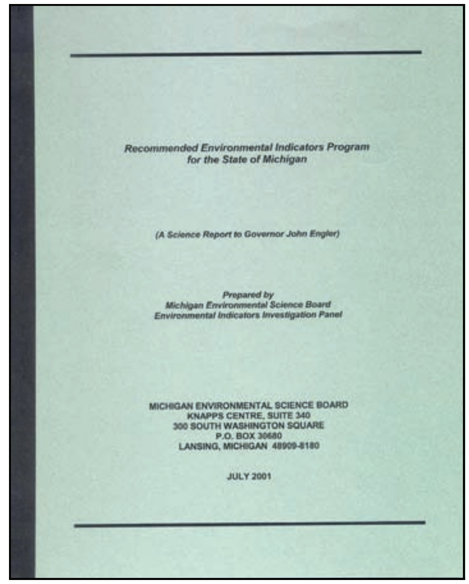
During the 1980s and 1990s, state and local governments began to move away from the strict regulatory approach to pollution control and began to explore many new and/or innovative, non-regulatory programs, such as pollution prevention and minimization, recycling, and, later, brownfield redevelopment programs. This same period also saw the beginnings of an enhanced awareness among many Michigan citizens, businesses, and communities regarding the need for greater environmental stewardship and the need to conserve. As a direct result of these and other factors, many of the air, water, and land environmental problems that were of greatest concern 30 years ago either have been corrected or are in the process of being corrected.

The state is now faced with new and more complex environmental issues. Unfortunately, many of the environmental concerns of today are not as obvious as were those of the past and are frequently now of a more diffuse nature (e.g., non-point source pollution, air deposition of contaminants, invasive non-native species, urban sprawl, accelerated change in climate and exposure to waste pharmaceuticals). Consequently, the extent of the problem is often more difficult to define and the corrective actions and other types of solutions more complex and/or elusive. Compounding this further has been a greatly enhanced technical capability to measure pollutants at ever decreasing levels coupled with an increased difficulty to understand the degree of actual risk that such pollutants pose to the environment and/or human health at such low levels.

The challenges facing Michigan in the 21st Century will be to accurately identify and track changes in the environment resulting from human-related activities and to develop meaningful ways to measure the change and the degree of success or failure of the regulatory and non-regulatory programs designed to protect the environment. To date, there have been several attempts to do this. However, many of the attempts employed either have not been designed to be integrated into a comprehensive understanding of the impact of human-related degradation or mitigation activities on the natural environment or have been incapable of differentiating natural from human-caused environmental change. Consequently, most of the attempts to identify and track human-influenced environmental change have resulted in a patchwork of disjointed programs and scientifically invalid measurements.

Public Act 195 of 1999 (Environmental Indicators Act) was signed into law in December 1999. The law requires the Michigan Department of Environmental Quality (MDEQ) to work with the Michigan Department of Natural Resources (MDNR) to prepare biennial reports on the quality of the state's environment based on scientifically supportable environmental indicators and using sound scientific methodologies.

On January 28, 2000, the Governor of Michigan requested the Michigan Environmental Science Board (MESB) to evaluate a series of environmental indicators proposed by the MDEQ and MDNR for use in the legislatively mandated report. The MESB report entitled, *Recommended Environmental Indicators Program for the State of Michigan*, was submitted to the Governor in July 2001. Of the environmental indicators proposed for consideration by the MDEQ and MDNR, the MESB recommended that 20 be included into a statewide environmental indicators program. The MESB also recommended that one additional indicator (Climate and Weather Change) be taken into consideration in the state's evaluation (Exhibit 1).



The first biennial *State of Michigan's Environment Report* (Biennial Report) was completed and transmitted to the Michigan Legislature in November 2001. The second and third Biennial Reports were completed in December 2003 and January 2006, respectively. In December 2005, the Environmental Indicators Act was amended by Public Act 313 changing the frequency of the report's preparation from a biennial to a triennial basis. The purpose of this document is to present the first triennial *State of Michigan's Environment Report 2008* (Triennial Report).

The 2008 Triennial Report is divided into three sections: environmental measures, programmatic measures,

Exhibit 1. Michigan Environmental Science Board Recommended Environmental Indicators

Ecological Indicators:	Land Use/Cover Breeding Bird Abundance Trends in Habitat of Interior and Edge Bird Species Trends in Game Fish Populations Trends in Benthic Macroinvertebrate and Fish Populations Trends in Frog and Toad Populations Invasive (Exotic) Species Forest Acreage, Mortality, Growth, and Removal Vegetation Structure and Diversity Lichen Communities
Physical/Chemical Indicators:	Ambient Levels of Criteria Air Pollutants Stream Flow Inland Lake Water Quality Contaminant Levels in Fish Inland Lakes Sediment Trends Contaminant Levels in the Connecting Channels, Saginaw Bay, Grand Traverse Bay, and Major Tributaries Climate and Weather Change
Future Indicators:	Ambient Levels of Air Toxic Contaminants Rates of Deposition of Persistent and Bioaccumulative Air Toxics and Acidic Components Trends in Mammal Populations
Optional Indicator:	Contaminant Levels in Bald Eagles

Source: Michigan Environmental Science Board, *Recommended Environmental Indicators Program for the State of Michigan,* July 2001.

and emerging contaminants of concern in Michigan. The first section presents the ecological, physical, and chemical measures used to track the overall quality of the state's environment and fulfills the legislative mandate. The second section discusses additional state agency measures that are tracked to fulfill various state or federal environmental programmatic requirements. These latter measurements, while in and of themselves may ultimately detect a change in the overall quality of the environment, are designed more to assess how well a given regulatory program is functioning to correct or control more short-term, localized environmental problems. The third section discusses several newly recognized contaminants that environmental and public health experts have an incomplete understanding regarding their potential for adverse environmental and human health effects.

As indicated in the previous three Biennial Reports, caution should be exercised with the information presented in this Triennial Report. First, care should be taken not to understate or overstate the importance of a change that may be observed in any given environmental indicator from one reporting period to the next. Two and even three years is an extremely short time frame for a natural or human-influenced disturbance or corrective action to be realized within most ecosystems. Also, with most environmental measures, it can take many years of monitoring data to properly identify and assess the emergence of either a positive or negative variation in the environment. The importance of this and subsequent Triennial Reports will be best reflected in terms of their ability to detect long-term changes that may be taking place in the environment, rather than short-term anomalies that may be observed from one reporting period to another.

Second, care also should be taken not to oversimplify the results of the Triennial Report. It is neither reasonable nor responsible to summarize the results of the collective environmental indicators down to a one- or two-word conclusion about the overall health of such a highly complex system as the state's environment. While certainly simple to understand, such relative comparison labels as *good, moderate, bad, healthy, unhealthy,* etc., are indefinable scientifically and often can be misleading. In almost all cases, additional qualifying information is needed to describe accurately what the various environmental measures appear to be indicating.

Finally, it is recognized that incomplete information exists for several of the environmental measures presented in this Triennial Report. These data gaps will be filled by successive Triennial Reports. With time, the Triennial Reports should provide Michigan with an invaluable tool to track and evaluate its ever changing environment. More importantly, the Triennial Reports should help to spur the development of new and innovative environmental stewardship policies and programs to further enhance the state's overall environmental quality.

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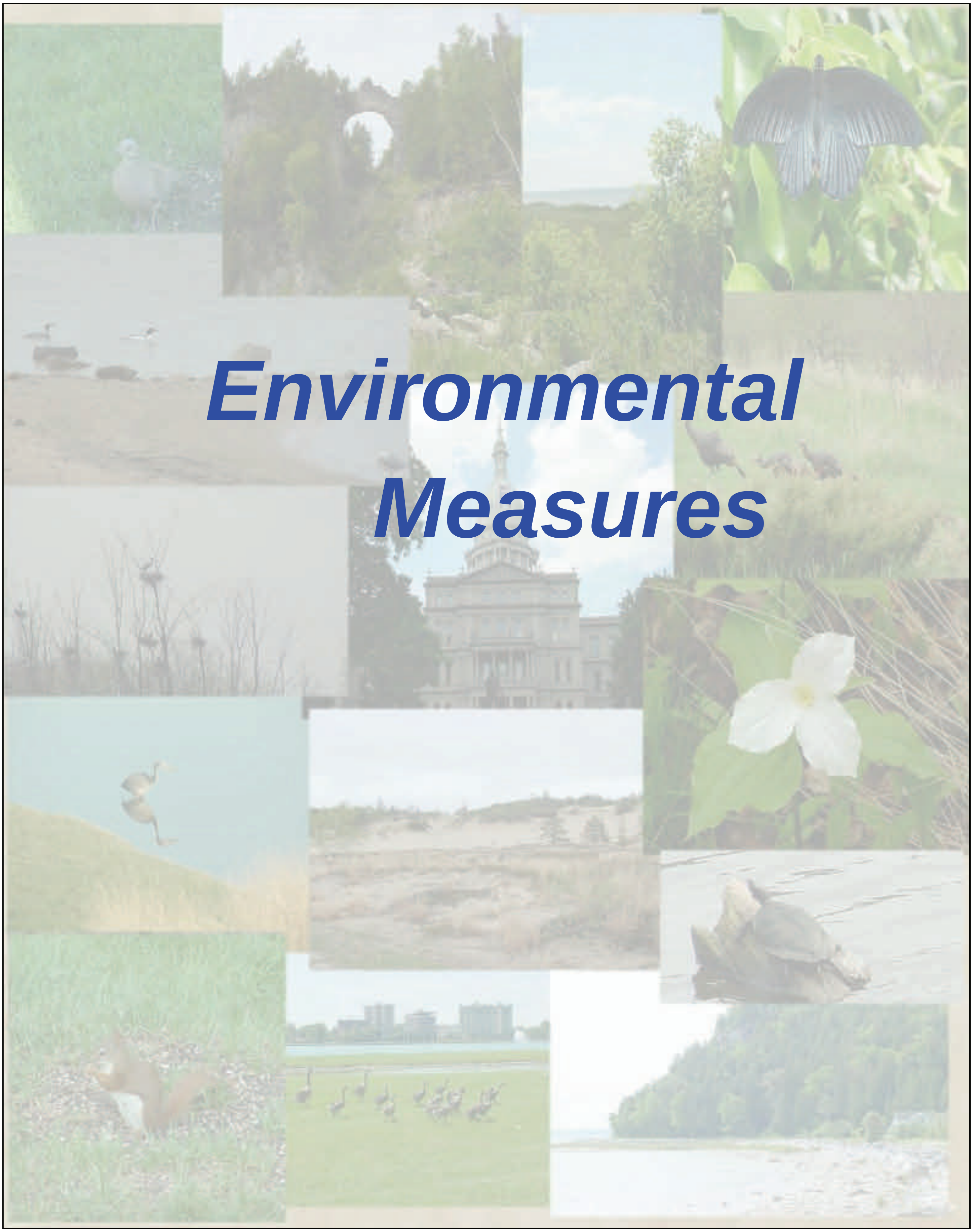
Triennial Report Editor

December 2008

The Michigan Envirothon has been in existence since 1994 and provides environmental and natural resources education to high school students and their adult advisors throughout the state of Michigan. The Michigan Envirothon is designed to foster critical thinking, wise stewardship, and community involvement. More information may be obtained by visiting the Michigan Envirothon Internet Site at www.michiganenvirothon.org.

Environmental Measures



Environmental Measures

Ecological Indicators

Trends in Land Use/Cover

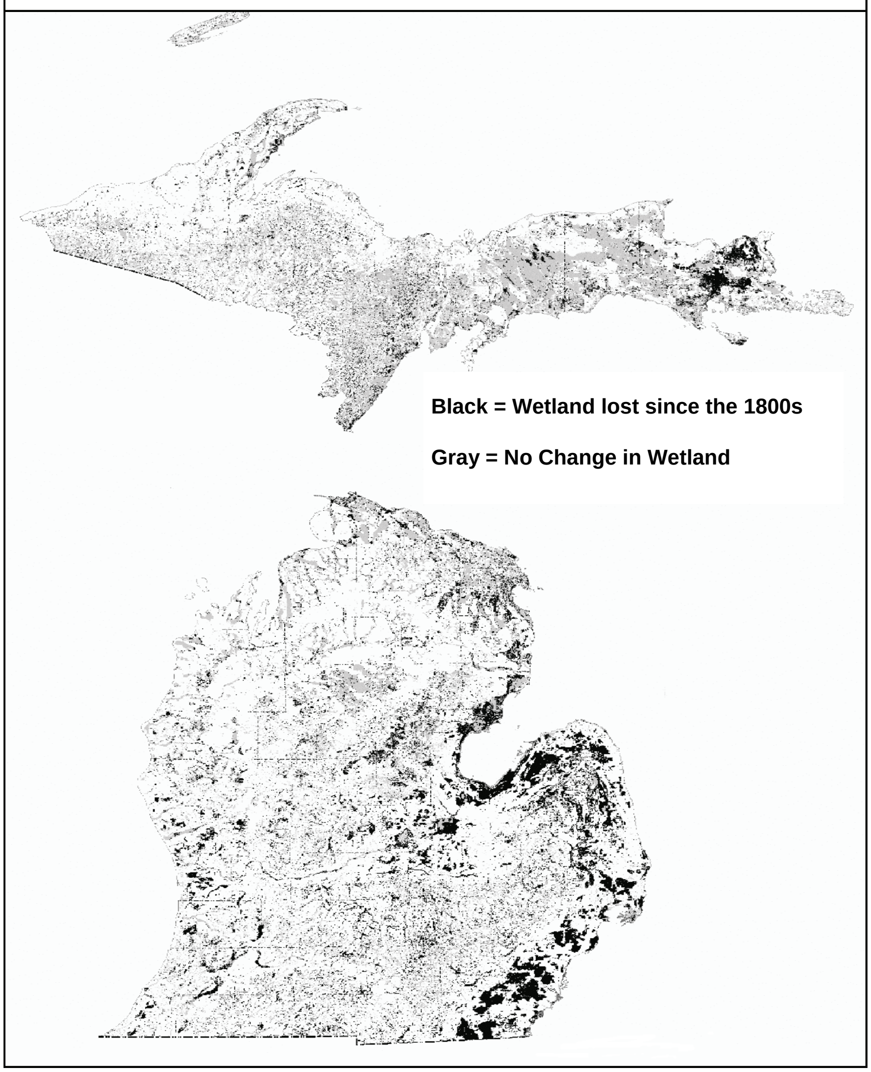
Monitoring change in land use/cover types provides a useful indirect measure of trends in ecosystem health. High rates of land conversion place stress on natural ecosystems. Human population growth and/or dispersal usually cause a conversion of land use/cover types from natural vegetation or agricultural 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 northern Michigan landscape and intensive agriculture and urban development in southern Michigan. Exhibits 2 and 3 provide a graphic representation of the loss of wetlands in Michigan between 1800 and 1980 and the percent change in natural 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 MDNR. 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 National Resources Inventory program. According to the USDA, between 1982 and 1997 there was a 30 percent increase in developed land with almost half that increase occurring between 1992 and 1997 (Exhibit 4). Most of this development occurred on former agricultural land. During this same time period, there was a loss of approximately 1.4 million acres of crop and pasture land.

Other noticeable recent trends include an increase in forests and a decrease in wetlands. Between 1982 and 1997, there was an increase of 538 thousand acres of forest on non-federal rural land in Michigan. The increase in forest was the result of natural succession of open fields and abandoned agricultural land. In 1978, Michigan had approximately 6.2 million acres of wetlands. 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. The most disturbing trend in land cover has been the rapid conversion of natural landscapes and agricultural areas to suburban and urban development. These conversions of agricultural land have traditionally resulted in increases in water and air pollution.

Exhibit 2. Changes in Michigan's Wetlands 1800 - 1980



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 parts of many cities. 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.

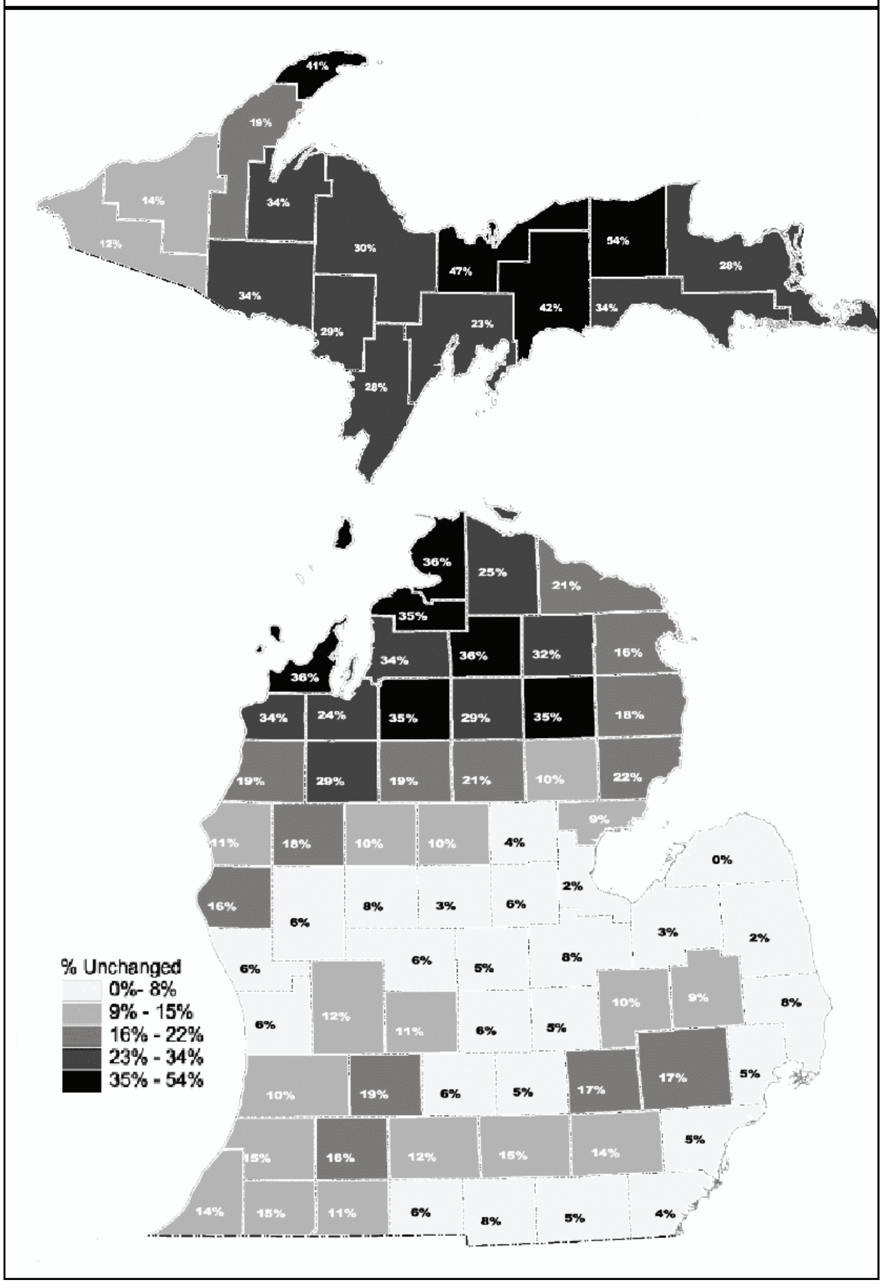
In 2001, the Michigan Land Resource Project looked at the future of Michigan's land-based industries if current development trends continue. The Michigan Land Resource Project projected that by 2040 the amount of developed land in Michigan will have increased by 178 percent, nearly three times that which currently is developed. At the same time, it was predicted that the amount of acres in agriculture, private forests, wetlands, and other vegetated lands, would decrease by 17 percent, 8 percent, 10 percent, and 24 percent, respectively (Exhibit 5).

In February 2003, the Governor of Michigan created the Michigan Land Use Leadership Council (Council). The Council was charged with studying and identifying trends, causes, and consequences of urban sprawl and providing recommendations designed to minimize the negative effects of current and projected land use patterns on Michigan's environment and economy. The Council's report entitled, *Michigan's Land, Michigan's Future: Final Report of the Michigan Land Use Leadership Council* (Land Use Report), was released in August 2003.

The Council's Land Use Report recommendations were organized along four categories (urban revitalization, land resource-based industries, planning and development regulation, and infrastructure and community services), and addressed nine key issues to combat urban sprawl The nine issues and the actions taken to date to address the issues are presented in Exhibit 6.

Among the recommendations in the Land Use Report, the Council called for the state to complete its natural features inventory and to update its 1978 Michigan Resource Information System Current Inventory by completing a new round of aerial photography and land use/cover classifications. The Land Use Report also called for the development of a report every five years that would evaluate the amount of farmland and forested lands that were in active production, the change in land cover by county, and the number of Michigan citizens housed each year in new construction.

Exhibit 3. Percent Change in Native Vegetation by County between the 1880s and 1900s



Since the release of the Council's Land Use Report in 2003, several pieces of legislation have been enacted, many state initiatives have been developed, and many new state polices implemented to begin the process of addressing the over 160 recommendations contained in the Land Use Report. Exhibit 7 highlights some of the key activities taken thus far by three state departments to address urban sprawl and the various problems that have resulted from it.

Changing long-held attitudes and past practices regarding how land should be used within the state will require a long-term commitment and a cooperative effort on the part of federal, state, and local governments, and the citizens of Michigan. A copy of the Council's Land Use Report may be obtained from the Governor's Internet site (www.michigan.gov/gov).

Trends in Forest Acreage, Mortality, Growth, and Removals

The Forest Acreage, Mortality, Growth, and Removals indicator addresses several dimensions relating to the health of Michigan's forests. As previously indicated, Michigan's forests have been recovering following over-exploitation and fire devastation that took place towards the end of the 19th Century and the beginning of the 20th Century. The state will never again see the vast forest acreages or the old growth forests that once were present; however, recent inventory data indicate the state's forests have been steadily recovering from the earlier devastation.

Five statewide forest inventories were conducted during the last century and information from a new inventory is now available. These inventories indicate that forest acreage has remained relatively stable since the 1950s. The only exception to this was a slight decrease between 1966 and 1980, followed by an expansion between 1980 and 1993 (Exhibit 8). Losses (or conversions out) of forested land between 1980 and 1993 were made up for by other lands being converted into forest. The

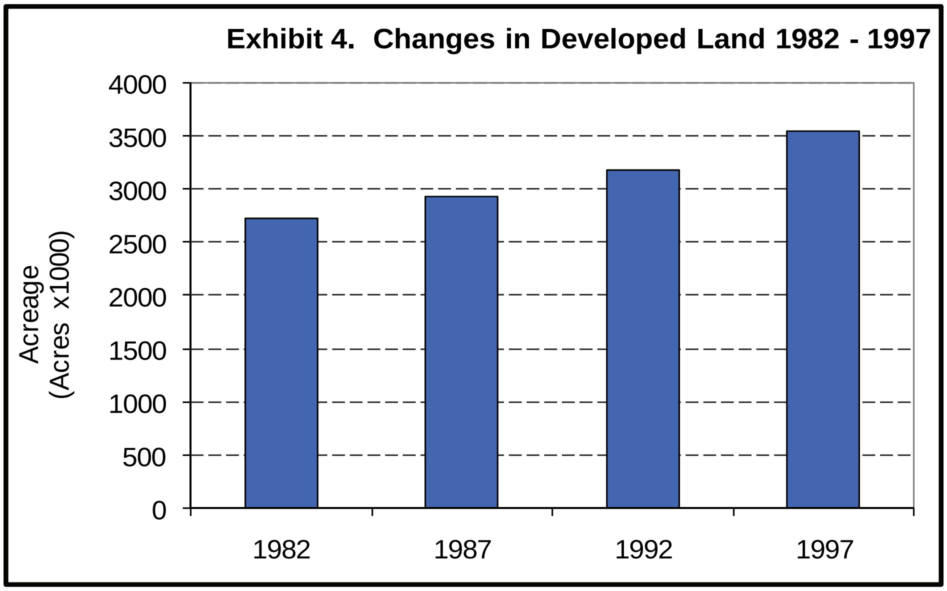
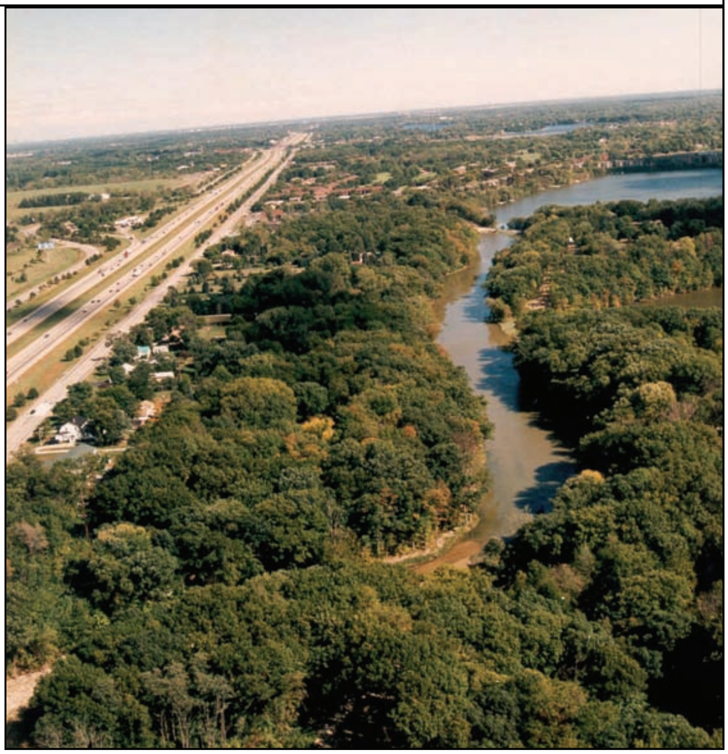


Exhibit 5. Classes of Land Use in 1980 and Projections to 2040

Land Use Classes	1980 (Millions of Acres)	2040 (Millions of acres)	Change	Percent
Agriculture	11.0	9.1	-1.9	-17%
Developed Land	2.3	6.4	+4.1	+178%
Private Forestland	18.2	16.9	-1.3	-8%
Other Vegetated Lands	2.9	2.2	-0.7	-24%
Wetlands	1.8	1.7	-0.2	-10%

Source: Public Sector Consultants, *Michigan Land Resource Project*, November 2001.

predominant land type converting into forest was agricultural. In contrast to the stable forest acreage, total standing timber volumes have almost tripled since the middle of the last century, reflecting a maturing forest. 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. Annual growth has steadily increased over the past 50 years (Exhibit 9).



Trends in Vegetation Diversity and Structure

Michigan's forests are some of the most diverse in the United States. 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 towards more shade-tolerant, late successional tree species. For example, aspen, paper birch, and jack pine, species particularly adapted to full sunlight, have been declining in acreage while the more shade tolerant species such as maples, northern white cedar, spruces, and oak-hickory types have been increasing. Similarly, animals that depend on pioneer tree species for habitat also have been declining. 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. Between 1980 and 1993, maple-beech-birch cover type, by far the largest in Michigan, increased by almost one million acres. Given existing conditions, the trend towards more shade tolerant, older trees can be expected to continue.

The MDNR, 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

Exhibit 6. Identified Land Use Issues and Initiatives to Date (Bold) to Address Urban Sprawl

- ➔ Preserving agricultural land, forests, wildlife habitat, and scenic resources that form the basis of Michigan's land resource-based industries by enhancing existing programs and creating new incentives for private land owners to maintain these valuable undeveloped open spaces (**A new Qualified Private Forest Reserve program is now in place providing tax credits).**
- ➔ Supporting efforts to make Michigan cities more livable by expediting the reuse of abandoned properties, controlling blight, encouraging private investment, encouraging mixed-use development, improving transportation options, supporting a full range of housing options, and attracting and retaining residents who can contribute to the viability of our urban core areas (**The Cool Cities and Cities of Promise programs are being applied to help address this issue).**
- ➔ Making better use of existing public infrastructure by encouraging public and private investment in already developed areas **(A more efficient Revenue Sharing has been proposed by the state to apply to this recommendation).**
- ➔ Providing new tools to local government to encourage better land use decisions that allow more compact, mixed-use development **(See MSU's new Smart Growth Assessment tool at www.landpolicy.msu.edu/sgrat/)** .
- ➔ Creating incentives to encourage interagency and intergovernmental cooperation in addressing land use issues and public investments of more than local concern **(See the state's Centers for Regional Excellence Initiative at www.w3.michigan.gov/cre)** .
- ➔ Encouraging private investment in already developed areas by removing governmental barriers and creating incentives **(See MEDC's Mega Grants and Tax Credit programs at www.themedc.org/).**
- ➔ Streamlining state and local government financial assistance and regulatory programs that support land use practices **(See the Cool Cities and Centers for Regional Excellence Resource Toolbox and Priority Access for Designees program at www.coolcities.com/)**.
- ➔ Seeking government partnerships with for-profit and non-profit sectors to create a range of affordable housing options **(See the MSHDA's Save the Dream program at www.michigan.gov/mshda/0,1607,7-141-7559_7561-188860--,00.html).**
- ➔ Identifying commerce centers where infrastructure is already serving relatively dense populations to guide the future investment of state resources to support private investment and development **(Legislation is pending in Michigan Legislature to establish commerce centers).** .

Source: Michigan Land Use Leadership Council, *Michigan's Land, Michigan's Future: Final Report of the Michigan Land Use Leadership Council*, August 2003.

Exhibit 7. Examples of Recent State Department Activities to Address Urban Sprawl

➔ **Michigan Department of Agriculture**
A new aerial photography survey of the state was completed in spring of 2007. Development of legislation to establish *Agricultural Production Districts* If passed, local units of government could grant certificates to owners of agricultural land that would allow them to pay in lieu of certain personal and property taxes, an alterative agricultural production tax, which would encourage retention and use of agricultural land. Initiation of a *Purchase of Development Rights Grant Program* to provide grants to local units of government to fund purchase of development rights on farmland in areas of the state that have comprehensive land use plans in place. .

➔ **Michigan Department of Environmental Quality**
The MDEQ has completed an internal review of all division programs for consistency with the Land Use Report. Of the approximately 160 recommendations of land use reform within this report, 88 have been found to have direct or indirect relevance to MDEQ programs. Of these 88 recommendations, the MDEQ currently is addressing 38 of them. An additional 18 are to begin implementation based on adjustments made to existing agency program policies. The MDEQ's goal is to become consistent with the Land Use Report in as many of its programs as possible. An additional 28 Land Use Report recommendations could be addressed by the MDEQ if additional resources and/or authority were obtained by statute.

➔ **Michigan Department of Natural Resources**
In 2008 the MDNR completed review of all of its owned parcels outside of dedicated management area boundaries in all 83 counties. These parcels were classified into one of three action categories: 1. Retention under state ownership and management, 2. Retention and transfer to another unit of government or an alternative conservation organization, or 3. Disposal because the parcel has limited natural resource, recreational, or cultural value. The MDNR is now in the process of administering the transfer or sale of parcels identified through the review process.

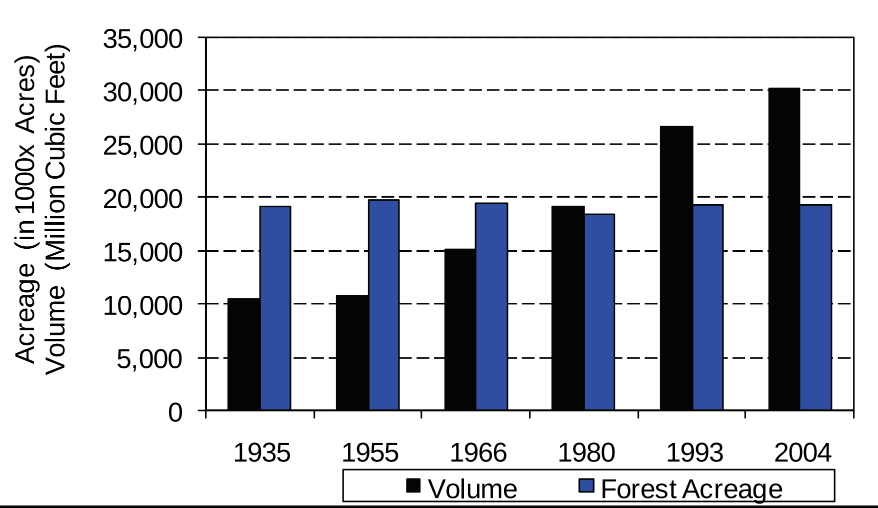
field identify nearly all the plant species on site, including locally rare species and exotic species from overseas. An immediate return from this evaluation will be to detect areas of exotic plant invasion and spread. Multi-scale data on plant diversity will be used to evaluate species richness patterns 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.

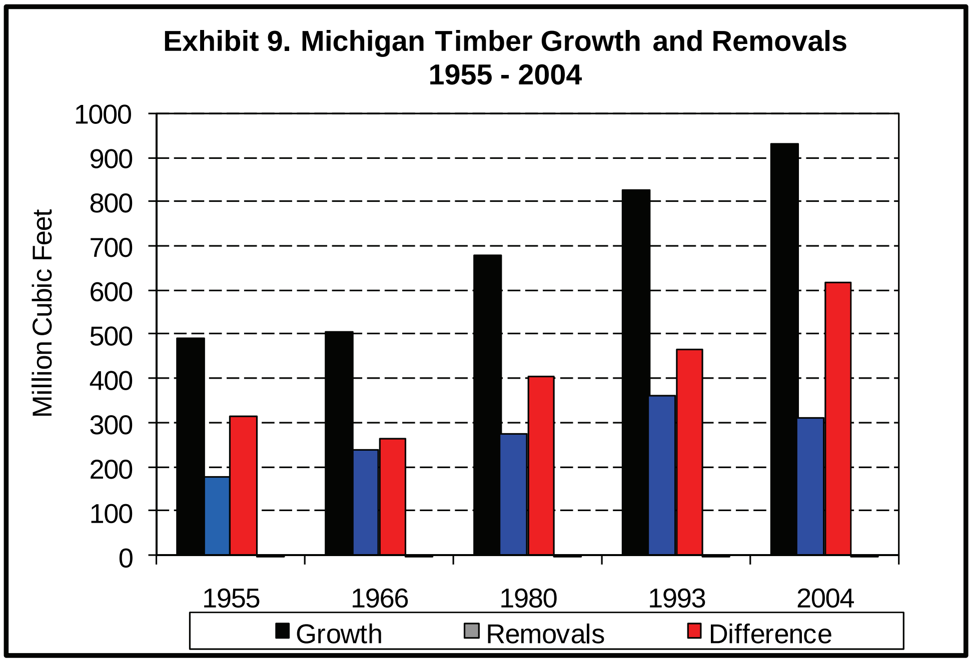
Trends in Lichen Communities

Lichens are unique organisms, 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

Exhibit 8. Michigan Forest Acreage and Volume 1935 - 2004





a bellwether of declining or improving environmental conditions.

The USDA Forest Service's FHM Program developed the lichen community indicator. On forested plots samples of each lichen species are

collected for laboratory identification and the relative abundance is estimated. Data collected in Michigan in 2000 identified 29 epiphytic lichen species representing 17 genera on Michigan plots (Exhibit 10).

This indicator is still in its early stages of development in Michigan. Ultimately, the collected data will be used to establish baseline information necessary to measure future changes in Michigan's environment. Over the next several years, the MDNR will be carefully monitoring changes in the abundance of lichen species, especially in the rarest species (Exhibit 11). Lack of funding for this facet of the FHM Program has prevented collection of lichen indicator data since 2000. It is anticipated that these data will be collected again beginning in 2009.

Trends in Mammal Populations

The majority of mammal population trends are identified by using indices such as the *Winter Track Survey* and *Harvest Surveys*. These indices use data that are significantly correlated to population size. Obtaining population counts for mammal species can be difficult because many mammals are elusive or have large home ranges or daily movement patterns that make them difficult to detect. Consequently, total population counts are attempted on only a few large mammal species that are easily seen or leave significant markings.

The MDNR conducts an annual Winter Track Survey for wolves. The Winter Track Survey provides a minimum wolf population estimate and is completed after new snow events to identify individuals and packs. The wolf population in the state's Upper Peninsula (excluding Isle Royale) showed steady growth between the onset of monitoring in 1989 and 2007 (Exhibit 12). From

1994 to 2007, the population increased at an average annual rate of 19 percent. However, the average annual growth rate has declined as the population has increased. Three wolves were verified in the northern Lower Peninsula in 2004, but subsequent surveys have not confirmed the continuing presence of any wild wolves in that area.

Exhibit 10. Relative Lichen Abundance by Genus at 240 Forest Health Monitoring Plots in Michigan 2000

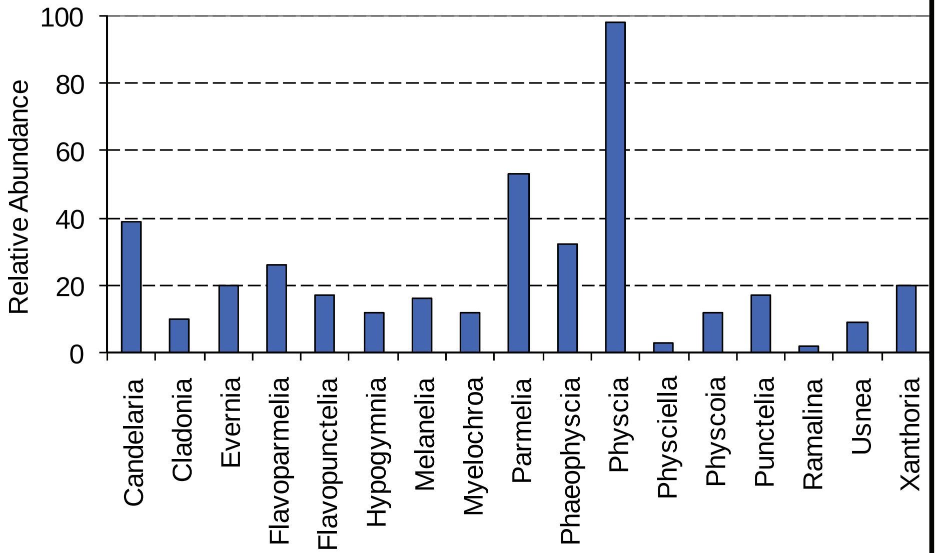
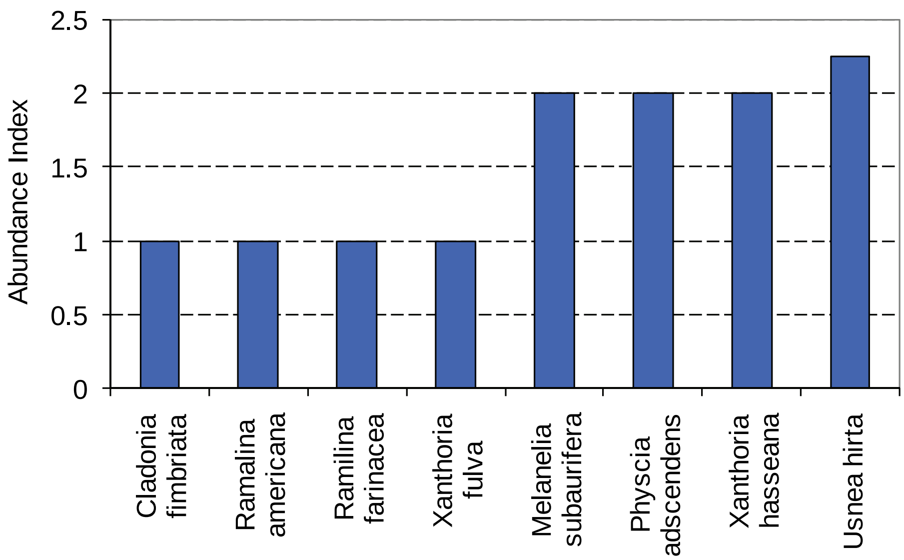


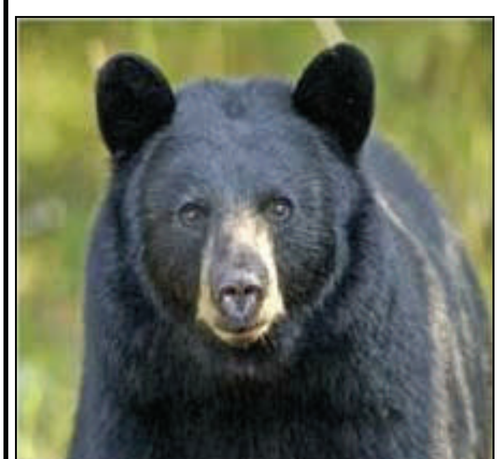
Exhibit 11. Average Relative Abundance of the Rarest Lichen Species at 240 Forest Health Monitoring Plots in Michigan 2000

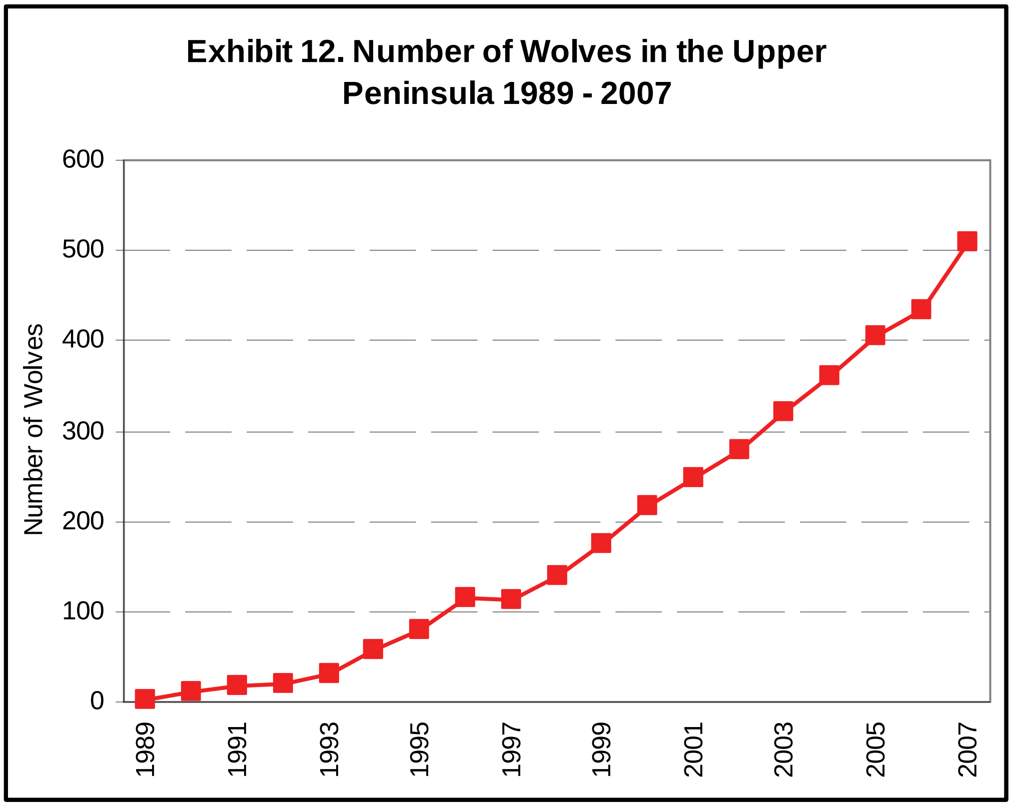


The recovery of the wolf population in the Upper Peninsula is a positive indicator of ecosystem health. As top predators, wolves perform an important ecological function by influencing prey abundance, improving the overall health of prey populations, and increasing food available to scavengers. They also can help control populations of secondary predators and have positive, indirect effects on multiple trophic levels.

The most readily available index of furbearer and small game populations are annual harvest surveys. Michigan conducts annual hunter and trapper harvest surveys for many species. Once hunting seasons have closed, surveys are randomly sent to hunters and trappers inquiring about their total harvest and effort (days) required to harvest selected species. The assumption is that effort is inversely related to population size; that is, as population declines the effort required to harvest an animal increases. Although this assumption is reasonably accurate, factors such as weather, timing of opening days, season lengths, and even economic conditions can affect the number of hunters and trappers and the amount of time spent pursuing game.

The harvest surveys provide a reasonably accurate assessment of the number of animals and can be a useful tool in tracking long-term





Trends in Breeding Bird Populations

Migratory songbird abundance can provide an excellent source of information on changes occurring at a landscape level. Since the mid-1960s, the USFWS has maintained an annual breeding bird survey to monitor bird abundance across the United States. While information at only the state level does not always provide reliable trends, combining data across physiographic regions does provide some level of reliability.

Michigan falls within two physiographic regions *(Great Lakes Transition* and *Great Lakes Plain*). Data collected over the last 25 years for the two physiographic regions indicate some common patterns among bird species. The largest decline has been observed in grassland species, such as the eastern meadowlark, bobolink, vesper sparrow, and Henslow's sparrow. Similarly, transitional

population trends once other influencing factors are taken into consideration. Trapper harvest surveys have been conducted annually since 1996 when they were reformulated into a standardized survey. Prior to 1996, they were not conducted on an annual basis. The harvest of several furbearer species are required to be registered. The registration information serves as another index on population. Harvests of furbearers (e.g., bear, fisher, marten, and otter) and small game species (e.g., snowshoe hare, squirrel, and cottontail rabbit) are estimated from survey results. Exhibit 13 presents hunter success harvest data for bear for the period 1990 to 2006. Except for a slight decrease in 1996, the bear population in Michigan has shown a general increase. Exhibits 14 and 15 present hunter harvest survey data for snowshoe hares and squirrels for the period 1952 to 2006, respectively. Part of the decline observed in annual small game harvest is related to declines in hunter participation and sales of small game licenses.

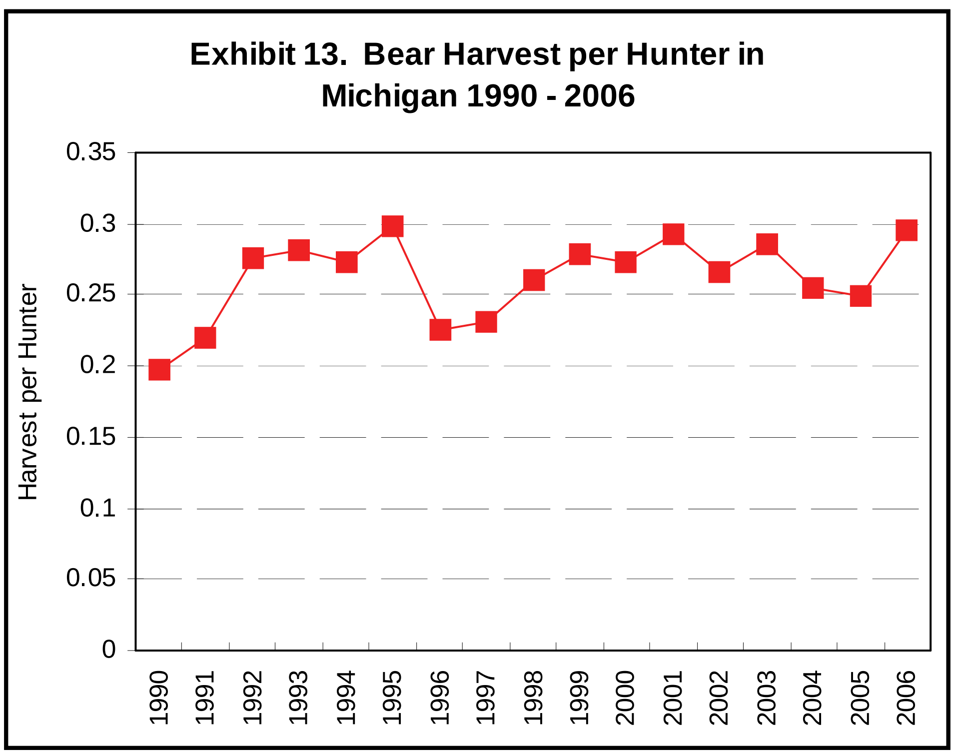


Exhibit 14. Hunter Harvest of Snowshoe Hares in Michigan 1952 - 2006

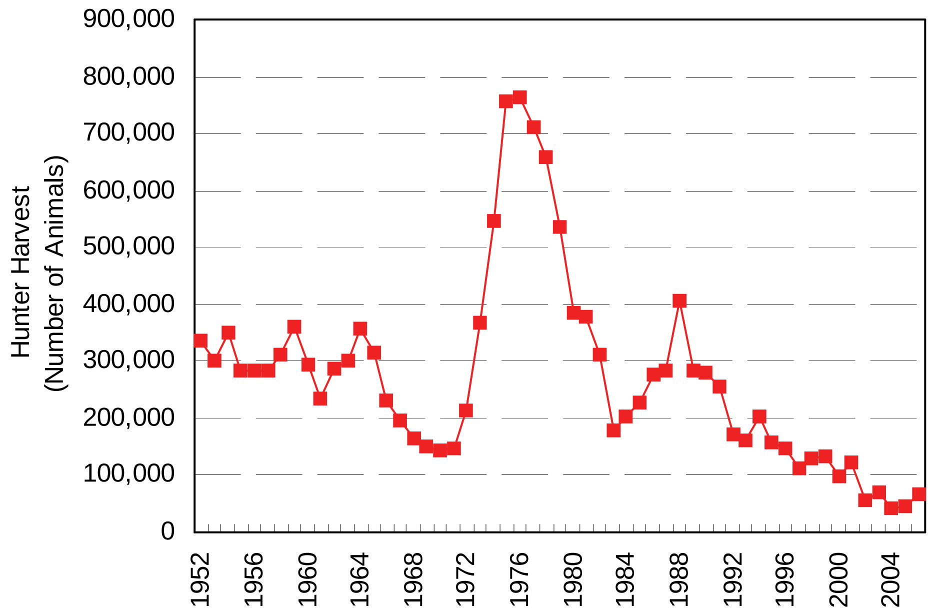
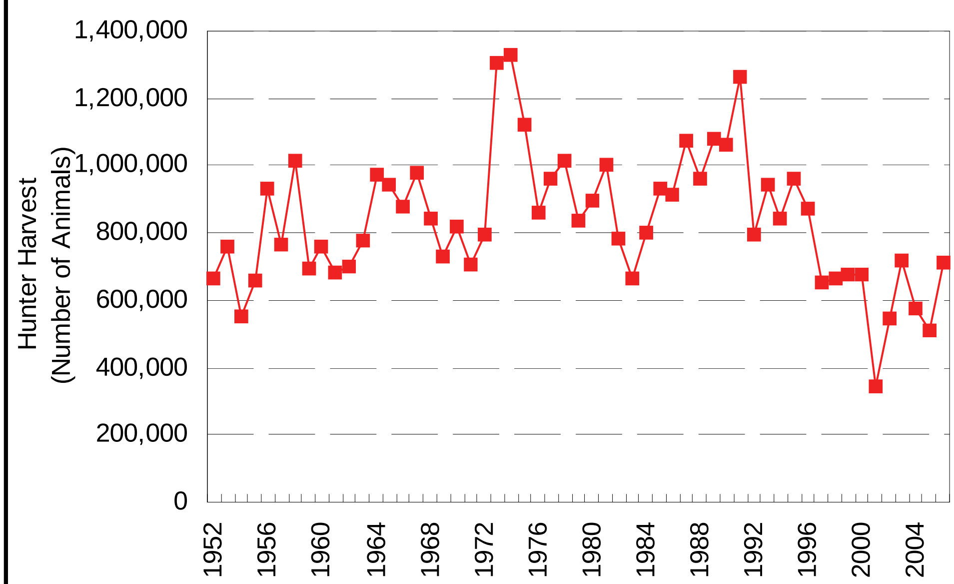


Exhibit 15. Hunter Harvest of Squirrels in Michigan 1952 - 2006



species, such as the golden-winged warbler, willow flycatcher, yellow-billed cuckoo, and American woodcock have shown sizable declines. During this same period, several generalist species, such as the house finch, northern cardinal, house wren, and eastern bluebird, which benefit from human activity, have demonstrated increases in population (Exhibit 16).

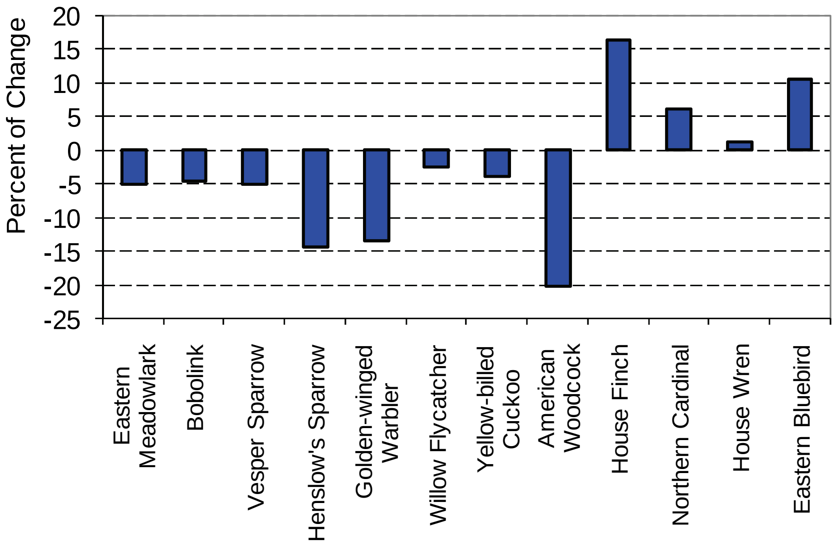
Observed declines in bird species can be attributed to several factors including habitat fragmentation and loss of early age shrub and forest systems. Decline of grasslands species has resulted from development and natural succession.

Trends in Bald Eagle Populations and Contaminant Levels

Population. The bald eagle is a top-level predator of aquatic ecosystems. The bald eagle's position at the top of the food chain makes it highly vulnerable to impacts that result 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 MDNR 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 526 occupied nests in 2007 (Exhibit 17). In addition to an increasing population, nest success, measured as number of nests producing fledged young, also has increased from 42 percent to 67 percent since 1961 (Exhibit 18). Lastly, productivity, the number of fledged young per occupied nest, has increased

Exhibit 16. Breeding Bird Population Change 1980 - 2004



from a low of 0.39 in 1963 to consistently near or above 1.0 (the healthy population level) in the past decade (Exhibit 18A). Combined, these three measures suggest that not only are bald eagles increasing in number, but that they also are successfully raising more young per breeding pair than in the past.

Contaminant Levels. The bald eagle's position at the top of the food chain also makes it a good indicator species for monitoring changing trends in levels of certain contaminants in the environment (e.g., polychlorinated biphenyls and mercury). The use of the bald eagle in this manner has been recognized by both the International Joint Commission, a United States-Canadian entity charged with overseeing Great Lakes water quality protection, and the United States Environmental Protection Agency (USEPA) as a useful Great Lakes Indicator of environmental health.

Building on an earlier research program, a consortium composed of the MDEQ, USFWS, and researchers from Michigan State University (MSU) and Clemson University initiated the Bald Eagle

Exhibit 17. Occupied Bald Eagle Nests in Michigan 1961 - 2007

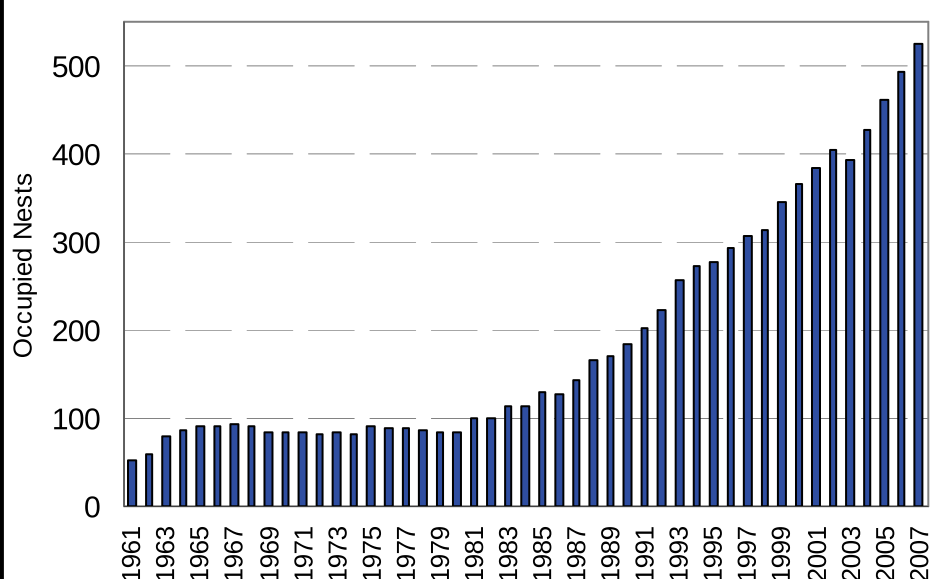
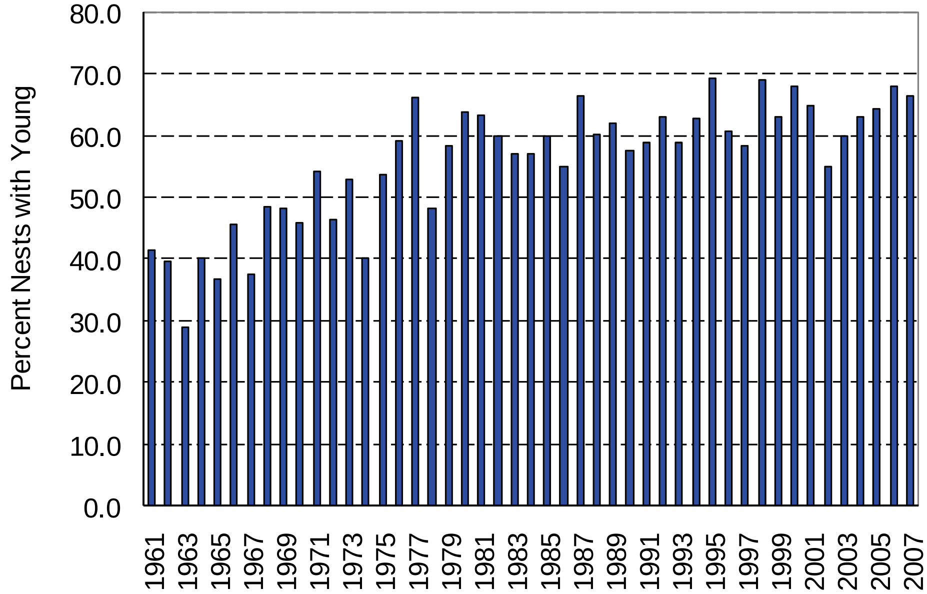


Exhibit 18. Success Rate for Occupied Bald Eagle Nests 1961 - 2007



Contaminant Monitoring Project in 1999. Under the project, eagle blood and feather samples are collected (using non-lethal procedures) from permanent inland nests, from nests in additional inland watersheds being assessed as part of the MDEQ's five-year rotating watershed schedule, and from Great Lakes and connecting channel nests.

Exhibit 19 shows changes in polychlorinated biphenyl (PCB) concentrations in bald eagles between the late 1980s - early 1990s and 1999 - 2004. PCB levels in the blood of bald eagles were dramatically lower in the 1999 - 2004 period compared to a decade ago for interior Upper Peninsula and Lower Peninsula nests and nests near Lakes Superior, Michigan, and Huron. The Lake Erie PCB data need to be judged with caution because only five eagles were sampled between 1999 and 2001.

Exhibit 20 compares the geometric mean mercury levels in bald eagle feathers between 1985 - 1989 and 1999 - 2004. Mercury concentrations showed a slight decrease between the two sampling periods.

Trends in Frog and Toad Populations

Michigan is home to 13 native species of frogs and toads. In recent years, scientists have been concerned about observed declines or population die-offs of several of these species worldwide. This concern was not only for the loss of the species themselves, but also for the loss of the habitats on which they depend. Frogs and toads are sensitive to changes in water quality and adjacent land use practices. Consequently, changes in their populations can serve as an index to changes in environmental quality. In 1996, the MDNR instituted a statewide volunteer calling survey to monitor frog and toad populations and to evaluate the amphibian decline issue in Michigan. It is anticipated that site-specific research projects may be initiated in areas where amphibian declines are identified to determine the causes of those declines and to gain insight into habitat degradation.

Exhibit 18a. Productivity Rate for Bald Eagles (Young Fledged per Occupied Nest) 1961 - 2007
(1.0=Healthy Population Level)

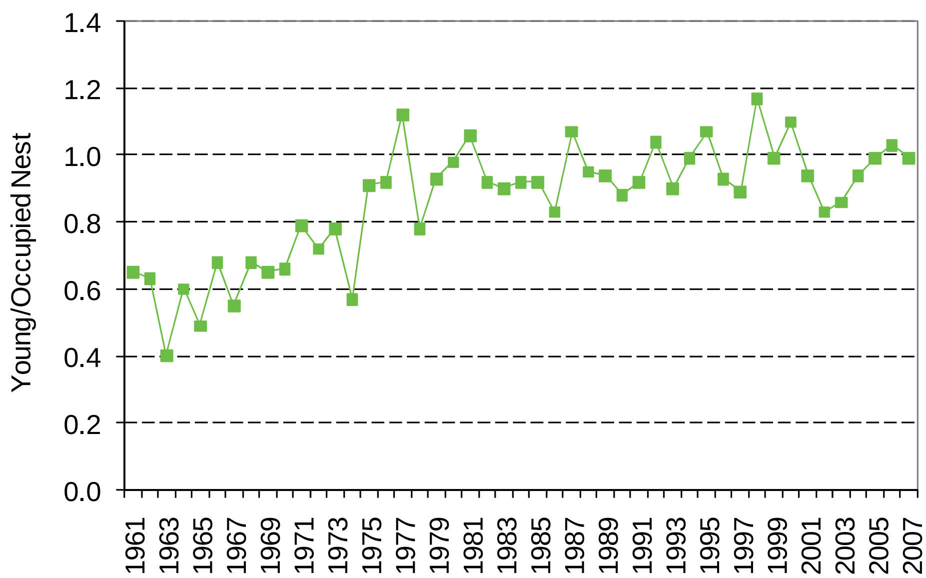


Exhibit 19. Geometric Mean Polychlorinated Biphenyl Concentrations in Nestling Bald Eagle Blood 1987 - 1992 and 1999 - 2004

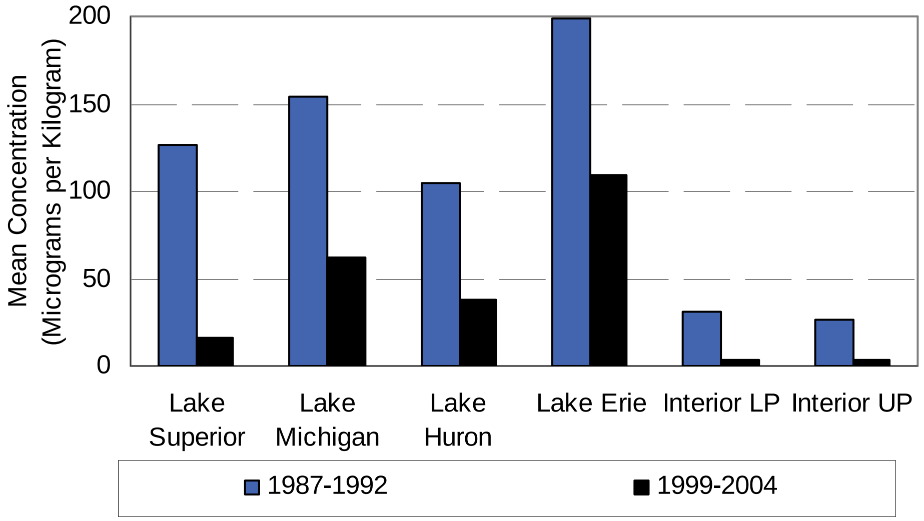
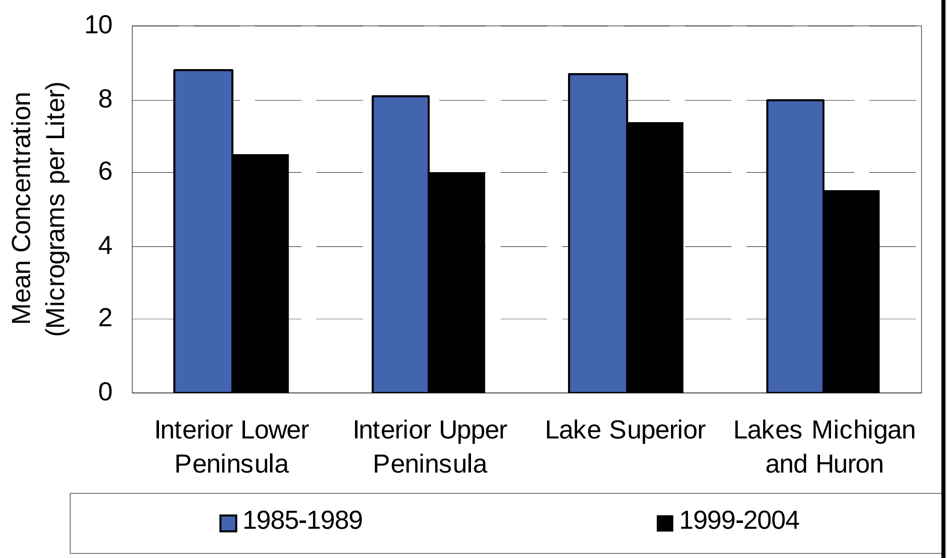


Exhibit 20. Geometric Mean Mercury Concentrations in Nestlng Bald Eagle Feathers 1985 - 1989 and 1999 - 2004

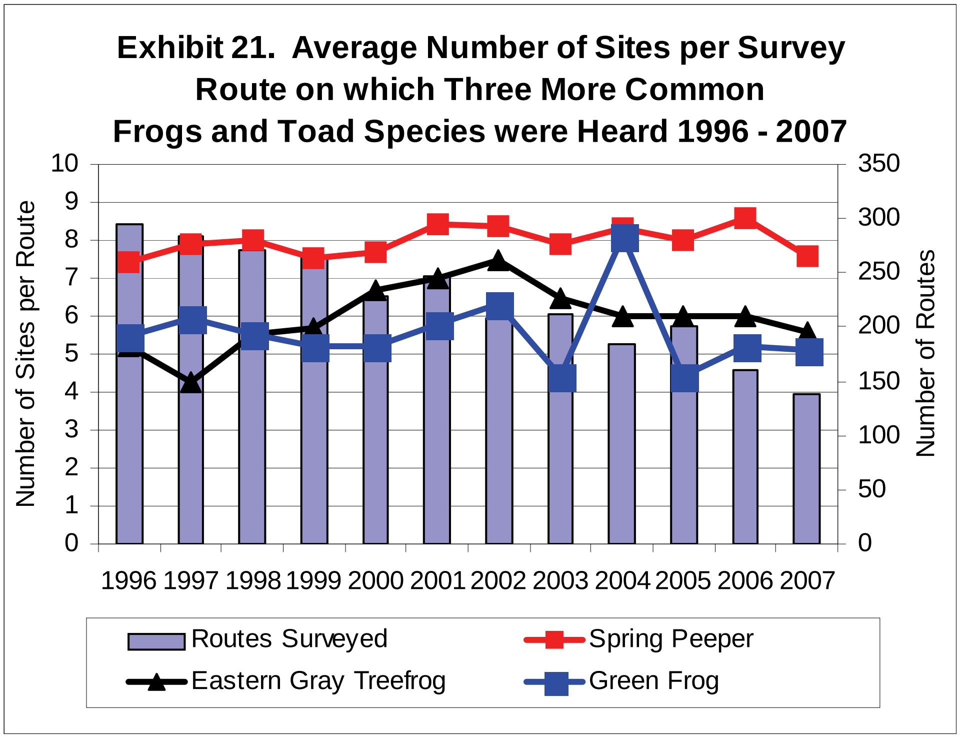


The initial amphibian survey protocol used by the state mirrored that of a long-running and successful survey in Wisconsin. Later, the United States Geological Survey (USGS) developed nationwide protocols as part of the *North American Amphibian Monitoring Program*, which Michigan is a participant. Survey routes currently consist of 10 sites at which volunteers stop and listen for the amphibians and record the species and an abundance index for each species on a data sheet. Each survey route is visited three times during the breeding season. Statewide surveys have not been conducted in the past, so any comparison to historical data is only possible for local areas.

Exhibits 21 and 22 illustrate abundances of six frog and toad species that have statewide distribution. The number of routes surveyed each year (solid bars) also tracks the level of volunteer effort. Exhibit 21 shows the average number of sites per route at which three of the most common species of frogs in Michigan (spring peeper, eastern gray tree frog, and green frog) were heard over the ten-year period. Trend analysis of these data currently shows no significant increase or decrease for any of these species.

Exhibit 22 shows the average number of sites per route at which three of the less common species of frogs and toads in Michigan (northern leopard frog, bullfrog, and American toad) were heard over the ten-year period. The fluctuation of abundance of the American toad is a good example of how factors in one year may impact survey results. The reason for the decline in 1998 of American toads is currently unknown. Hopefully, longer term monitoring should show if the low number of American toads in 1998 was the result of a natural fluctuation or a human-influenced environmental factor. Trend analysis shows no significant increase or decrease in the northern leopard frog or bullfrog.

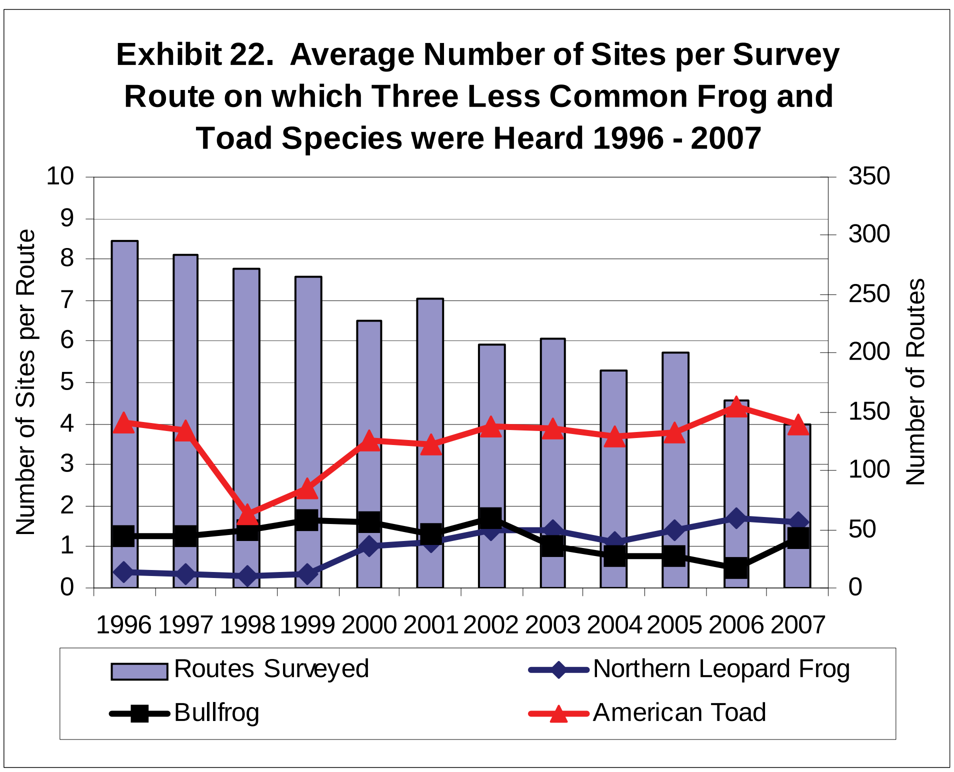
Long-term trends will require many years of data before meaningful information can be discerned. It is known that natural fluctuations occur in



amphibian populations. Many years of data will be necessary in order to be able to distinguish these fluctuations from those caused by human-related factors such as pesticide use or habitat losses. Weather factors also play an important role in calling surveys and can affect the amount and the quality of the data in any one year. The MDNR plans to continue the statewide surveys indefinitely and hopes to maintain a consistent and knowledgeable volunteer workforce.

Trends in Fish Populations, Benthic Macroinvertebrates, and Contaminant Levels

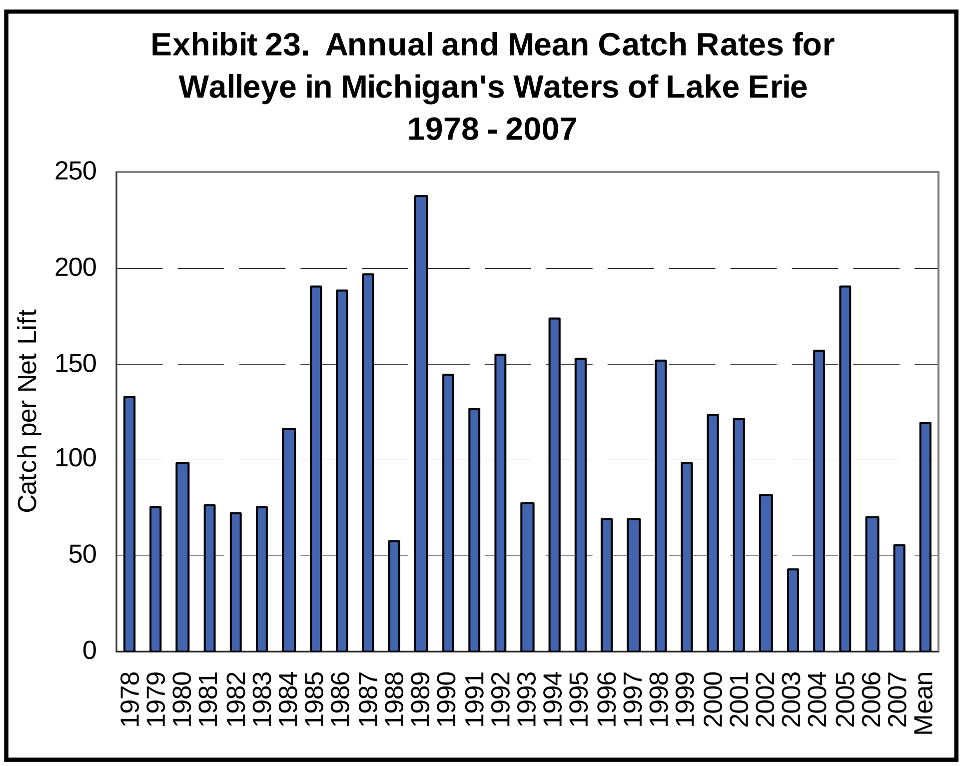
Walleye in Lake Erie. The MDNR has employed an experimental gill net fish sampling protocol at two stations in western Lake Erie since the fall of 1978 as part of a cooperative interagency Walleye Assessment Program. This protocol, referred to as the *Index Gill Net Survey*, typically includes two 1,300-foot sets of variable-mesh multi-filament gill nets at each sampling station. The gill nets are suspended six feet below the surface of the water. The Index Gill Net Survey is conducted during early October each year.



Gill net catch rates reflect trends in walleye abundance. Exhibit 23 shows the trend in the total walleye catch rate for each year of the MDNR 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, but declined again in 2006 and 2007. Annual walleye abundance is strongly related to annual variation in reproductive success. This is reflected in yearling catch rates each year (Exhibit 24). Poor recruitment for Lake Erie walleye is well illustrated in the low catch rates observed for yearlings from the 2000, 2002, 2004, and 2006 year classes. In contrast, the yearling catch for the 2003 year class indicates reproductive success was the highest achieved since the mid-1980s.

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. Lake trout numbers are a good indicator of aquatic ecosystem health. Lake trout are long-lived and accumulate toxins in their bodies. The concentrations of these toxins are monitored by the MDEQ to evaluate potential health risks to the public. Imbalance in fish community dynamics also is reflected in shifts in lake trout population dynamics. During the 1940s and 1950s, lake trout populations significantly declined due to high levels of commercial exploitation and parasitism by the non-native sea lamprey. Subsequently, an extensive lake trout rehabilitation program was implemented to re-establish self-sustaining populations. Lake trout populations increased during the 1970s and early 1980s due to sea lamprey control, 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 a 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. During the period of increasing wild lake trout abundance, hatchery lake trout abundance and survival declined.



Currently, lake trout populations are nearly rehabilitated in all areas of Michigan's waters of Lake Superior, except in Whitefish Bay (Exhibit 25). Hatchery lake trout comprise less than 20 percent of lake trout abundance in Michigan's waters of Lake Superior, except in Whitefish Bay where most fish are of hatchery

origin. 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 in Keweenaw Bay may be affecting recovery of lake trout and is monitored closely. Another concern in the fish community that may be

affecting lake trout dynamics is the high predator to prey ratio. Lake trout growth rates have declined to the lowest levels since the 1970s. Recent survey data indicate that the major prey fish of lake trout (rainbow smelt and lake herring) are at low abundance levels.

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 because 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 ground water 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. Forest harvesting practices may either enhance or detract from trout habitat quality.

The MDNR has sampled trout populations for many years at fixed sites in portions of the upper Au Sable River system in Crawford County. Fall standing stocks (expressed in pounds per acre) of brook and brown trout in the mainstem and north branch of the Au Sable River were generally higher during the 1960s and 1970s than in subsequent decades (Exhibit 26). Standing stocks were substantially lower than average in all three branches from about 1985 to 1995, but have been increasing since that time. The declines in total trout standing stocks were caused primarily by declines in growth, survival, and reproductive rates for brown trout. This resulted in fewer large fish and lower standing stocks. Extensive additions of large woody material intended to increase availability of protective cover may be partially responsible for the recent increases in trout stocks. In addition, privately- and publicly-funded habitat restoration efforts have been directed toward reducing erosion of sediment into the river system and removing excess sand bedload by way of

Exhibit 24. Catch Rates by Year Class for Yearling Walleye in Michigan's Waters of Lake Erie 1977 - 2006

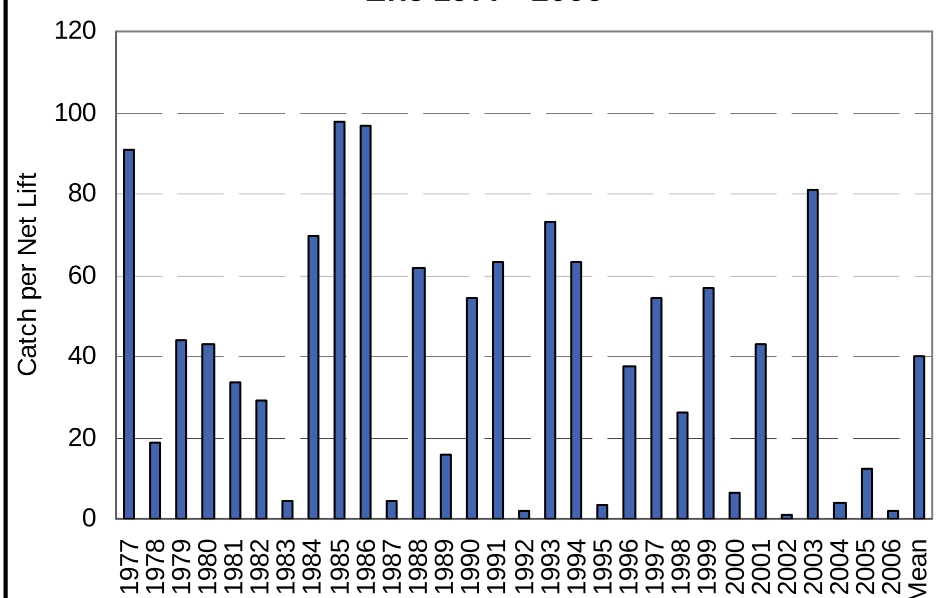
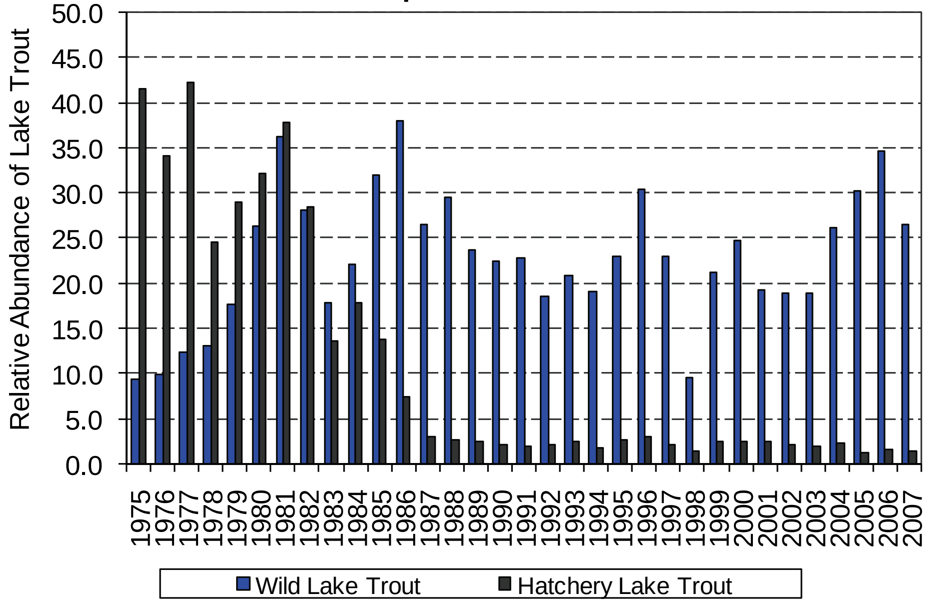
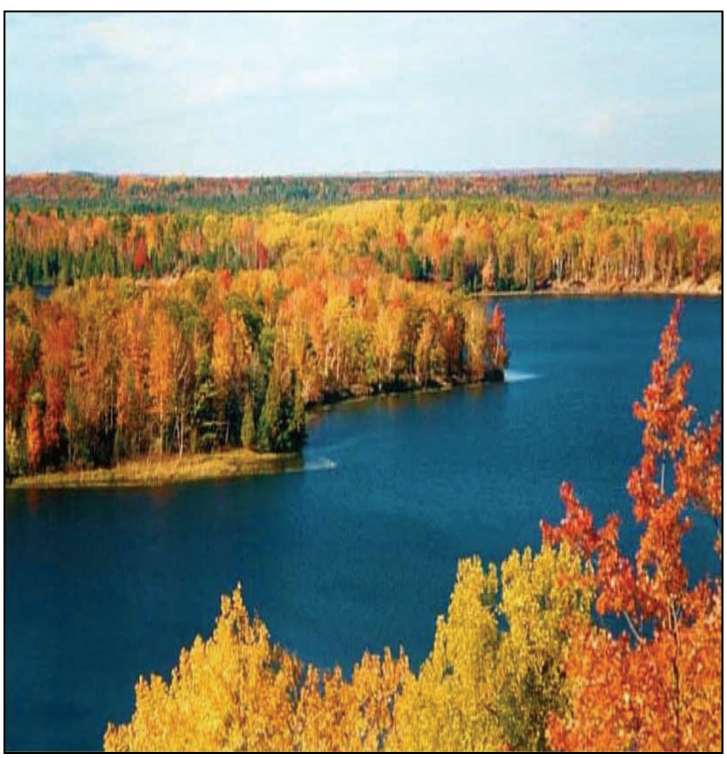


Exhibit 25. Trends in Abundance of Wild and Hatchery Lake Trout in Michigan's Waters of Lake Superior 1975 - 2007



sediment basins. 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 and the range of trout densities observed was quite large (Exhibit 27). Average total brook and brown trout density during each decade (1960s through 1990s) has been very similar. Total density of trout since 2000 has been higher than the long-term average for the period of record in all three branches. Contemporary trout abundance in the upper Au Sable River is indicative of good overall habitat quality.



Abundance of trout in the upper Au Sable River system does not necessarily reflect regional trends in habitat quality. In 2002, the MDNR implemented stream sampling protocols that will provide more comprehensive information on the status and trends in fish populations over a broader geographic area. Results of sampling conducted under the 2002 protocols are provided later in this report.

Benthic Macroinvertebrates. The MDEQ collects data on the relative abundance of benthic macroinvertebrates and fish in wadable streams and rivers throughout Michigan. These surveys, which are a major component of the state's watershed assessments, are conducted on a five-year rotating basin schedule to support the National Pollutant Discharge Elimination System and nonpoint source protection programs. The sampling method, known as *Procedure 51*, is a rapid assessment protocol designed to quickly assess stream and aquatic life conditions. Biologists sample streams to identify the benthic macroinvertebrate and fish species present and estimate their relative abundance. Fish are not always collected due to the extra time, equipment, and staff required. As a result, benthic macroinvertebrates are collected from many more sites than fish.

Because Procedure 51 is a rapid assessment technique, it is considered more of a qualitative rather than quantitative measure. Quantitative, statistical measures for each species, such as population densities, currently are not widely used. This limits the use of these data as a long-term, consistent water quality indicator. Another limitation is the absence of fixed sites that are monitored for biota on a regular basis, since watersheds are assessed over a five-year rotating basin schedule.

The MDEQ is developing a statistically-based network design and sampling procedure to measure long-term trends in benthic macroinvertebrates at a mix of fixed and randomly selected stations. This procedure was implemented in part in 2006, and will be more fully in subsequent years. The results will be summarized in future Triennial Reports.

Status and Trends Protocols. Assessing the status of over 10,000 inland lakes and 36,000 miles of stream habitat in Michigan is a daunting task. Over the past several decades, the MDNR has conducted numerous surveys of fish populations in lakes 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, with the intention of 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 inferences regarding status and trends in fish populations and communities across broader spatial or temporal scales. Consequently, this historical data strategy does not allow fishery managers to put the results of individual lake surveys in the context of larger scale trends that may need to be addressed. Recognizing the limitations of this approach to provide regional or statewide trends in fish populations, the MDNR formed the Resource Inventory Planning Committee in 1995 to develop a more scientifically sound sampling protocol. As a part of this committee's work, the MDNR instituted the Status and Trends Sampling Program in 2002. This program annually evaluates habitat conditions and fish communities at approximately 30 of 65 fixed stream locations, 20 randomly selected stream locations, and 40 randomly selected lakes throughout the state to obtain statistically sound estimates of status and trends of game fishes,

Exhibit 26. Fall Standing Stock of Brown and Brook Trout in Three Branches of the Au Sable River System 1960 - 2007

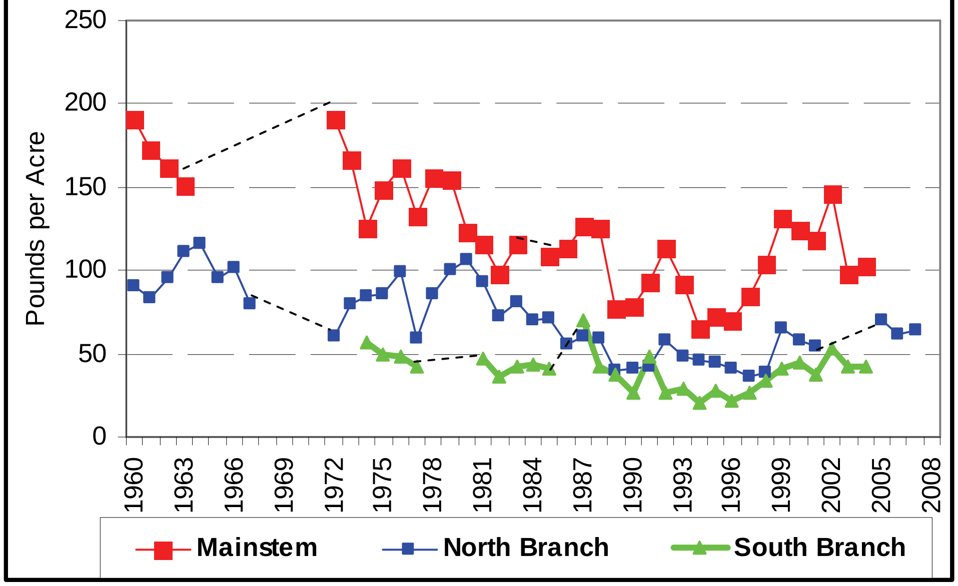
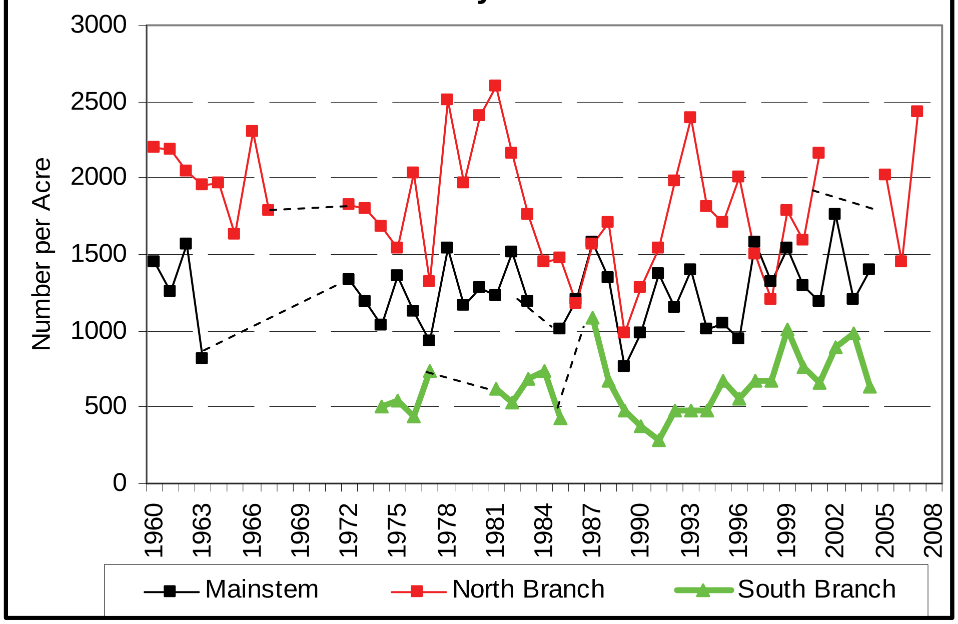


Exhibit 27. Fall Numbers of Brown and Brook Trout in Three Branches of the Au Sable River System 1960 - 2007



non-game fishes, and aquatic habitat while still providing information essential for effective fisheries management. During 2002 - 2007, 163 randomly selected lakes and 60 fixed and 105 random stream locations were sampled (Exhibit 28). Data analysis for both of these sampling programs is ongoing. It is anticipated that results from this analysis will be available for the next Triennial Report.

Contaminants in Fish. The MDEQ 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 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. These samples have been used to develop sport fish consumption advisories and to track environmental trends.

Since the 1970s, pollution control efforts have resulted in significant reductions of many contaminants. For example, PCBs in whole lake trout from the Great Lakes have declined dramatically (Exhibit 29). These data also indicate that PCB levels in lake trout from the Great Lakes, after declining from the 1970s through the mid-1990s, have remained fairly constant in recent years. In addition, PCB levels have declined in the edible portion of Chinook salmon from Lakes Michigan and Huron, although these declines also have leveled off in recent years (Exhibit 30). Based on these data, the general population consumption advisory for Chinook salmon was removed in 1996. Additional lake trout and Chinook salmon were collected between 2001 and 2007, but results have not yet been released by the USEPA.

The MDEQ coordinates the collection and analysis of whole fish from eight inland lakes as part of an effort to measure spatial and temporal trends in contaminant concentrations. Samples are collected from each site every two to five years. Select species of adult fish from each lake are targeted. Statistically significant changes in mercury concentrations were detected in data sets from four of the eight inland lakes. Mercury concentrations declined in fish from two of the four inland lakes where a trend could be detected (Exhibit 31). Although mercury concentrations apparently increased in lake trout from Grand Sable Lake (Alger County), that conclusion is based on only three sample years, and fish have not been collected there since 1995.

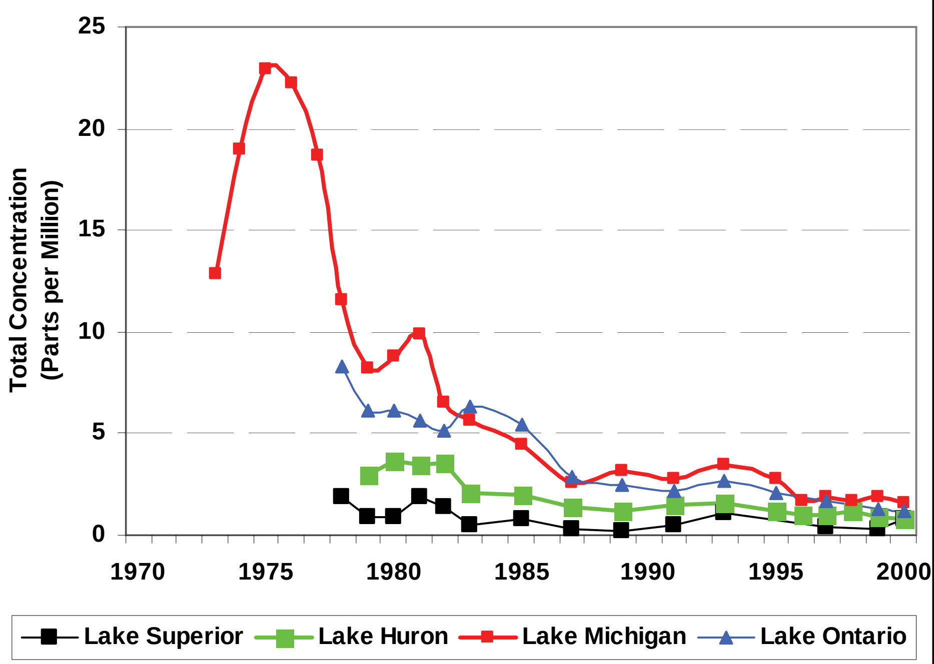
Trends in Endangered, Threatened, and Special Concern Species

The MDNR, through an agreement with the MSU Extension - Michigan Natural Features Inventory (MNFI), conducts field surveys to locate and identify endangered and threatened plant and animal species and natural communities throughout the state, and maintains databases on the various species and community locations. An *Endangered species* is one that is in danger of extinction throughout all or a significant part of its range in Michigan. A *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. The MNFI databases include plant and animal species that are protected under Part 365, Michigan Endangered Species, of the Natural Resources and Environmental Protection Act, 1994 Public Act 451, as amended (Michigan Endangered Species Act).

Also included in the databases are plant and animal species of *Special Concern*. While not afforded legal protection under the Michigan

Exhibit 28. Locations of Fixed and Random Sites on Rivers and Lakes Selected for Monitoring Long-term Trends in Fish Populations 2002 – 2007

Exhibit 29. Polychlorinated Biphenyl Concentration in Lake Trout from Four Great Lakes 1970 - 2000



Endangered Species Act, many of these species are included because of declining or relic populations in the state. Should these species continue to decline, they would be recommended for threatened or endangered status. Monitoring and protection of these species now, before they reach dangerously low population levels, may help to prevent the need to list them in the future by maintaining adequate numbers of self-sustaining populations within Michigan. Some other potentially rare species also are listed as Special Concern pending more precise information on their population status. When such information becomes available, these species could be moved to threatened or endangered status or deleted from the databases. Exhibit 32 presents the number of animals and plants that are currently considered Endangered, Threatened, or of Special Concern in Michigan.

Exhibit 33 presents the frequency counts of occurrence of Endangered, Threatened, and Special Concern species in Michigan. The purpose of Exhibit 33 is to provide a graphic representation of where historical and modern observations of such plants and animals have occurred and where surveys for specific species or natural communities have been conducted. The frequency count consists of the number of occurrences of a species or natural community within each public land survey system section (one square mile) and is based on the known geographic extent of each occurrence. In some cases, the extent of an occurrence is only known in general terms. In other cases, the extent of an occurrence may be very specifically known.

The use of the state's lists of Endangered, Threatened, and Special Concern Species as a statewide environmental indicator was not recommended originally by the MESB for inclusion in the Biennial Reports. The reason for this was that many endangered and threatened species tend to be very localized and, therefore, changes in their status would not necessarily be representative of a change in the state environment as a whole. Also, such species lists tend not to

Exhibit 30. Polychlorinated Biphenyl Concentration in Chinook Salmon Fillets from Lakes Michigan and Huron 1983 - 1999

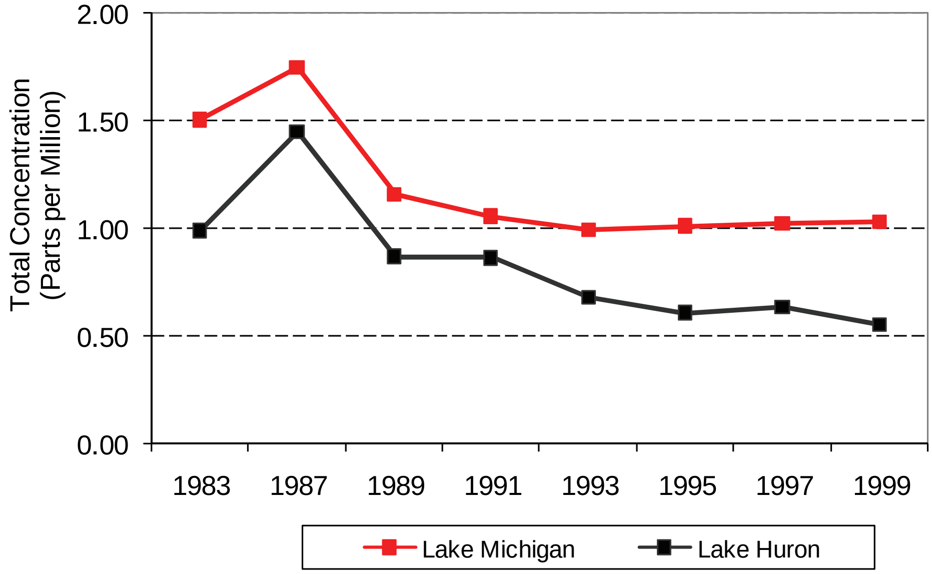
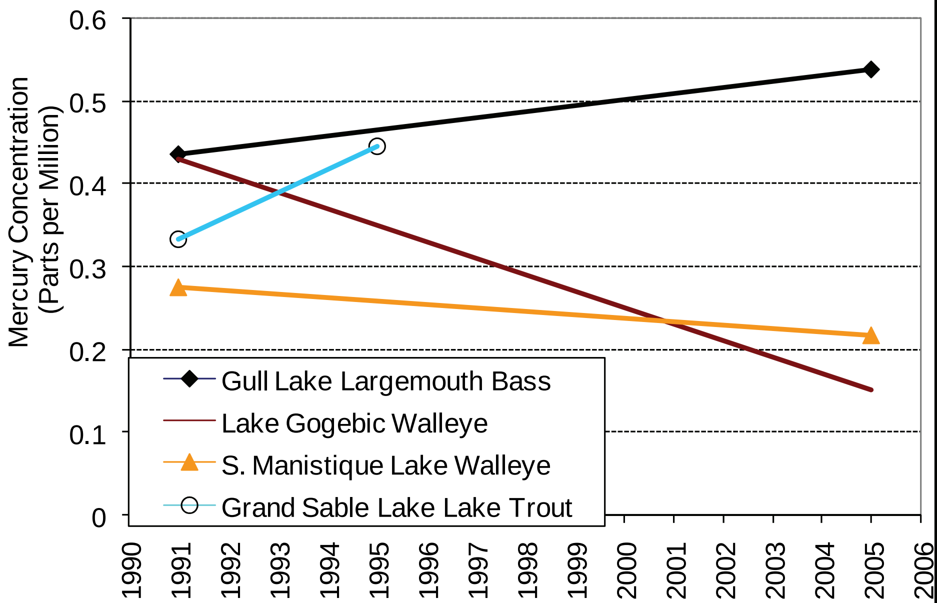


Exhibit 31. Temporal Changes in Mercury Concentrations at Selected Inland Lake Whole-Fish Trend Monitoring Sites 1991 - 2005



distinguish between naturally rare species from those that have been or are being depleted in numbers due to changing environmental conditions and/or direct or indirect human intervention. However, extensive lists, such as Michigan's, of geographically and ecologically diverse species coupled with known habitat requirements and population trend information for

these species (i.e., whether a species is increasing, decreasing, or stable) can serve over time as an indirect measure of the state's biological diversity and species richness and provide an indirect measurement of a changing environment. Consequently, this measure was included in the 2003 Biennial Report and will be continued to be addressed in this and subsequent Triennial Reports.

Trends in Exotic Species

Exotic species are plants and animals that have been introduced by human activity into an ecosystem in which they are not native. Once introduced, many of these species spread naturally, producing a significant change in the composition, structure, or processes of the invaded ecosystems.

Introductions of exotic species whether intentionally or unintentionally, play a major role in modifying terrestrial and aquatic ecosystems of the Great Lakes Basin. Freed from competitors, predators, parasites, and pathogens that naturally regulate populations in their native environments, some exotic species can become a nuisance by growing at or near their potential exponential growth rate, out-competing native species for food and other habitat resources. Invasions of terrestrial and aquatic ecosystems by exotic nuisance species now rank second only to habitat loss as the major threat to biodiversity in the Great Lakes Basin. Exhibit 34 presents the number of exotic terrestrial and aquatic plants and animals that are *known* to have been introduced into the Great Lakes Basin since the 1800s. The exact number is not known, but is thought to be much larger.

In 2005, Michigan completed its first statewide *Wildlife Action Plan*, which is a strategy to conserve all of the state's wildlife. This effort resulted in the identification of the greatest threats to conservation in Michigan. Invasive species were identified as one of the top two statewide threats. Presently, the MDNR is developing an operational plan to identify needed action items to address the threat of non-native invasive plant species.

Exhibit 32. Numbers of Plants and Animals Considered Endangered, Threatened, or of Special Concern in Michigan 2007

Category	Endangered Species	Threatened Species	Special Concern Species
Plants	51	210	110
Animals			
Snails	2	2	29
Mussels	8	2	8
Insects	8	11	75
Fish	8	7	11
Amphibians	1	1	2
Reptiles	2	2	6
Birds	8	13	21
Mammals	4	2	4
Total Animals	41	40	156
Total Plant and Animals	92	250	266

Source: Michigan Natural Features Inventory, 2007.

The Transgenic and Nonnative Organisms (Part 413 of Public Act 451 of 1994) regulations were enacted in 2005. This legislation established a list of species whose possession was either restricted or prohibited and penalties were developed for illegal possession. Also, a permitting system was authorized and established for possession of invasives for scientific and educational purposes. To date, fewer than ten permits have been authorized. An invasive species fund has been created in the Michigan Department of Treasury to receive fines, permit costs, and donations. While the law does allow for the establishment of permit costs, due to the limited number of permits being issued, the MDNR has not promulgated rules to collect these fees.

Exotic Terrestrial Species. Currently, 47 exotic terrestrial plant and animal species are *known* to have successfully invaded the Great Lakes Basin (Exhibit 34). One of the more recent species that has had a major environmental and economic impact on Michigan is the emerald ash borer.

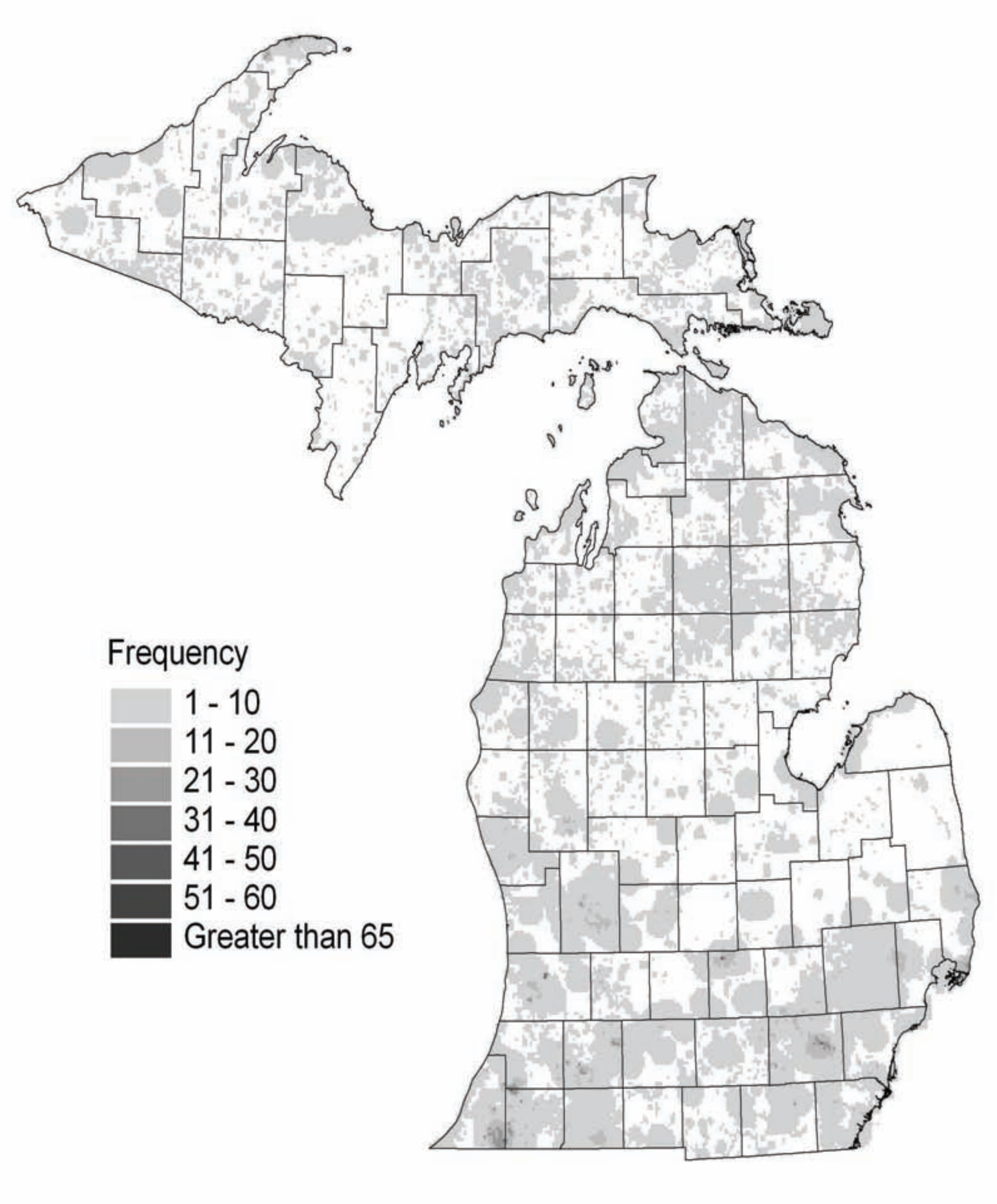
The emerald ash borer is native to eastern Russia, northern China, Japan, and Korea and affects ash trees. The insect was first detected in the summer of 2002 in six southeast Michigan counties and in Windsor, Ontario, Canada. Data from the most recent surveys indicate that Michigan's Lower Peninsula is generally infested and emerald ash borer outliers exist in the east end of the Upper Peninsula. The emerald ash borer also has been confirmed in seven northeastern and midwestern states and in Canada (Exhibit 35).

To date, the emerald ash borer has destroyed or damaged millions of ash trees across the Lower Peninsula. Immediate efforts within Michigan to contain the emerald ash borer have entailed quarantining counties where the insect has been found and effectively limiting the movement of hardwood firewood, ash trees, branches, lumber and other ash tree materials that may be harboring the insect. A permanent inspection station at the Mackinac Bridge also has limited the movement of hardwood firewood and ash logs into Michigan's Upper Peninsula.

Addressing outlying infestations of emerald ash borer continues to be a priority in Michigan and nationally. A project to Slow Ash Mortality (SLAM) in the east end of the Upper Peninsula was begun in 2008 following recent detections of the emerald ash borer there.

The overall goal of the SLAM project is to evaluate the effectiveness, practicality and challenges associated with an integrated, multi-year strategy designed to slow the expansion of ash mortality in a localized emerald ash borer outlier. The information, experience, and results acquired from this pilot project will serve as a

Exhibit 33. Frequency of Occurrence of Endangered, Threatened, and Special Concern Species in Michigan 2007



model for an approach that could be incorporated into the national emerald ash borer program. The Moran/St. Ignace outlier in Mackinaw County is an ideal site for this pilot project as it is geographically distinct and separated from emerald ash borer infestations in Lower Michigan by the Mackinac Straits. The oldest galleries observed were initiated by larvae in 2005, indicating the site was infested only recently. Results from the delimiting survey suggest that overall the emerald ash borer density remains relatively low. A high proportion of larvae developing on infested trees appear to be two-year larvae that will not complete development and emerge until 2009.

Exhibit 34. Numbers of *Known* Exotic Terrestrial and Aquatic Plant, Animal, and Virus Species Introduced into the Great Lakes Basin 2008

Ecosystem Type	Plant Species		Animals Species				Virus	Total
	Phytoplankton	Vascular	Invertebrates	Insects	Fish	Birds		
Terrestrial	--	37	--	7	--	3	--	47
Aquatic	27	60	68	2	26	--	3	186
Total Species	27	97	68	9	26	3	3	233

Sources: National Oceanic and Atmospheric Administration's National Center for Research on Aquatic Invasive Species, Great Lakes Environmental Research Laboratory: *Great Lakes Aquatic Nonindigenous Species List,* March 2008. Center for Exotic Species, Michigan Technological University, April 2003. National Invasive Species Council, July 2007.

Specific objectives of the Michigan SLAM Project include:
1. Development of an integrated, multi-year strategy to suppress emerald ash borer population growth and slow the progression of ash mortality at the Moran outlier site;
2. Implementation of the integrated strategy beginning in 2008;
3. Evaluation of the success of the integrated SLAM approach; and
4. Evolution and expansion of the SLAM approach for implementation at additional pilot sites.

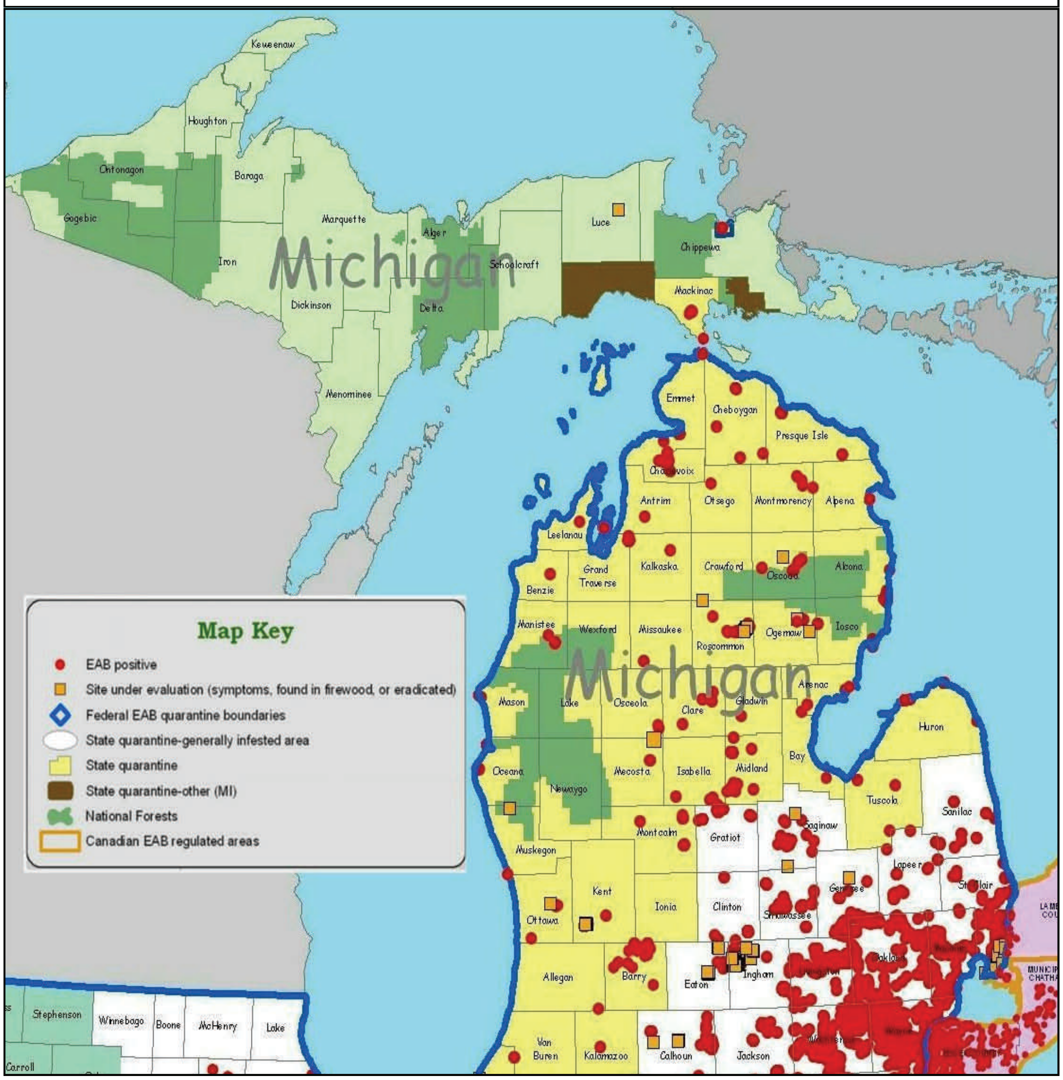
Efforts also are underway by the *Emerald Ash Borer Task Force* to learn more about the emerald ash borer's biology and to develop additional control and detection options through research projects spearheaded by MSU. Members of the Emerald Ash Borer Task Force include representatives from the Governor Office, Michigan Department of Agriculture (MDA), MDNR, MSU, and the USDA's Animal and Plant Health Inspection Service and Forest Service, in cooperation with local units of government and various industry groups, associations, and universities. One research activity that currently is being evaluated suggests that a component (a naturally occurring fungus) of a USEPA-approved commercially available bioinsecticide, *BotaniGard ES*, can cause a fatal infection to the larval stage of the emerald ash borer without harming animals or humans. This bioinsecticide is being field-studied to confirm its effectiveness against the insect.

Recently a new insecticide, Tree-age® (active ingredient emamectin benzoate), was registered for use in Michigan against the emerald ash borer. This systemic insecticide is injected through the bark at the base of ash trees. Tree-age® is more effective in a tree that is reasonably healthy than in a tree that has already been severely injured by emerald ash borer larvae. Bioassays were conducted in 2007 by MSU and the U.S. Forest Service to assess survival of emerald ash borers caged for four days with leaves from treated and untreated leaves. In all the bioassays, 100 percent of the emerald ash borers that fed on leaves from emamectin benzoate-treated ash trees died. This material shows considerable promise for protecting street and landscape ash trees from being killed by the emerald ash borer.

Exotic Aquatic Species. Currently, 186 exotic aquatic plant and animal species are *known* to have been successfully introduced into the Great Lakes Basin since the 1800s (Exhibit 36). The list of exotic aquatic species, which is continually updated, is maintained by the National Oceanic and Atmospheric Administration's (NOAA) National Center for Research on Aquatic Invasive Species and can be accessed on the NOAA Internet site (www.glerl.noaa.gov/res/Programs/ncrais/great_lakes_list.html). 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 exotic aquatic species were introduced into the Great Lakes during the last half of the 20th Century (Exhibit 37).

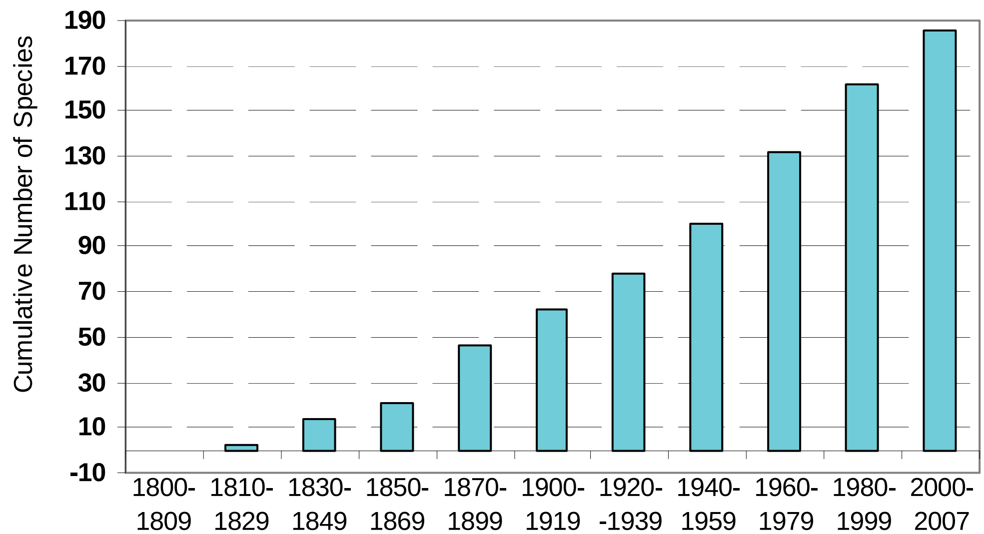
The four primary routes of entry for aquatic exotic species into the Great Lakes include ballast water from ocean-going ships, unintentional releases, multiple sources, and unknown sources (Exhibit 37). Not all non-native species become invasive and cause economic or environmental harm, but a few cause major damages. Some of the more problematic introductions in recent decades have been the sea lamprey, Eurasian watermilfoil, and zebra mussel. The latter two species 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 in terms of control of the Eurasian watermilfoil and research has yet to discover an effective control for the zebra mussel.

Exhibit 35. Locations of Emerald Ash Borer Infestations in Michigan



While some progress has been made to decrease the number of new exotic aquatic species being introduced into the Great Lakes, much remains to be accomplished. Pursuant to federal law, ships entering the Great Lakes are now required to exchange their ballast water at sea, flushing out organisms, and raising the salinity of the ballast water to kill freshwater organisms that might remain alive in the ballast tank. Although open water exchange helps to reduce the risk of finding exotic aquatic species in ballast tanks and sediments, it does not

Exhibit 36. Introduction of Exotic Aquatic Species into the Great Lakes 1800 - 2007

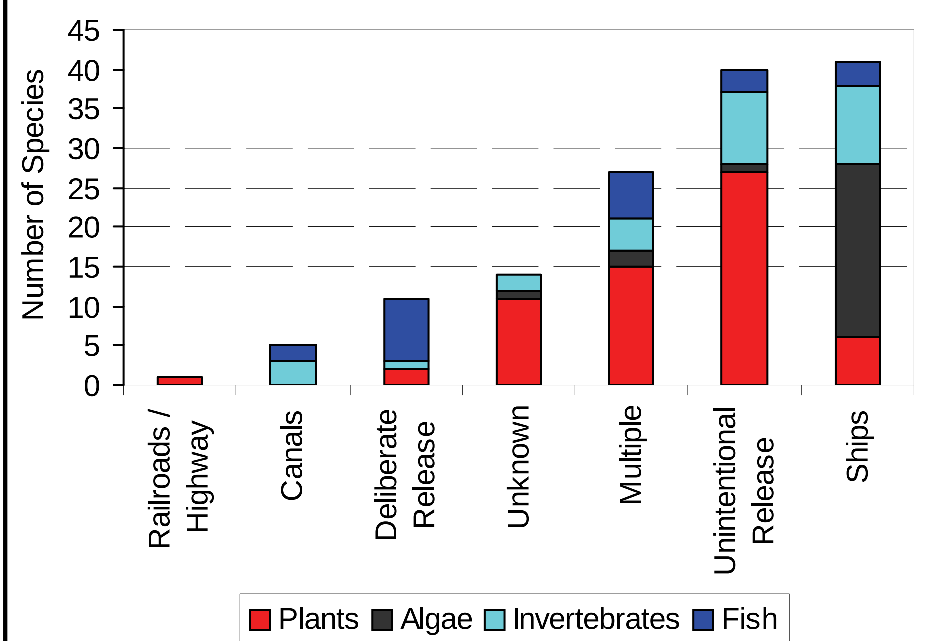


ensure protection of the Great Lakes since even with ballast pumping, many aquatic species remain in the unpumpable residual ballast water and sediments and can gain entrance into the Great Lakes. A ship under this condition is referred to as *No Ballast on Board* (NOBOB). Over 90 percent of vessels entering the Great Lakes are NOBOB and contain viable forms of life, including potential aquatic invasive species. Many NOBOB vessels contain fresh or low-salinity water from other countries that can pose an especially serious risk of new exotic aquatic species introductions. Michigan supports the adoption of strict, mandatory regulations for NOBOB vessels that are the same as for ships in ballast.

State, Federal, and International Ballast Water Action. In 2001, Michigan legislation was passed (Section 3103, *Ballast Water Reporting Program*, 2001 Public Act 451) requiring the MDEQ to determine annually whether ballast water management practices are being complied with by all vessels operating on the Great Lakes and the St. Lawrence Seaway. Oceangoing vessels are required to report compliance with the *Code of Best Management Practices for Ballast Water Management* developed by the Shipping Federation of Canada. Non-oceangoing vessels are required to report compliance with a set of voluntary best management practices developed by the Lake Carriers Association and the Canadian Shipowners Association to reduce the number of introductions of exotic aquatic species into the Great Lakes. A list of the ships reporting compliance with the voluntary best management practices is maintained on the MDEQ's Internet site (www.michigan.gov/deqballastwaterprogram). In 2007, over 231 vessels complied with the MDEQ reporting requirements.

In June 2005, legislation (2005 Public Act 33) was signed that established a requirement for a ballast water discharge permit from ocean-going ships in Michigan ports. The permit requires ocean-going vessels to either not discharge ballast water or to treat ballast water before discharge to prevent introductions to the Great Lakes by exotic aquatic species. The general permit was issued in

Exhibit 37. Sources of Entry of Exotic Species into the Great Lakes



October 2006 and became effective January 1, 2007. In 2007, 92 ships representing 28 shipping companies obtained a port operations permit from the MDEQ.

In March 2005, a decision by the Northern District Court in California ordered the USEPA to rescind a rule to exempt the discharge of ships' ballast water from regulation under the 1972 Clean Water Act. The court determined that permits for ballast water discharge should be issued beginning September 30, 2008. The USEPA appealed the ruling. A decision on the case in the 9th Circuit Court of Appeals in California is expected in 2008.

Internationally, a Convention for the Control and Management of Ships' Ballast Water and Sediments (Convention) was adopted by the International Maritime Organization (IMO) in 2004. The Convention sets a ballast water discharge standard and timetable for compliance, pending ratification by at least 33 member states of the IMO. Full compliance by all ships, pending ratification, is scheduled to occur in 2016. As of 2008, eight member states have ratified the convention. Federal ballast water regulations are in various bills before Congress. Further action on the issue may take place by the end of 2008.

Aquatic Nuisance Species Management Plan. In 2002, Michigan released an update to its 1996 *Nonindigenous Aquatic Nuisance Species State Management Plan*, which was approved as Michigan's plan under the auspices of the federal National Nuisance Species Act. The 2002 document entitled, *Michigan's Aquatic Nuisance Species State Management Plan Update: Prevention and Control in Michigan Waters* (2002 Plan), provides a framework for action and outlines critical steps necessary to help prevent and control aquatic nuisance species (exotic aquatic species) in the state. Most key recommendations of the 2002 Plan have been implemented. For example, Executive Order 2002-21 created an Aquatic Nuisance Species (ANS) Council in November 2002. The ANS Council is charged with the responsibility of advising the Office of the Great Lakes, MDEQ, MDNR, MDA, and the Michigan Department of Transportation on:

1. Implementation and updating of Michigan's 2002 Plan;
2. Efforts to maximize interdepartmental coordination of existing aquatic nuisance species programs;
3. Issues pertaining to preventing and controlling the spread of aquatic nuisance species within the state for new aquatic nuisance species programs;
4. Information and education activities about aquatic nuisance species; and
5. Research and monitoring activity coordination pertaining to aquatic nuisance species.

Additional activities by the state and others have

included:

1. The designating of an annual *Aquatic Invasive Species Awareness Week* in June in association with Michigan's *Summer Free Fishing Weekend*;
2. The conducting of an annual student poster contest for students grades six through eight to encourage critical thinking and to demonstrate their knowledge of Great Lakes aquatic invasive species;
3. The conducting of an information and education small grants program to provide seed money to encourage development aquatic nuisance species outreach programs in local communities;
4. The launching of a public outreach campaign to educate the Michigan citizenry about the potential for *Hydrilla spp*, an aggressive, non-native aquatic plant, to invade Michigan waters and the need for volunteer citizen monitoring;
5. The surveying of Michigan boaters on aquatic nuisance species knowledge and behavior practices; and
6. The development of a Michigan Clean Boats, Clean Waters Program modeled after Wisconsin's successful volunteer education program.

In March 2008, the Michigan Office of the Great Lakes began a process to update the 2002 Plan by hosting of a one-day stakeholder's workshop to obtain input for a revision. Discussions and recommendations resulting from this workshop will form the foundation of the update of Michigan's ANS state management plan. available on the MDEQ's Internet site (www.michigan.gov/deqmiglprotectionfund).

Physical and Chemical Indicators

Ambient Levels of Criteria Air Pollutants

Pollutants, both manufactured 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 last 35 years as sources of air pollution have

been identified and corrective solutions implemented. However, with lowered funding and new health standards there remain challenges.

National Ambient Air Quality Standards 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 MDEQ operates an air monitoring network in 23 counties, which represents the overall air quality in the state. Currently (2008), all areas in Michigan are in compliance with the USEPA criteria pollutant standards implemented for carbon monoxide, lead, nitrogen dioxide, particulate matter less than 10 micrometers in diameter, and sulfur dioxide. In 2006 and 2008, the USEPA implemented new standards for ozone and particulate matter less than 2.5 micrometers in diameter and parts of Michigan are not in attainment with these standards. Additional information on Michigan's air quality is available in the MDEQ's Annual Air Quality Report (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 emissions of carbon monoxide.

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.

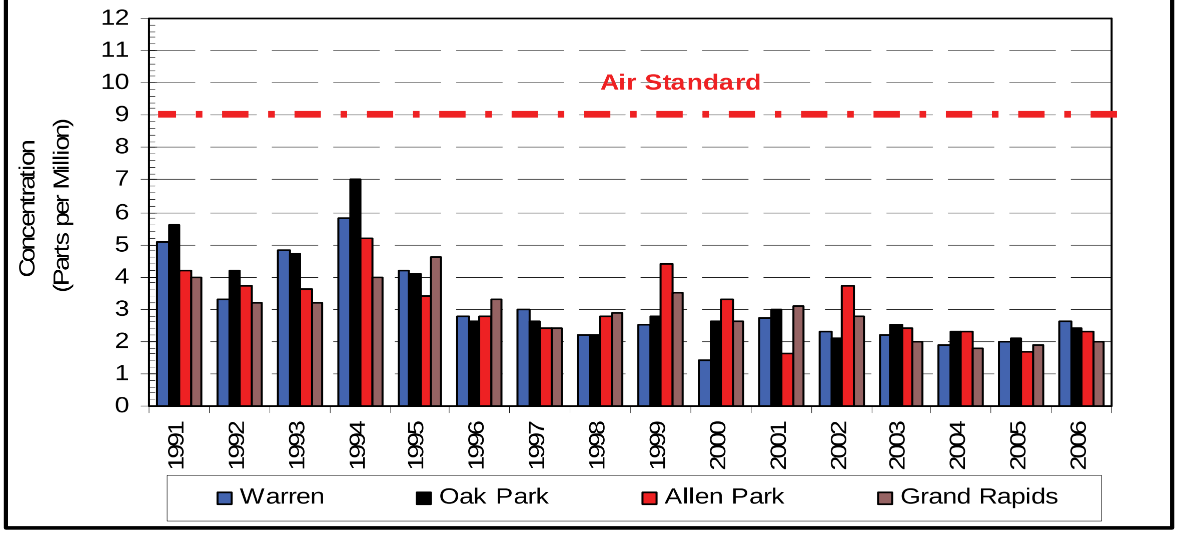
In urban areas, as much as 95 percent of all carbon monoxide emissions come from automobile exhaust. Michigan's on-road motor vehicle sources account for 69 percent of the state's carbon monoxide emissions. Michigan's non-road vehicle sources contribute 28 percent of the state's carbon monoxide emissions. 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 2 percent. For the Detroit area, fossil fuel combustion from electric utilities, industrial, commercial, and residential sources, as well as iron and steel manufacturing and foundries, were the leading point sources of carbon monoxide.

From 1979 to 1984, the carbon monoxide levels in the Detroit area had exceeded the National Ambient Air Quality Standard for 8-hour exposure. Since that time, there have been no exceedances. Exhibit 38 indicates a clear downward trend since 1979 (when the USEPA first established criteria for the National Air Monitoring Sites). This trend represents a 50 percent decrease in average carbon monoxide levels every 10 years, or 0.31 parts per million (ppm) per year. On August 30, 1999, the Detroit area was taken off the list of problem areas for carbon monoxide.

Exhibit 38. Ambient Carbon Monoxide Trends 1991 - 2006

(8-Hour Carbon Monoxide Levels at Specific Monitoring Sites)

Routinue CO monitoring Discontinued April 2007



The decline of carbon monoxide in the Detroit area follows a national trend, even though there is an increase in the number of vehicle miles. 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.

The new monitoring regulations no longer require carbon monoxide monitoring. Thus when the MDEQ's Air Monitoring Unit budget was cut in April 2007, all but two carbon monoxide monitors were shut down. The Grand Rapids and Allen Park monitors were kept running and later replaced with trace (i.e., high) gas carbon monoxide monitors as part of the National Core Monitoring (NCORE) Program. During 2009, contingent upon adequate levels of funding, Michigan is planning to continue to operate its trace level carbon monoxide monitors to ramp up for full-scale NCORE operations for 2011.

Lead. The most common sources of lead emissions are gasoline additives, non-ferrous smelting plants, and battery manufacturing. Historically, lead was added to gasoline as an additive 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 and battery plants are the major sources of lead nationwide. For combustion sources, lead is an impurity found in coal, oil, and waste oil, as well as municipal solid waste and sewage sludge incineration.

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. Average quarterly lead levels across Michigan are about 50 times below the air quality standard of 1.5 micrograms per cubic meter. The average air quality concentration for lead in the Detroit area in 2006 was 98 percent lower than the high in 1983 (Exhibit 39).

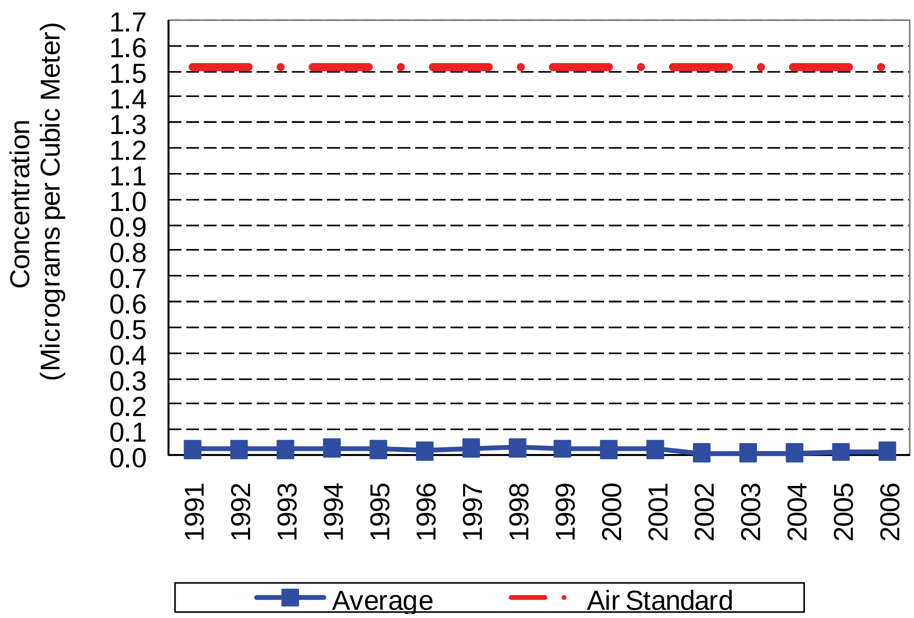
Currently the USEPA is revamping the lead National Ambient Air Quality Standard. When the USEPA completes this review, the MDEQ will re-evaluate its lead monitoring program.

Nitrogen Dioxide. Nitrogen dioxide is formed during high temperature combustion processes, such as those from power plants burning coal, oil, and gas fuels and from burning fuels in motor vehicle engines. 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 over the city.

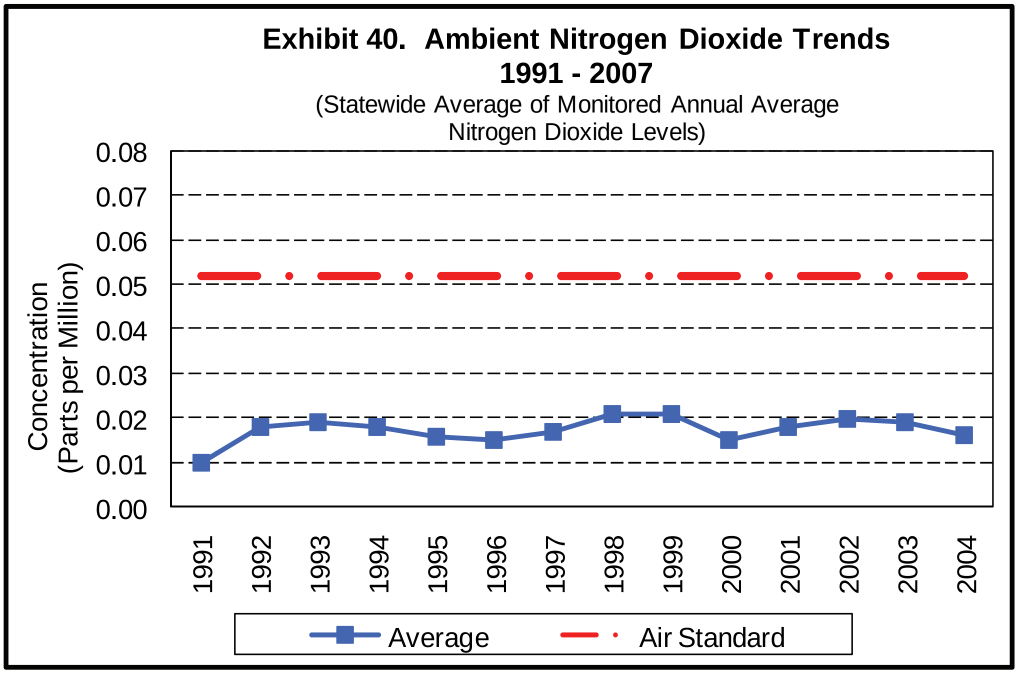
The human respiratory system is susceptible to effects caused by exposure to nitrogen dioxide. Asthmatics are particularly sensitive to these effects.

Regulations on vehicle emissions over the past few decades and reductions in emissions from power plants due to stricter regulations and new

Exhibit 39. Ambient Lead Trends 1991 - 2006
(Statewide Average of Monitored Quarterly Lead Levels)

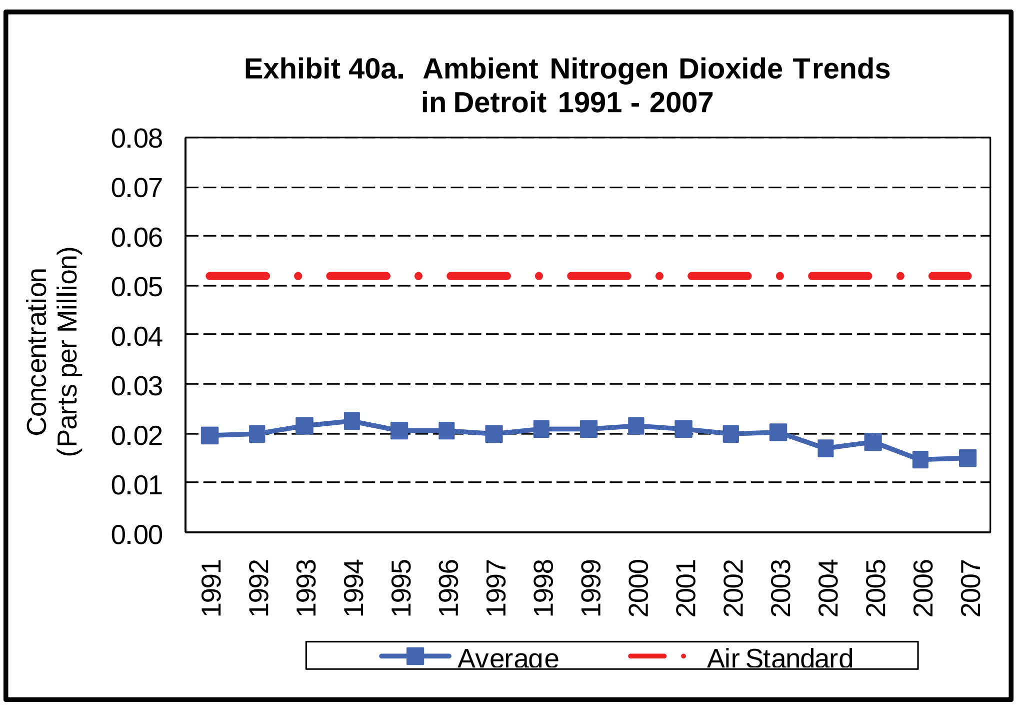


technologies have contributed to a decreasing trend. Michigan has never recorded a violation of the nitrogen dioxide standard. In Michigan, 46 percent of nitrogen dioxide producing compounds come from on-road sources and 31 percent come from point sources such as industrial, commercial, institutional, and residential fossil fuel combustion.



Statewide monitoring results show that ambient nitrogen dioxide levels have remained near the 0.02 ppm level since 1992, which is less than one-half of the standard (Exhibit 40). Michigan has never recorded a violation of the nitrogen dioxide standard. From 1991 to 2007, the Detroit area continually has been well below the National Ambient Air Quality Standard for nitrogen dioxide by an average of 43 percent (Exhibit 40a).

Beginning in October, regulations no longer require nitrogen dioxide monitoring. Consequently, when the MDEQ's air monitoring budget was cut in April 2007, all but one nitrogen dioxide monitor in Detroit were shut down. Trace nitrogen dioxide (includes more species of nitrogen) monitors for the NCORE sites at Grand Rapids and Allen Park were deployed in December 2007.



During 2009, contingent upon adequate levels of funding, the MDEQ will continue to operate its nitrogen dioxide monitor at E. Seven Mile Road in Detroit and operate its trace nitrogen dioxide monitors at the Grand Rapids and Allen Park sites for full-scale NCORE operations, which is due January 1, 2011.

Ozone. Depending on its location in the atmosphere, ozone is considered either "good" or "bad." Good ozone occurs naturally in the stratosphere approximately 10 to 30 miles above the Earth's surface and forms a layer that protects the Earth from the sun's harmful rays. In the Earth's lower atmosphere, ground-level ozone is considered bad. Ground-level ozone is created by chemical reactions in the atmosphere involving other air pollutants in the presence of sunlight. These reactions usually occur during the hot summer months from photochemical reactions between nitrogen oxides (NOx) and volatile organic compounds (VOCs).

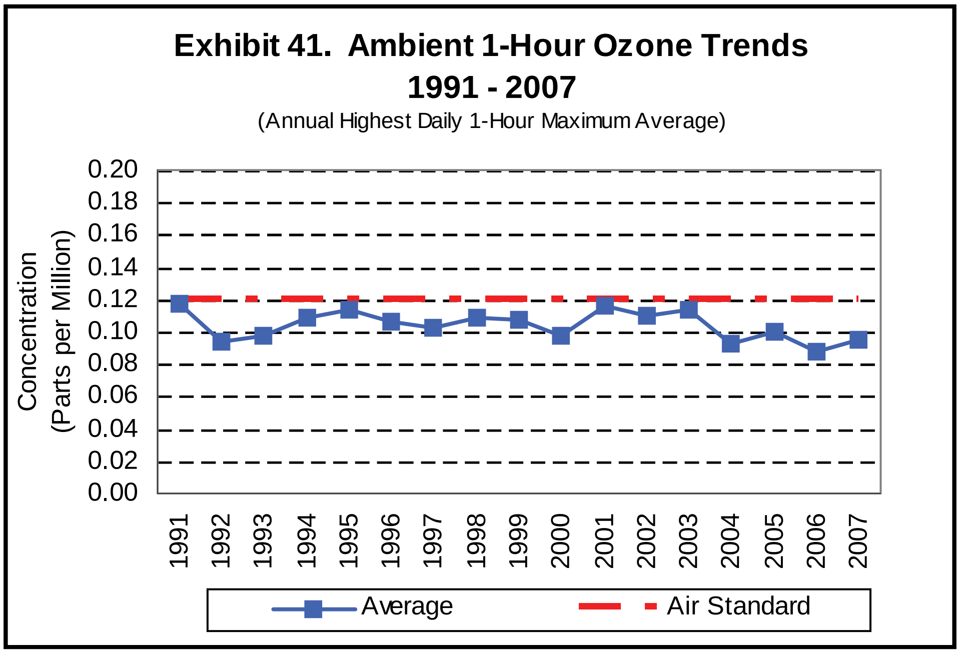
The primary sources of VOCs include motor vehicle exhaust, gasoline storage and transfer, paint solvents, and degreasing agents. The primary NOx sources are power plants and motor vehicles. Natural sources of VOCs and NOx include lightning and terpene emissions from pine trees and other vegetation. Sunlight initiates the reaction, which is why elevated ozone concentrations occur during the warmer, sunnier months of the year. In addition to the formation of ozone, these reactions form many other products, which, when combined with ozone, are called *photochemical smog*. Photochemical smog is a brownish, acrid mixture of many gases and particles. The color and odor of smog are due to compounds other than ozone.

Ozone irritates the human respiratory system and can cause coughing and chest pains upon deep inspiration in exercising individuals. Ozone also can be responsible for crop damage and increased deterioration of rubber, dyes, paints, and fabrics.

Ground-level ozone can be transported hundreds of miles. As a result, the long-range transport of air pollutants impacts the air quality of areas far downwind from their source. Transported ozone and ozone precursors from Gary, Indiana, Chicago, Illinois, and Milwaukee, Wisconsin, and other upwind source areas affect the levels of ground-level ozone in Michigan.

Within Michigan, 63 percent of the ozone-producing pollutants are emitted by vehicles. The remaining 37 percent are emitted from combustion of fuels, chemical and petroleum manufacturing, and naturally from vegetation. Exhibit 41 displays 1-hour ozone trends and Exhibit 42 shows a comparison between the 8-hour standard and trends in urban areas.

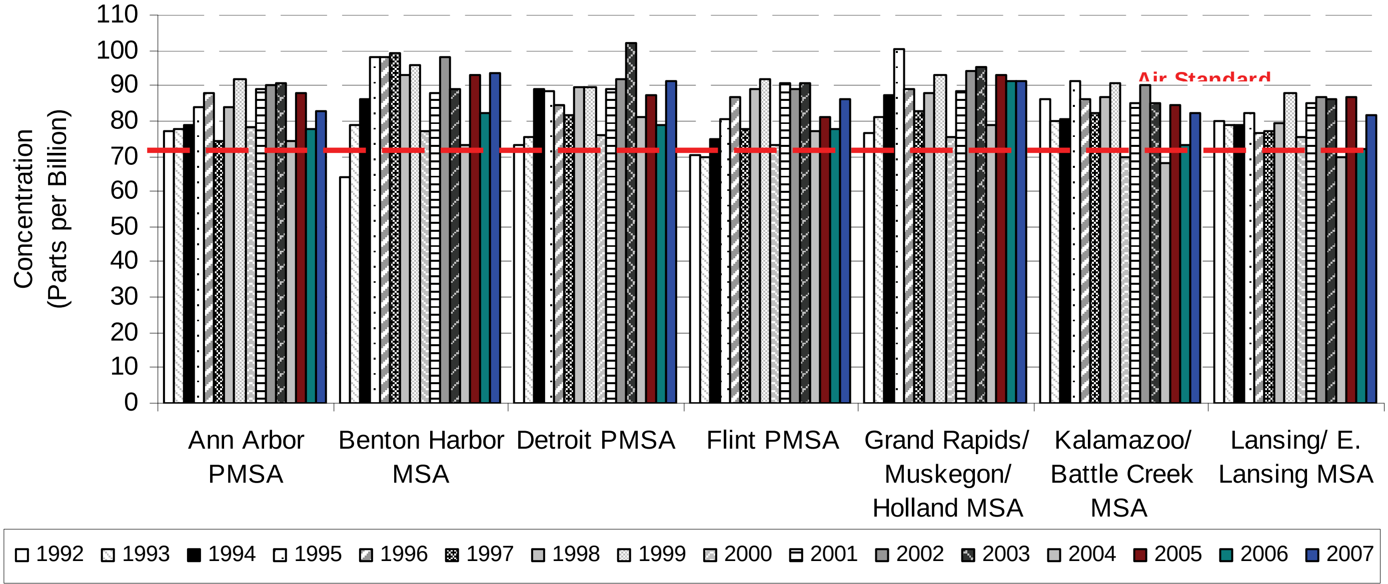
The USEPA updated the 8-hour standard for ozone in March 2008. Exhibit 43 shows the current 8-hour ozone nonattainment designations. Exhibit 43a shows what the designations would look like if based on the updated standard.



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. Particulates with a diameter of less than 10 micrometers in diameter are referred to as PM_{10} while very fine particles equal to or less than 2.5 micrometers in diameter are referred to as $PM_{2.5}$. Particulate can be emitted directly (primary) or formed in the atmosphere (secondary). PM_{10} is composed largely of primary particles such as smoke, dust, dirt, soot, fly ash, and condensing vapors. Industrial processes that cause these emissions include combustion, incineration, construction, mining, metal smelting, metal processing, and grinding. Other sources include motor vehicle exhaust, road dust, wind-blown soil, forest fires, and volcanic activity.

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 the

Exhibit 42. Ambient 8-Hour Ozone Trends
1992 - 2007
(Metropolitan Statistical Areas Annual Fourth Highest 8-Hour Ozone Levels)



most susceptible. PM_{10} is especially problematic, because it can penetrate deep into the lungs and remain there. Particulate matter also can impair visibility, damage materials, and create soiling.

Levels of annual average PM_{10} have remained well below the annual PM_{10} standard at most locations (Exhibit 44). The high 2003 value at the Dearborn station was the result of heavy construction performed near the monitor and does not meet data collection criteria. This site has historically measured the highest levels statewide. Michigan is designated as being in attainment with the PM_{10} standard.

In 2006, the USEPA implemented a new 24-hour standard for $PM_{2.5}$. The particles or droplets have many different chemical compositions, depending on the source of the emissions. Also, chemical reactions can occur in the atmosphere to form new chemical compounds or change the form from gases and liquids into solid particles. $PM_{2.5}$ is composed of many more of these secondary particles. Examples include sulfates formed from

Exhibit 43. Current Eight-hour Ozone Nonattainment Designations

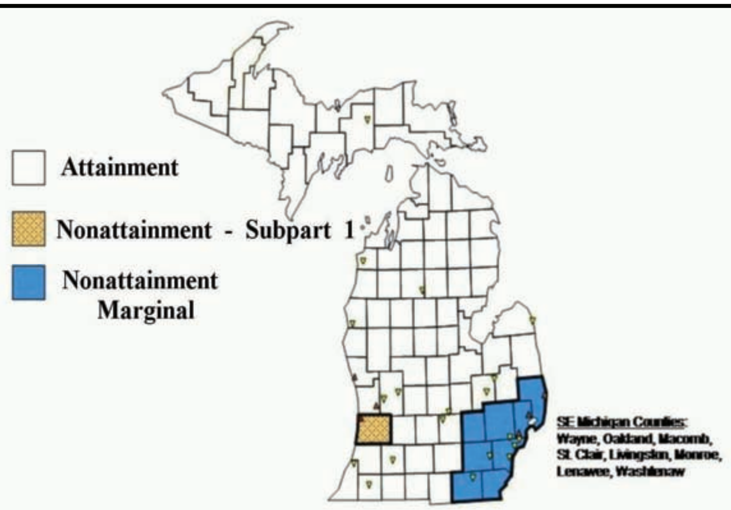
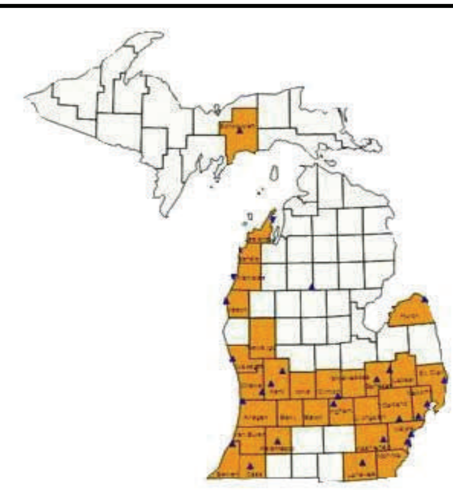


Exhibit 43a. Eight-hour Ozone Nonattainment Designations with new 0.075 ppm Standard



power plant emissions and nitrates from power plants and automobiles.

Due to the recent initiation of $PM_{2.5}$ monitoring in 1999, long-term historical trend information is unavailable. However, (Exhibit 45) shows the $PM_{2.5}$ levels monitored at eight urban areas relative to the annual $PM_{2.5}$ standard. Exhibit 46 shows the state's current $PM_{2.5}$ nonattainment designations.

Sulfur Dioxide. Nationwide, the largest source of sulfur dioxide is coal-burning power plants. State regulations require that most of the coal burned in Michigan contain 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.

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. Sulfuric acid also is a component of acid rain, which can potentially acidify lakes, streams, and soils and corrode building surfaces.

Levels of sulfur dioxide have fallen to no more than one-fourth of the annual standard (0.030 ppm) since 1991 (Exhibit 47). Monitored levels statewide also have remained well below the 24-hour standard (0.14 ppm not to be

Exhibit 44. Ambient Particulate Matter (PM_{10}) Trends 1991 - 2007

(Annual Arithmetic Mean at Specific Monitoring Sites)

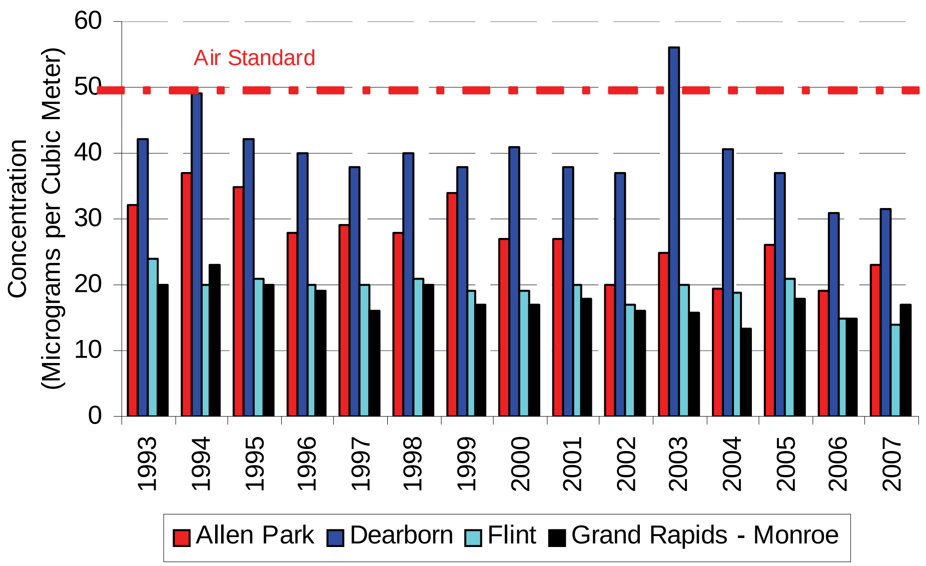


Exhibit 45. Ambient Particulate Matter ($PM_{2.5}$) Trends by Metropolitan Statistical Area 1999 - 2007

(Annual Average)

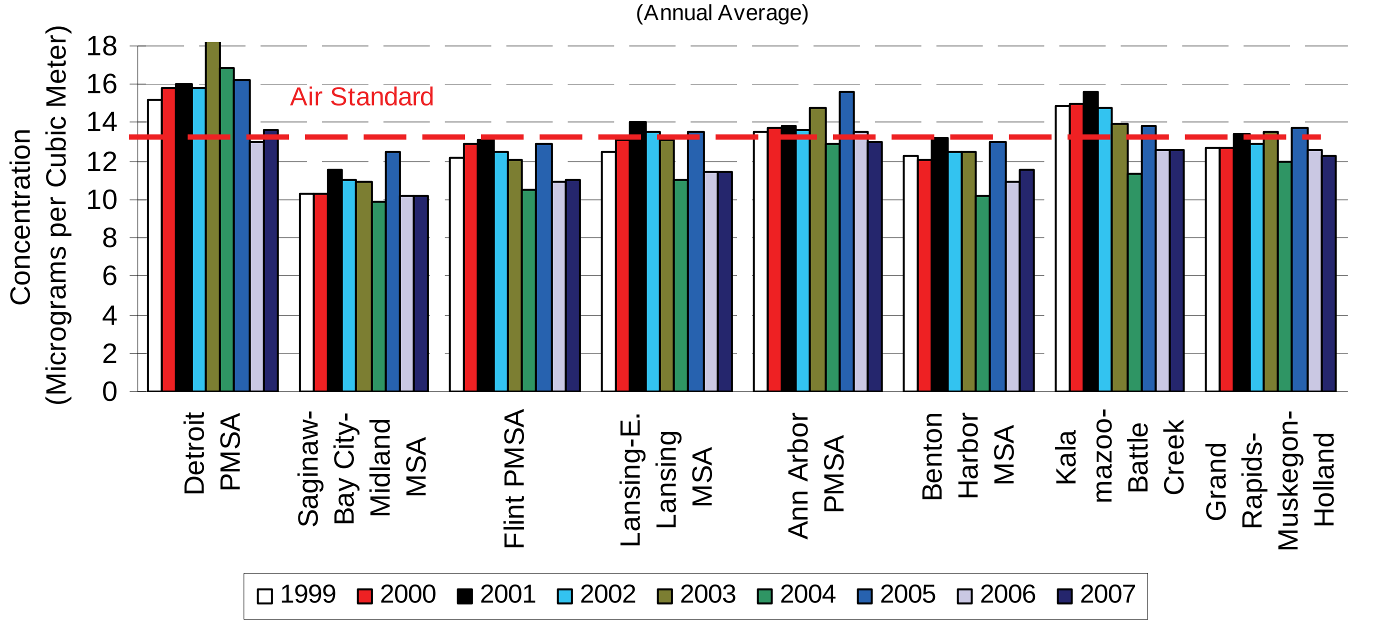
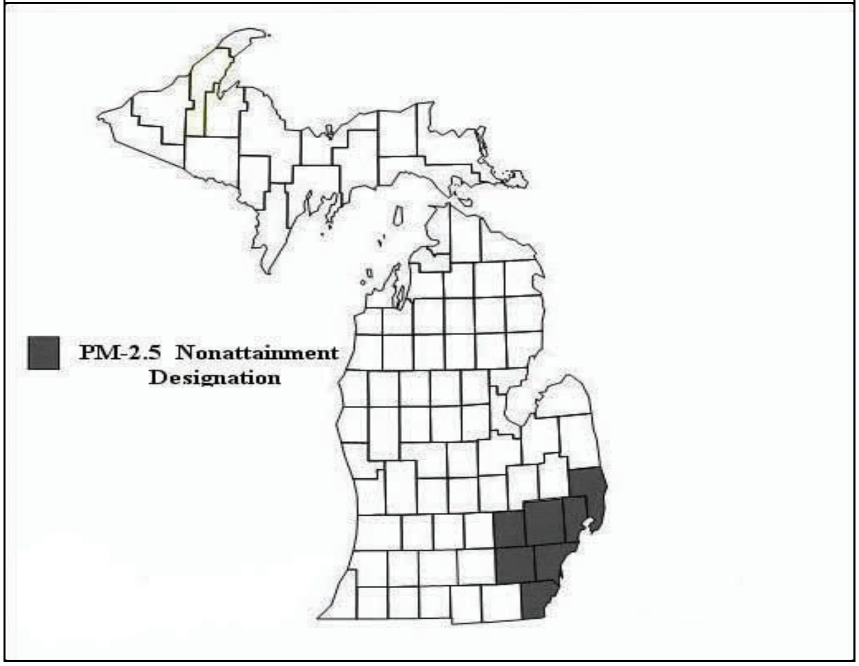


Exhibit 46. $PM_{2.5}$ Nonattainment Designation 2007



exceeded more than once per year). The state has maintained an attainment designation for sulfur dioxide since 1982.

The October 17, 2006 monitoring regulations no longer require sulfur dioxide monitoring. Due to funding cuts in April 2007 to the MDEQ's air monitoring budget, all but one monitoring site in Detroit were closed. Contingent upon adequate funding, the state will continue to operate the Southwest High School for sulfur dioxide and also NCORE operated trace sulfur dioxide at Allen Park and Grand Rapids.

Air Quality Index

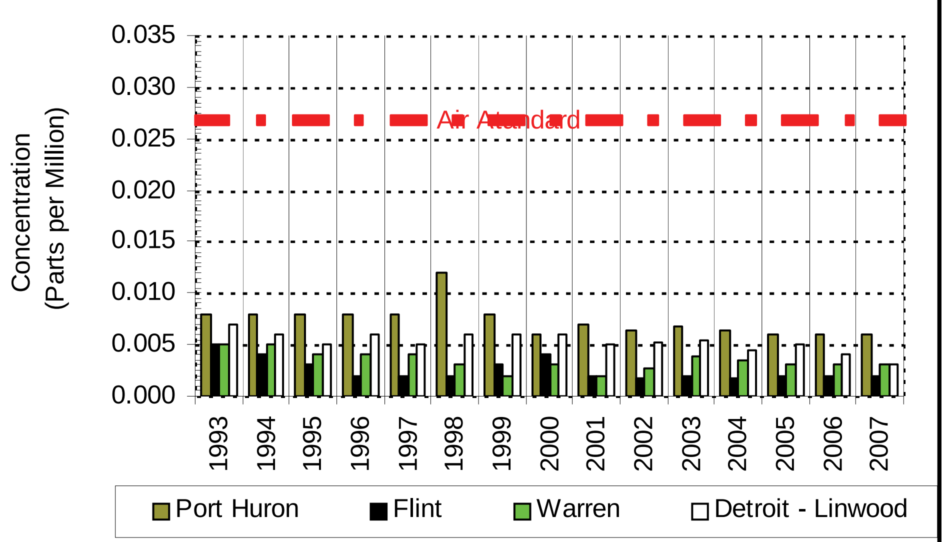
The Air Quality Index (AQI) was developed by the USEPA to provide a simple and uniform way to report daily air quality. The AQI provides advice to the public about the health effects associated with various levels of air pollution, including recommended precautionary steps if conditions warrant. In 1999, the USEPA revised the AQI. The category *unhealthy for sensitive groups* was added to the existing health indicator categories of *good, moderate, unhealthy, very unhealthy*, and *hazardous*. Also in 1999, the USEPA changed the health indicators for the AQI by incorporating the new 8-hour ozone and $PM_{2.5}$ readings. These changes resulted in a substantially higher number of days that were considered to be *unhealthy for sensitive groups.*

The AQI values are available to the public and news media on the Internet on a near real-time basis for a number of metropolitan areas in Michigan. Exhibits 48 and 49 reflect the current AQI categories and health indicators for the years 1993 – 2004. This was calculated by the USEPA by re-evaluating the earlier years and applying the new health indicators. However, the $PM_{2.5}$ monitoring (and AQI scoring for it) only began in 1999. 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*.

While based on actual measurements, caution should be exercised with the use of the AQI, since the health classification labels are quite general and are, therefore, subject to interpretation. Additional information on the AQI, including the

Exhibit 47. Ambient Sulfur Dioxide Trends 1991 - 2007

(Annual Arithmetic Mean Levels at Specific Monitoring Sites)



daily AQI values for Michigan monitoring sites, is available on the MDEQ's Air Quality Internet site (www.deqmiair.org). MIAir, the MDEQ's new air quality reporting webpage, provides current air quality information to the public and was released in 2006. It displays air quality forecasts, the current AQI, continuous air monitoring data, and animated O_3 and $PM_{2.5}$ maps as a public service.

Ambient Levels of Air Toxics Contaminants

There are many more atmospheric contaminants than just the six criteria pollutants. The additional air pollutants are referred to as *air toxics*. While there are health reference levels for many air toxics, these generally are not as well established as the criteria pollutants' National Ambient Air Quality Standards. The available air toxics monitoring data also are limited. Consequently, air toxics emissions and monitoring data are not as well characterized as are the data for the six criteria pollutants.

The MDEQ's Air Toxics Monitoring Program was established in January 1990. Since the program's inception, approximately 50 toxic organic compounds and 13 trace metals have been monitored at various urban locations throughout the state. With cuts to the MDEQ's air monitoring budget, the state's air toxics monitoring program has been reduced. Detailed information on which air toxics are still being monitored is available in the MDEQ's Internet Site (www.michigan.gov/deqair).

The USEPA has developed a nationwide air toxics monitoring network. This network is providing measurements of ambient concentrations of air toxics at monitoring sites throughout the United States that can be used in the estimation of human and environmental exposures to air toxics. Dearborn, Michigan, is one of those sites.

In 2004, the MDEQ and the USEPA's National Exposure

Exhibit 48. Air Quality Index: Number of Unhealthy Days for the General Population (Excluding Sensitive Groups) 1993 - 2007

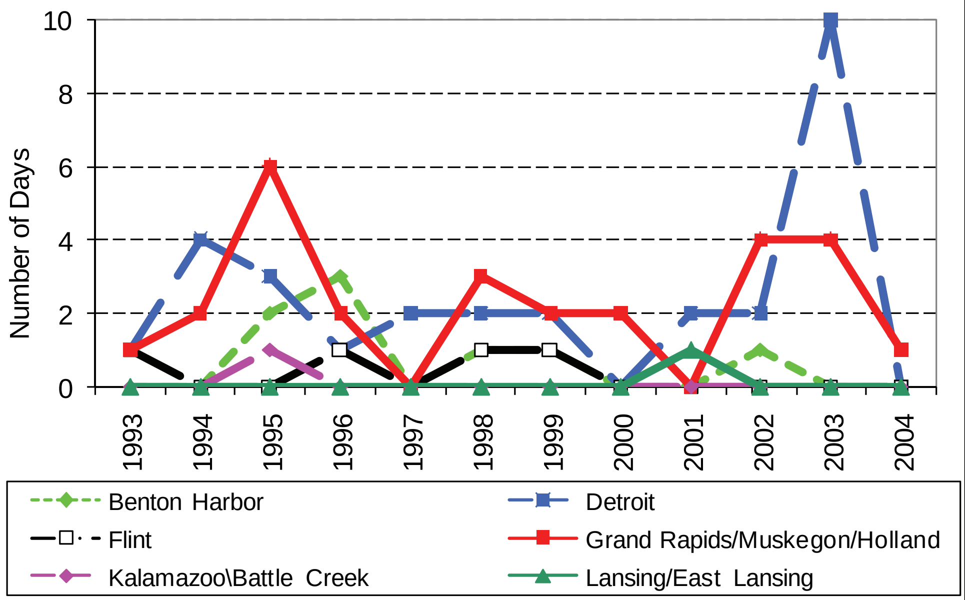
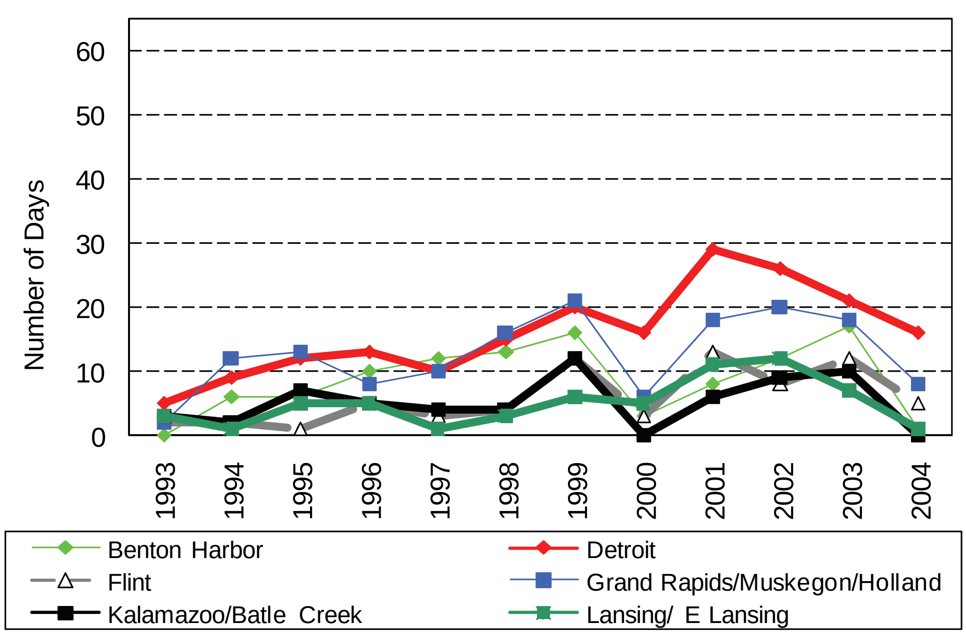


Exhibit 49. Air Quality Index: Number of Unhealthy Days for Sensitive Groups 1993 - 2007



Research Laboratory and National Health and Environmental Effects Research Laboratory began conducting the Detroit Exposure Aerosol Research Study (DEARS). The DEARS is a three-year field monitoring study that was designed to measure exposure and describe exposure relationships for air toxics, PM components, PM from specific sources, and criteria pollutants in Detroit. The study includes monitors at the Allen Park site, indoor/outdoor monitors at participants' homes, and personal exposure monitors. More information on DEARS can be found on the USEPA Internet site (www.epa.gov/dears/).

Deposition of Persistent and Bioaccumulative Air Toxics

Some air toxics can persist and bioaccumulate in the environment. For these substances, deposition to the ground and water is a concern because of potential ecological impacts and human exposure. The MDEQ and the University of Michigan currently are conducting a study of mercury deposition in Michigan. Urban sites were located in Grand Rapids, Detroit, and Flint and rural sites were located in Dexter, Pellston, and Eagle Harbor. Additionally, the USEPA is monitoring for metals, PCBs, pesticides, and polycyclic aromatic hydrocarbons at Eagle Harbor, Sleeping Bear Dunes, and other locations around the Great Lakes Basin. Additional information on this study will be available in the 2011 Triennial Report.

Inland Lake Water Quality

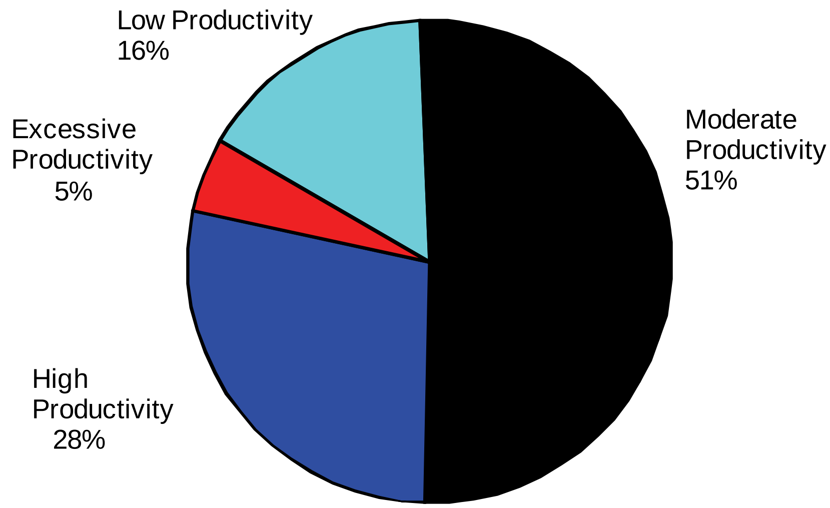
The federal Clean Water Act requires states to assess lake water quality and to categorize lakes according to their *trophic status*, an indicator of biological productivity. Lake trophic status is the level of growth of algae and higher plants, or primary productivity, as measured by phosphorus content, algae abundance, 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 coldwater 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%) were categorized as moderately productive lakes or low productive lakes. Only five percent of the lakes evaluated were categorized as excessively productive lakes (Exhibit 50).

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 the 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 2006 - 2007, volunteers monitored these primary lake productivity indicators on 119 lakes. For these lakes, the majority exhibited moderate

(50%) to low (36%) productivity. Thirteen percent of the monitored lakes were categorized as having high productivity and one lake exhibited excessive productivity (Exhibit 51).

Exhibit 50. Historical Classification of 730 Michigan Public Lakes

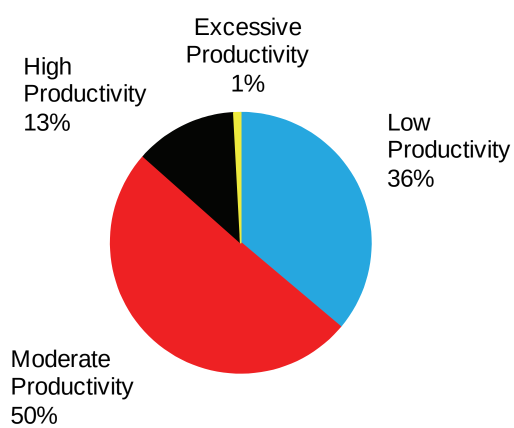


The Cooperative Lakes Monitoring Program is a cost-effective volunteer program for increasing baseline water quality data and lake productivity classifications for Michigan's inland lakes. The long-term monitoring program can provide information to evaluate water quality variability and trends in these lakes. However, results from the volunteer program alone only provide information on lakes where volunteers choose to participate in the program and may not be representative of lakes statewide. Consequently, the MDEQ is using money from the Clean Michigan Initiative (CMI) Fund to expand the program and to re-establish monitoring of public access lakes across the state. This effort will build upon the historical lake data that exist and supplement the information generated from the volunteer monitoring program.

The MDEQ, in partnership with the USGS, has re-established a Lake Water Quality Assessment Monitoring Program for public access lakes in Michigan. 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 534 public access lakes through 2007. Of the 534 lakes sampled, 17 percent were characterized as low productive (oligotrophic) lakes, 55 percent as moderately productive (mesotrophic) lakes, 24 percent as highly productive (eutrophic) lakes, and 4 percent as excessively productive (hypereutrophic) lakes. This work is continuing on 76 lakes in 2008.

The CMI Fund also continues to support work by the USGS to explore the feasibility and practicality of using remote sensing satellite imagery for lake water quality assessments that will enable the MDEQ to estimate productivity in inland lakes statewide. Statistical models for predicting lake water clarity and chlorophyll content have been developed and tested with data collected from the Cooperative Lakes Monitoring and Lake Water

Exhibit 51. Classification of 119 Lakes Monitored through Michigan's Cooperative Lakes Monitoring Program during 2006 - 2007



Quality Assessment Monitoring Programs. An on-line statewide application tool for predicting lake water clarity and chlorophyll content was launched in 2008. The statistical models and on-line application tool will continue to be enhanced and refined during the next several years along with the inland lakes data collection effort (mi.water.usgs.gov/splan1/sp00301/remotesensing.php).

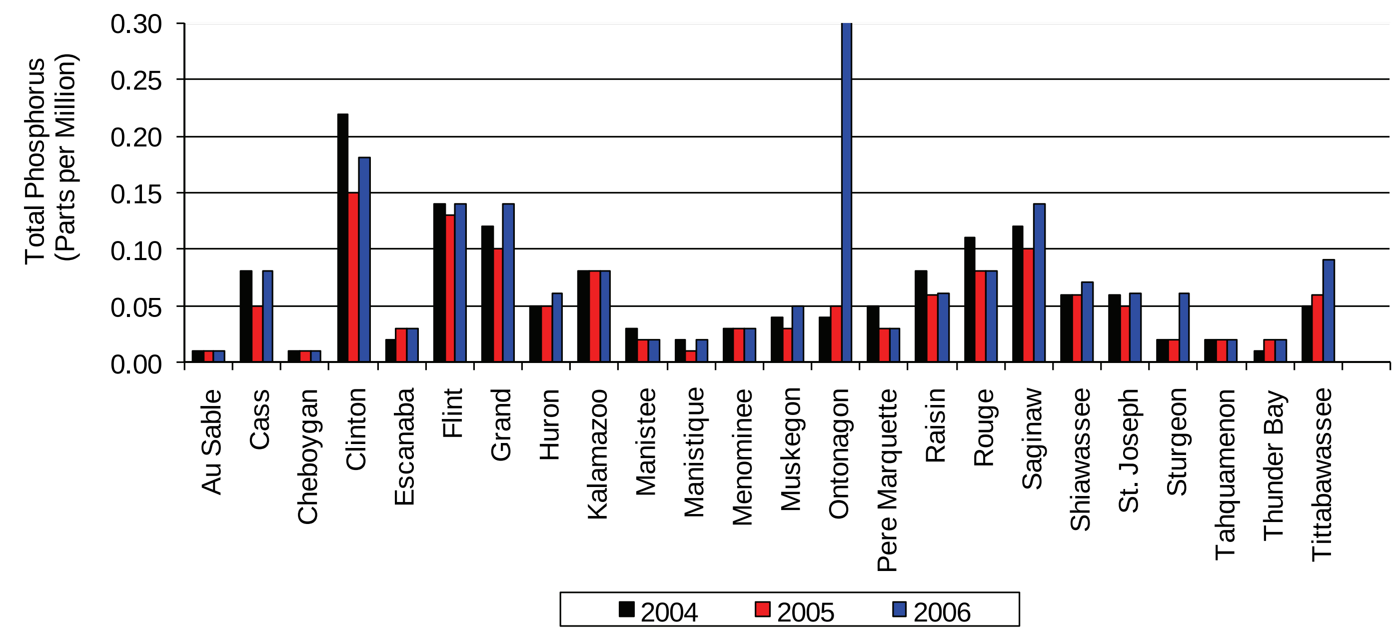
In 2007, Michigan participated in the USEPA supported National Lakes Assessment Survey (www.epa.gov/owow/lakes/lakessurvey/). The MDEQ coordinated Michigan's involvement in the survey in which 50 Michigan inland lakes were monitored. The survey was designed to help the USEPA to provide regional and national estimates of the condition of lakes, as well as statewide assessments for those states who participated in the survey. Data from the survey will be analyzed and compiled by the USEPA and partnering agencies in 2008, with a final report issued in 2009.

Surface Water Chemistry

Consistent with a *Water Chemistry Trend Monitoring Plan* developed by the MDEQ and the USGS, water samples have been collected from 31 major Michigan rivers since 2000. Water samples 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 52 shows a comparison of total phosphorus concentrations among 24 inland rivers for the period 2004 - 2006. 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

Exhibit 52. Average Total Phosphorus Concentrations in Selected Michigan Rivers in 2004 - 2006



relatively undeveloped, heavily forested watersheds.

Exhibit 53 presents the average annual total phosphorus concentrations from eight locations throughout the inner Saginaw Bay. Between 1993 and 2006, average phosphorus levels were lowest in 1996 and 2005 (0.15 ppm) and highest in 1998 (0.36 ppm). Overall, these data present no indication of any water quality trend for the Saginaw Bay at this time. The MDEQ 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 of these actions.

Exhibit 53. Average Annual Total Phosphorus Levels in Saginaw Bay 1993 - 2006

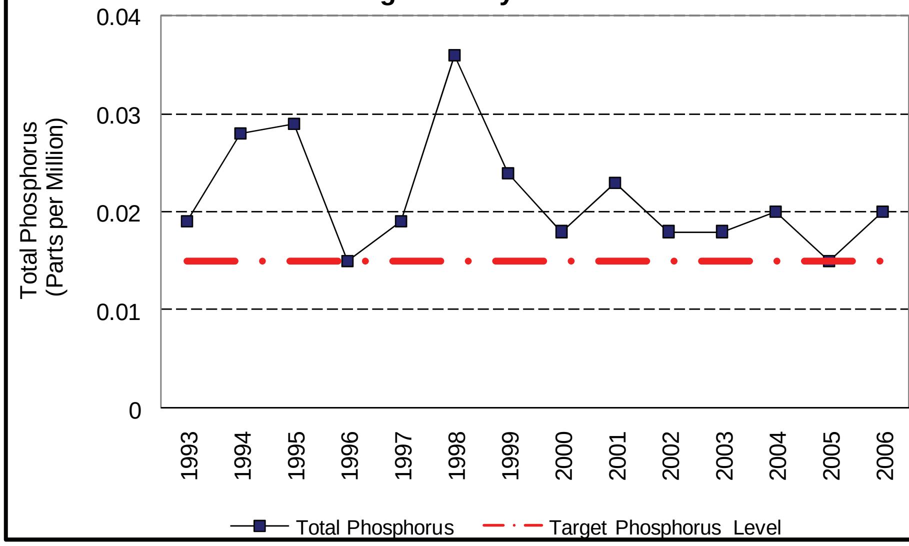


Exhibit 54 shows average concentrations of total mercury in 24 Michigan rivers for the period 2004 - 2006. The highest average annual mercury concentration occurred in the Ontonogan River in 2006 (12.3 parts per trillion - ppt), due to a very high value (45 ppt) from one sample during the year. The lowest concentration was found in the Cheboygan River in 2006 (0.37 ppt). Mean mercury levels exceeded the Michigan water quality standard (1.3 ppt) in 21, 20, and 20 of the Michigan rivers sampled in 2004, 2005, and 2006, respectively. As was the case with the phosphorus river data (Exhibits 51 and 52), no clear trend in water quality can be discerned from the collected mercury river data at this time.

Inland Lake Sediments

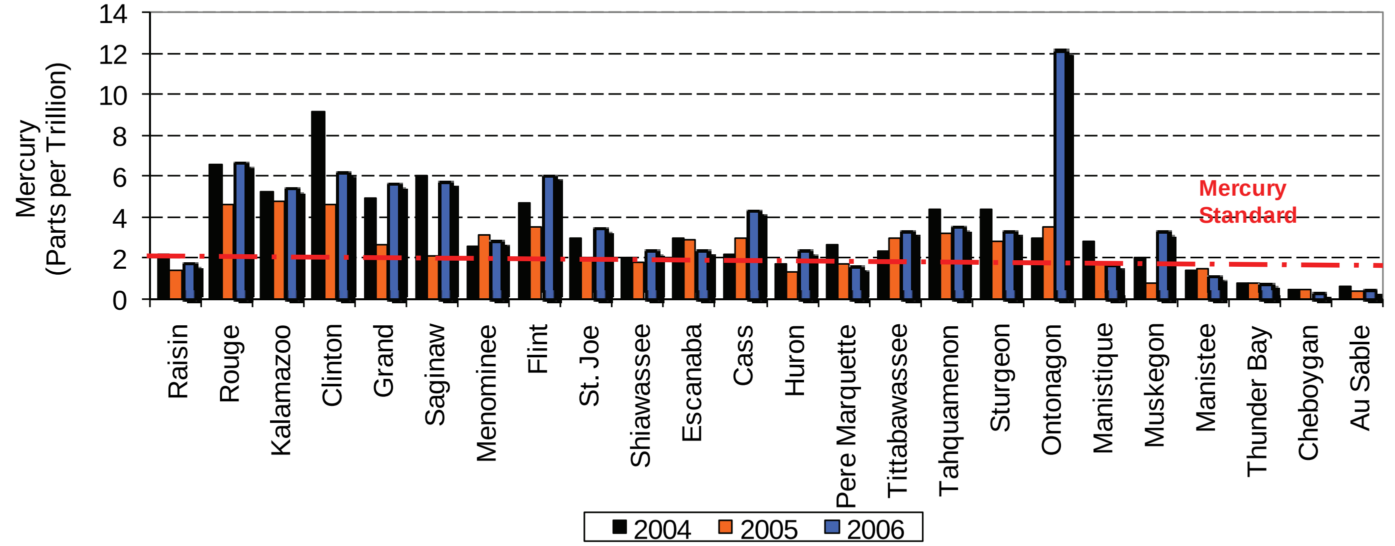
Contaminated sediments can directly affect bottom dwelling organisms and represent a continuing source for toxic substances in aquatic environments that may impact wildlife and humans through food or water consumption. Measuring trends in the accumulation of toxic chemicals in sediments is useful to assess the overall quality of aquatic systems. As material is deposited on the bottom of lakes over time, the sediments serve as a chemical recorder of temporal trends of toxic contaminants. Consequently, the assessment of chemical trends in inland lake sediments is an integral component of the MDEQ's overall water quality monitoring program.

In 1999, a joint initiative between the MDEQ and MSU was begun to monitor inland lake sediments. The objectives of the joint initiative were to:

1. Determine historical and current concentrations of metals and persistent organic pollutants in bottom sediments of selected Michigan inland lakes;
2. Measure temporal and spatial trends in the loadings of heavy metals to Michigan's inland lakes;
3. Determine the contaminant anthropogenic sediment inventory of selected inland lakes;
4. Determine whether new chemicals are accumulating in the sediments of inland lakes;
5. Provide data to support long-term monitoring strategies; and
6. Provide data to support the MDEQ's water quality protection projects and evaluate their effectiveness.

Since 1999, sediment core samples have been collected from 35 inland lakes in Michigan of which

Exhibit 54. Average Total Mercury Concentrations in Michigan Rivers 2004 - 2006



six of these lakes have been sampled twice. Samples were analyzed for mercury, trace metals, and selected organic contaminants, including PCBs and pesticides. Using advanced analytical methods, researchers are able to determine historical concentrations of different contaminants over time. Detailed evaluations are described in annual reports prepared by MSU and the MDEQ (www.michigan.gov/deq).

Exhibit 55 shows the lead accumulation rates in sediment cores in four lakes for the period 1900 – 2000. Lead accumulation rates increased until the 1970s, when leaded gasoline was banned, and then decreased to the present. There also is a general geographic trend exhibited, with lakes in the more populated southern part of the state typically having higher accumulation rate trends than lakes farther north. Some of these lakes will be scheduled to be sampled again in 2010.

Exhibit 56 shows sediment trend data on copper concentrations in selected Michigan lakes for the period 1805 - 2001. Sediment core samples show peak values of copper near 500 milligrams per kilogram (mg/kg) in Cadillac Lake; almost tenfold higher than the next highest lake, Whitmore Lake. Copper concentrations decreased in Cadillac Lake sediment since the early 1990s, but remain high. The higher concentrations observed in Cadillac Lake are thought to be due to the use of copper sulfate to control algal growth. Sediments from Whitmore and Mullet Lakes show an increase in copper concentrations in the mid-1940s. While concentrations of copper in Mullet Lake have clearly decreased to the present, copper

Exhibit 55 Lead Accumulation Rates in Four Lakes 1900 - 2000

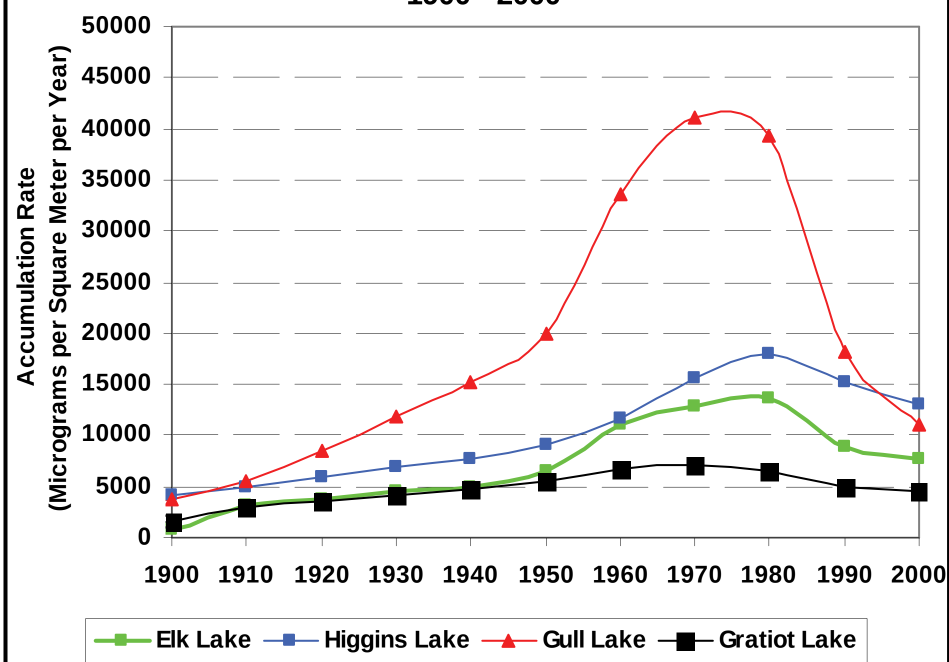
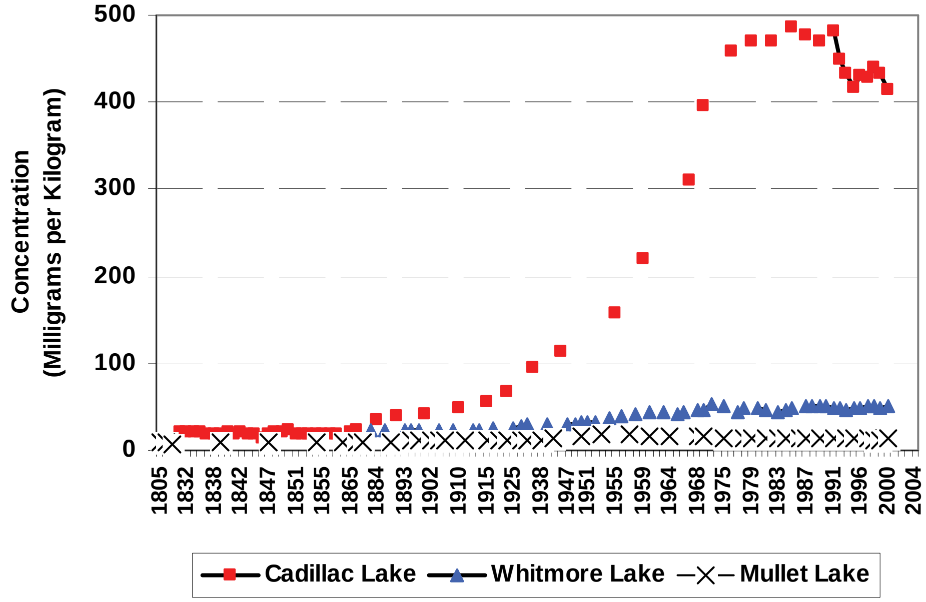


Exhibit 56. Concentrations of Copper in Sediments from Cadillac, Whitmore, and Mullet Lakes 1805 - 2001



concentrations in Whitmore Lake do not show a decreasing trend.

Exhibit 57 shows concentrations of mercury in sediments from Higgins and Crystal (Benzie County) Lakes during the period 1825 - 2000. Common among many Michigan lakes are episodic mercury accumulation events that occur over short time periods (years) with regularity. Some of the events can be attributed to historical increases in mercury deposition (e.g., World War II), while others are a possible indication of watershed-scale sources of mercury loadings (e.g., Higgins Lake). Many Michigan lakes also exhibit accumulation rates that increase to the sediment surface, indicating a current yet undefined source of mercury to the lake (e.g., Crystal Lake).

In general, preliminary results for mercury concentrations in Michigan Lakes show background (i.e., pre-industrial revolution) mercury concentrations ranging from 0.015 – 0.1 mg/kg (similar to those found in the Great Lakes), and peak mercury concentrations ranging from 0.16 – 3.64 mg/kg. For comparison purposes, sediments with mercury concentrations at or exceeding 2 mg/kg are considered to have a high probability of causing severe effects on bottom-dwelling organisms (sediment clean-up efforts often have a goal of 1.0 mg/kg of mercury in sediment). Final results from this sediment monitoring effort are further described in annual reports prepared by MSU and the MDEQ.

In addition to the lake sediment assessment program, the MDEQ also participates in the removal of contaminated sediments from lakes and steams. Exhibit 58 show the cubic yards of sediment that have been removed from Michigan lakes and streams since 1997. Approximately 32,100 cubic yards of material were removed from the St. Mary's River at the Tannery Bay site in 2007. This project was completed with Great Lakes Legacy Act funds. Also, approximately 37,000 cubic yards were removed from the Kalamazoo River Superfund site.

Exhibit 57. Concentrations of Mercury in Sediment from Higgins and Crystal Lakes (Benzie County) 1825 - 2000

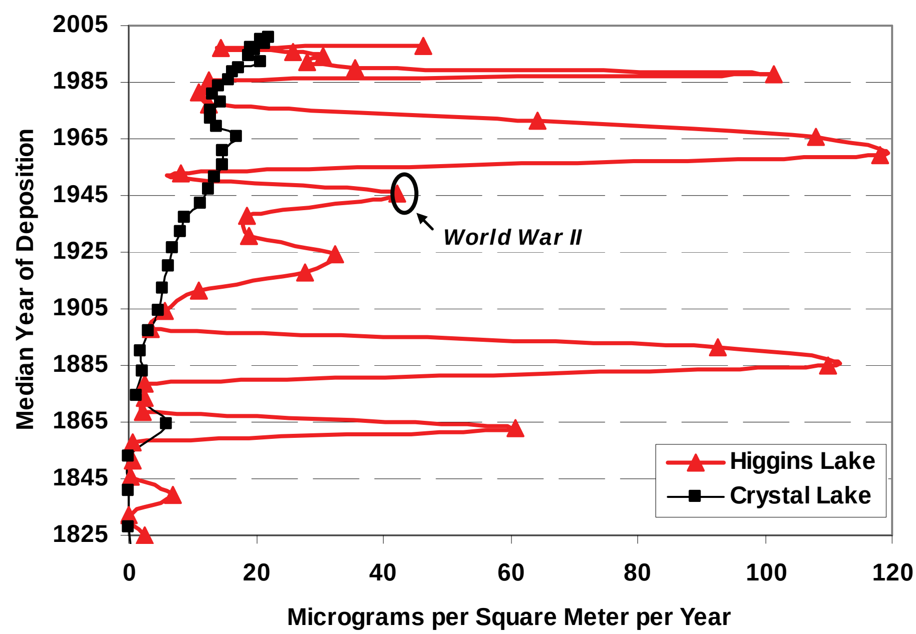
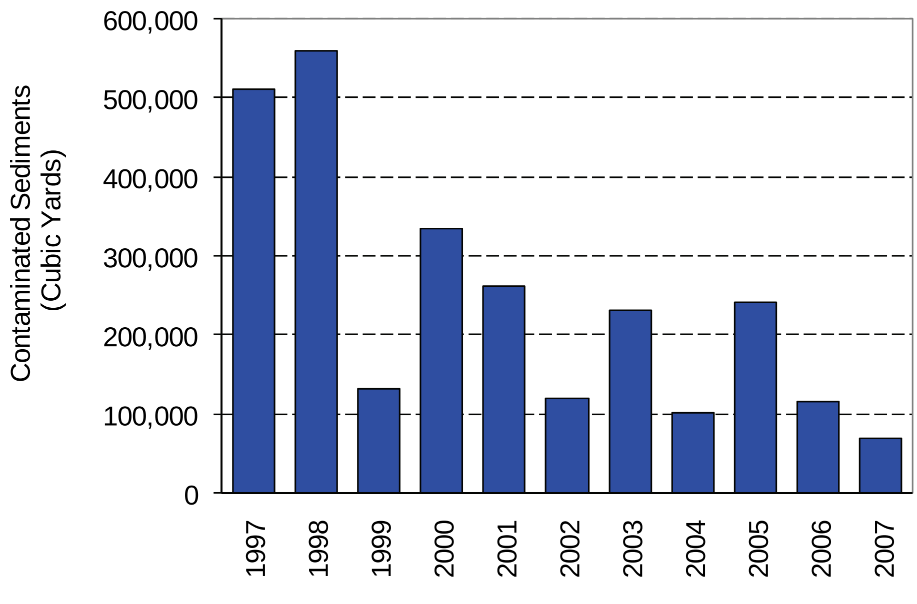


Exhibit 58. Cubic Yards of Contaminated Sediments Removed from Surface Waters 1997 - 2007



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 and lakes and reservoirs occurring in stream systems.

Changes in flow patterns reflect changes in runoff from land, ground water 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% exceedance frequency), median (50% exceedance frequency), and low (90% 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.

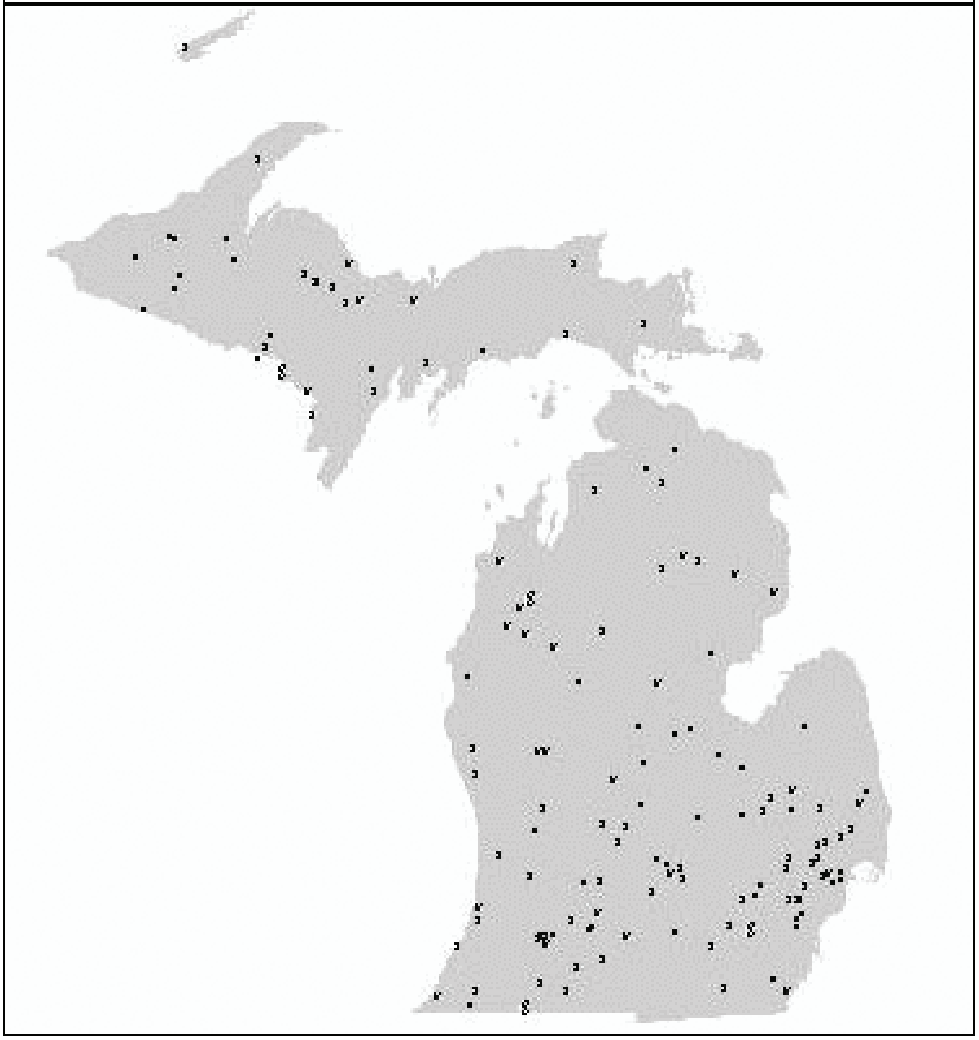
The status of flow is determined by comparing recent flow patterns to a benchmark. This benchmark can be based on presettlement flows or from the earliest period of record. Models have been developed that predict stream flow as a function of geology, stream size, and current land cover characteristics. 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 150 stations statewide (Exhibit 59).

Great Lakes Water Level Trends

The Great Lakes Basin lies within eight United States states and two Canadian provinces and comprises the lakes, connecting channels, tributaries, and ground water that drain through the international section of the St. Lawrence River. Lake levels are determined by the combined influence of precipitation (the primary source of natural water supply to the Great Lakes), upstream inflows, ground water, surface water runoff, evaporation, diversions into and out of the system, consumptive uses, dredging, and water level regulation. Because of the vast water surface area, water levels of the Great Lakes remain relatively steady, with a normal fluctuation ranging from 12 to 24 inches in a single year.

Exhibit 59. Geographic Distribution of Active Stream Gauging Stations Overseen by the United States Geological Survey



Climatic conditions control precipitation (and, therefore, ground water recharge), runoff, and direct supply to the lakes, as well as the rate of evaporation. During dry, hot weather periods, inflow decreases and evaporation increases, resulting in lower lake levels and reduced flows.

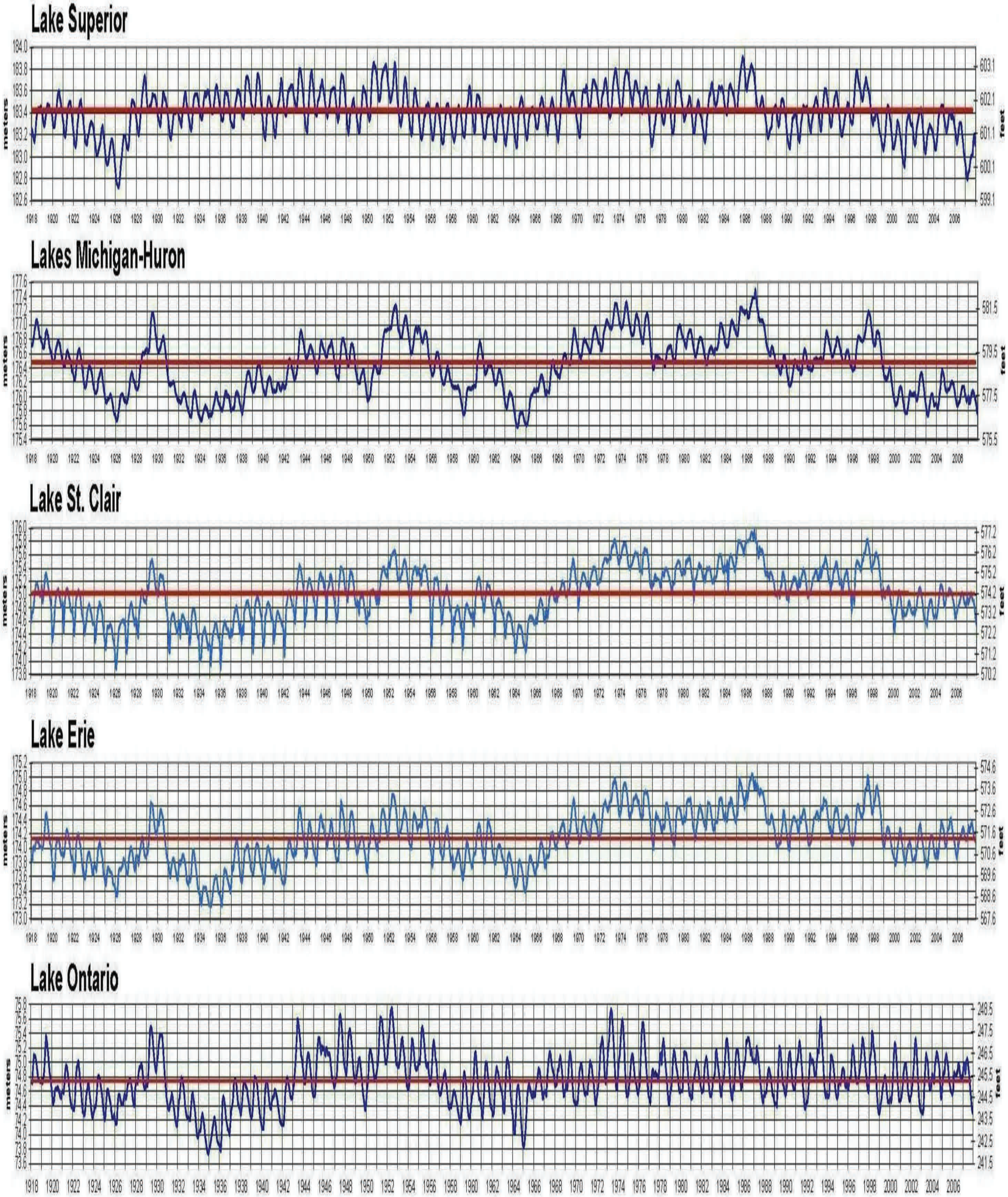
During wet colder periods, higher levels and increased flows occur. Exhibit 60 shows the monthly mean and long-term annual average water levels of the Great Lakes for the period 1918 - 2007.

Between 1918 and 1998, there have been several periods of extremely high and extremely low water levels and flows. Exceptionally low levels were experienced in the mid-1920s, mid-1930s, and early 1960s. High levels occurred in 1929 - 1930, 1952, 1973 - 1974, 1985 - 1986, and 1997 - 1998. Studies of water level fluctuations have shown that the Great Lakes can respond relatively quickly to periods of above average or extreme precipitation, water supply, and temperature conditions.

Great Lakes levels are highly sensitive to weather fluctuations, as illustrated by the impact of high water levels in the early 1950s and mid-1980s and of low water levels in the 1930s and mid-1960s. Significant and cyclic climatic variability will continue regardless if human intervention is superimposed or not on natural fluctuations. An example of how quickly water levels can change in response to climatic conditions occurred during 1998 - 1999, when the water levels of Lakes Michigan and Huron dropped 22 inches in 12 months.

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 control work obstructions, dredging, and diversions, still can have an impact on lake levels. For example, dredging in the connecting channels can have a significant impact on lakes above the point of dredging. Out-of-basin diversions or other large removals and large consumptive uses, by contrast, can reduce water levels both above and below the actual point of withdrawal and also reduce flows in the system.

Exhibit 60. Monthly Mean (Blue) and Long-term Annual Average (Red) Great Lakes Water Levels 1918 – 2007 (In Meters and Feet)



A 5-year International Upper Great Lakes Study was instituted by the International Joint Commission in March 2007 to evaluate options for improvements to the existing St. Mary's 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.

Great Lakes Ice Cover Trends

The State of the Lakes Ecosystem Conference (SOLEC) currently has developed over 80 indicators designed to assess the overall quality of and track the changing conditions of the Great Lakes over time. The indicator that is currently used by the SOLEC to assess extent of Great Lakes ice during the winter months is Indicator #4858: *Ice Duration on the Great Lakes Indicator*.

Changes in water and air temperatures will influence ice development on the Great Lakes and, in turn, affect coastal wetlands, near shore aquatic environments, and inland environments. Air temperatures over a lake are one of the few factors that control the formation of ice on that surface. Colder winter temperatures increase the rate of heat released by the lake, thereby increasing the freezing rate of the water. Milder winter temperatures have a similar controlling effect, only the rate of heat released is slowed and the ice forms more slowly. Globally, some inland lakes appear to be freezing up later and breaking up earlier, than the historical average, based on a study of 150 years of data.

The freezing and thawing of lakes is an important aspect to many aquatic and terrestrial ecosystems. Many fish species rely on the ice to give their eggs protection against predators during the late part of the ice season. Near shore ice has the ability to change the shoreline as it can encroach upon the land during winter freeze-up times. Even inland systems are affected by the amount of ice that forms, especially within the Great Lakes Basin. Less ice on the Great Lakes allows more water to evaporate and be spread across the basin in the form of snow. This can have an effect on the foraging animals that need to dig through snow during the winter in order to obtain food.

Historical observations of the Great Lakes data showed no real conclusive trends with respect to the date of freeze-up or break-up. A reason for this could be that due to the sheer size of the Great Lakes, and the inability (at least before satellite imagery) to observe the whole lake during the winter season.

However, there are enough data collected from ice charts to suggest there has been a decrease in the maximum ice cover per season over the last 30 years. The trends on each of the five Great Lakes show that during this time span the maximum amount of ice forming each year has been decreasing, which correlated to the average ice cover per season observed for the same time duration. Between the 1970s and the 1990s there was at least a 10 percent decline in the maximum ice cover on each lake, nearly 18 percent in some cases, with the greatest decline occurring during the 1990's (Exhibit 61).

Exhibit 61. Great Lakes Mean Ice Coverage 1970 – 1999

Lake	1970 - 1979	1980 - 1989	1990 - 1999	Change from 1970s to 1990s
Erie	94.5%	90.8%	77.3%	-17.2%
Huron	71.3%	71.7%	61.3%	-10.0%
Michigan	50.2%	45.6%	32.4%	-17.8%
Ontario	39.8%	29.7%	28.1%	-11.7%
Superior	74.5%	73.9%	62.0%	-12.6%

Source: Ferris, G. 2003. Ice duration on the Great Lakes indicator #4858, pp 71-72. In *State of the Great Lakes 2003*. State of the Lakes Ecosystem Conference, Environment Canada and U.S. Environmental Protection Agency. 102p.

According to the 2007 assessment of the SOLEC Ice Duration on the Great Lakes Indicator and based on current data, it is anticipated that ice formation on the Great Lakes may continue to decrease in total cover if current predictions of milder winters hold true. Additional years of Great Lakes ice formation data will need to be gathered to further substantiate this observation.

Climate and Weather Trends

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. From the period 1890 to the 1930s, summer temperatures increased and precipitation decreased. Winter temperatures continued to rise into the 1950s and there was a wet, cool trend from the late 1950s into the 1970s. The 1980s, 1990s, and 2000s (thus far) have tended to provide slightly warmer temperatures as compared to the 1950s through 1970s.

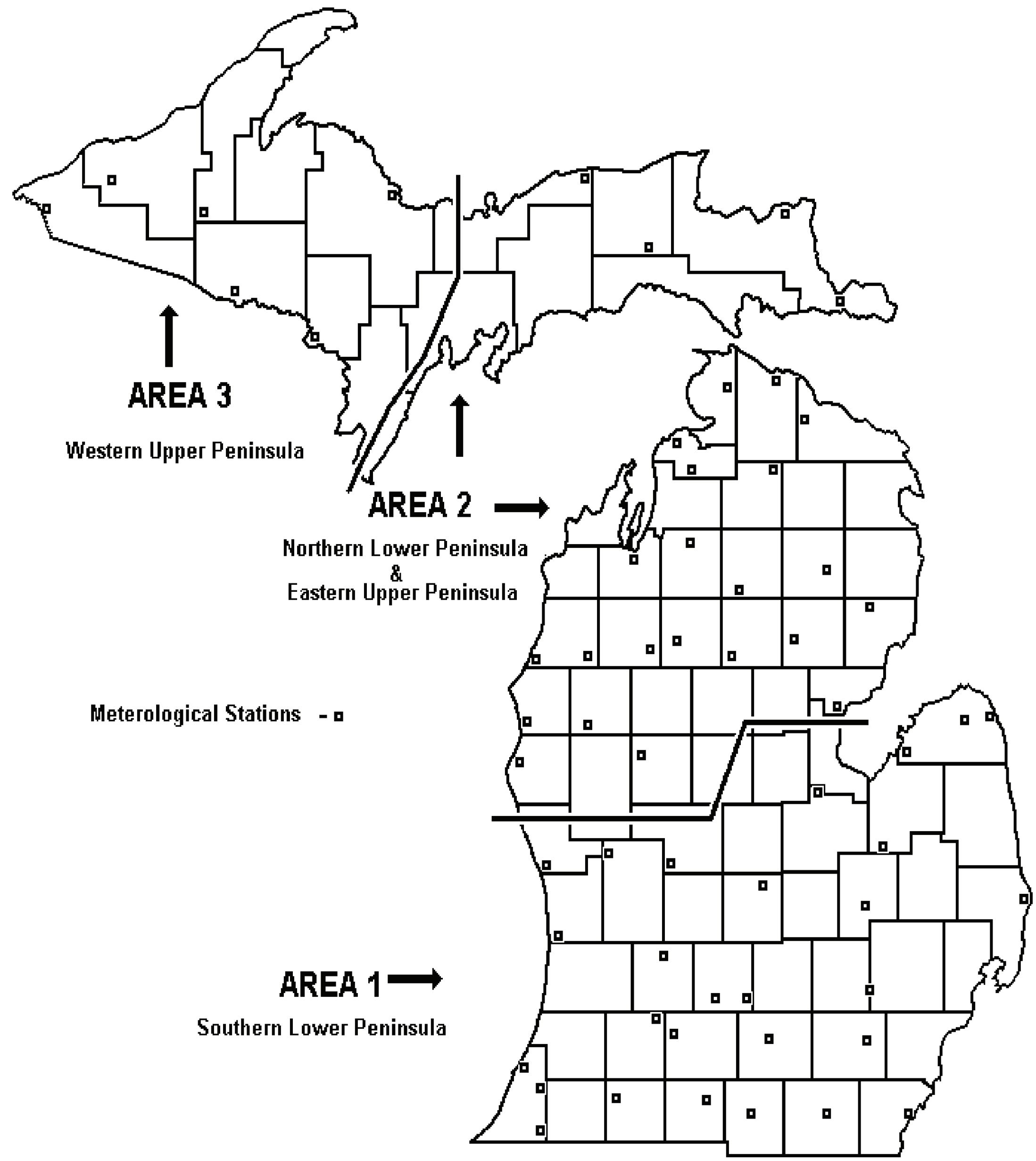
Michigan's current climate may be broadly characterized as being dominated by three general weather patterns. The two most dominant patterns originate from west to north and from west to south, influencing weather in northern Michigan and southern Michigan, respectively. The approximate boundary or tension 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 (Exhibit 62). Due in part to the generally higher elevations and more northerly location, cooler temperatures, severe thunderstorms and high winds are common.

The weather data referenced in this Triennial Report were obtained from the National Climatic Data Center. These data were initially compiled from 60 sites across the state and then aggregated to the three areas to be representative of the southern Lower Peninsula, the combined northern Lower and

Exhibit 62. Meteorological Station Locations in Michigan



eastern Upper Peninsulas, and the western Upper Peninsula (Exhibit 62). Nine meteorological measurements (average annual temperature, average annual daily maximum temperature, average annual daily minimum temperature, average diurnal temperature, length of growing season, heating degree days, cooling degree days, total annual snowfall, and total annual precipitation) are tracked and evaluated for each of the three Michigan areas.

During the development for this environmental measurement, a statistical analysis was conducted on the available climatological data. It was the initial intent to report climate data from 1895 to the present; however based on a statistical analysis of the data, such a report would not have been valid since the climate data collected from 1895 to 1948 carries with it a statistical sampling bias (due to the fact that most of the early sampling stations were located in large cities and additional rural stations were added gradually over time). To ensure that no seasonal bias was introduced into the analyses, only those sites having at least 50 percent statistically defensible data were included in the analysis. Consequently, it was determined that sufficient quality data only exist for all the Michigan climatic regions from 1949 to 2007 despite the fact some stations have data as far back as 1895. This verification was completed for each of the nine individual meteorological measurements.

Exhibits 63a to 63i present the nine meteorological measurements and trends for the southern Lower Peninsula, the combined northern Lower and eastern Upper Peninsula, and western Upper Peninsula. Based on a statistical analysis of these meteorological data, there is currently no compelling evidence to date to infer that Michigan's climate, although continuing to exhibit cyclic behavior, has changed *significantly* over the last 58 years. Michigan's meteorological measurements will continue to be collected and reported on in each subsequent Triennial Report.

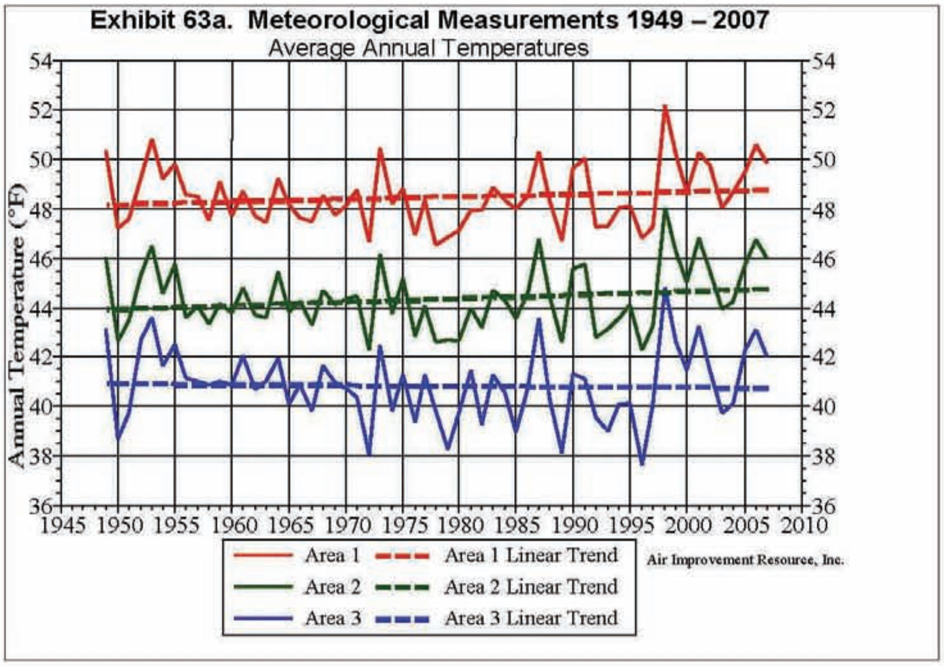


Exhibit 63a. Meteorological Measurements 1949 – 2007
Average Annual Temperatures
Annual Temperature (°F)
54
52
50
48
46
44
42
40
38
36
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
Area 1
Area 1 Linear Trend
Area 2
Area 2 Linear Trend
Area 3
Area 3 Linear Trend
Air Improvement Resource, Inc.

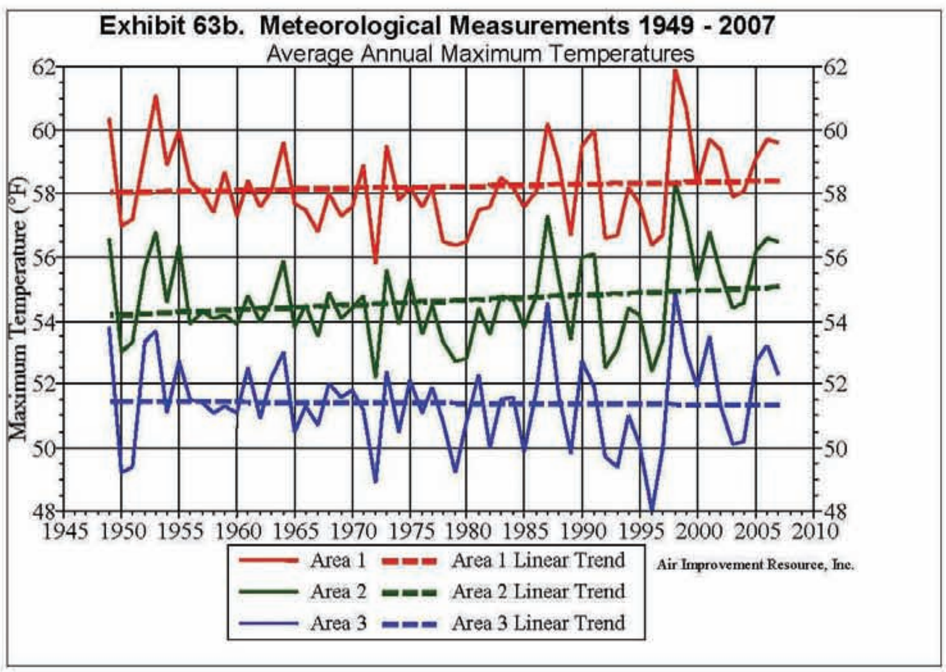


Exhibit 63b. Meteorological Measurements 1949 - 2007
Average Annual Maximum Temperatures
Maximum Temperature (°F)
62
60
58
56
54
52
50
48
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
Area 1
Area 1 Linear Trend
Area 2
Area 2 Linear Trend
Area 3
Area 3 Linear Trend
Air Improvement Resource, Inc.

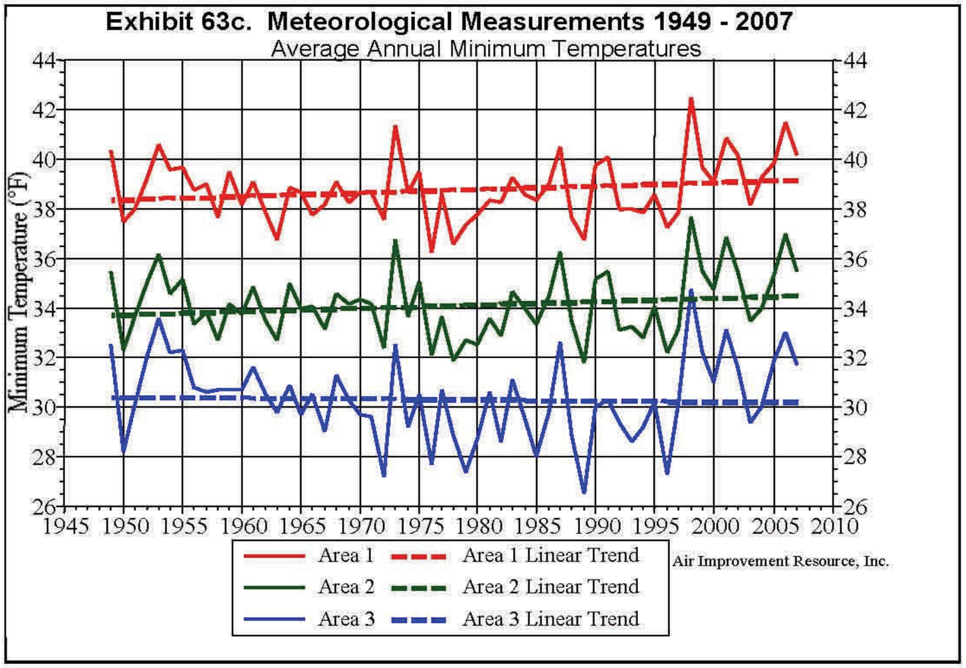


Exhibit 63c. Meteorological Measurements 1949 - 2007
Average Annual Minimum Temperatures
Minimum Temperature (°F)
44
42
40
38
36
34
32
30
28
26
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
Area 1
Area 1 Linear Trend
Area 2
Area 2 Linear Trend
Area 3
Area 3 Linear Trend
Air Improvement Resource, Inc.

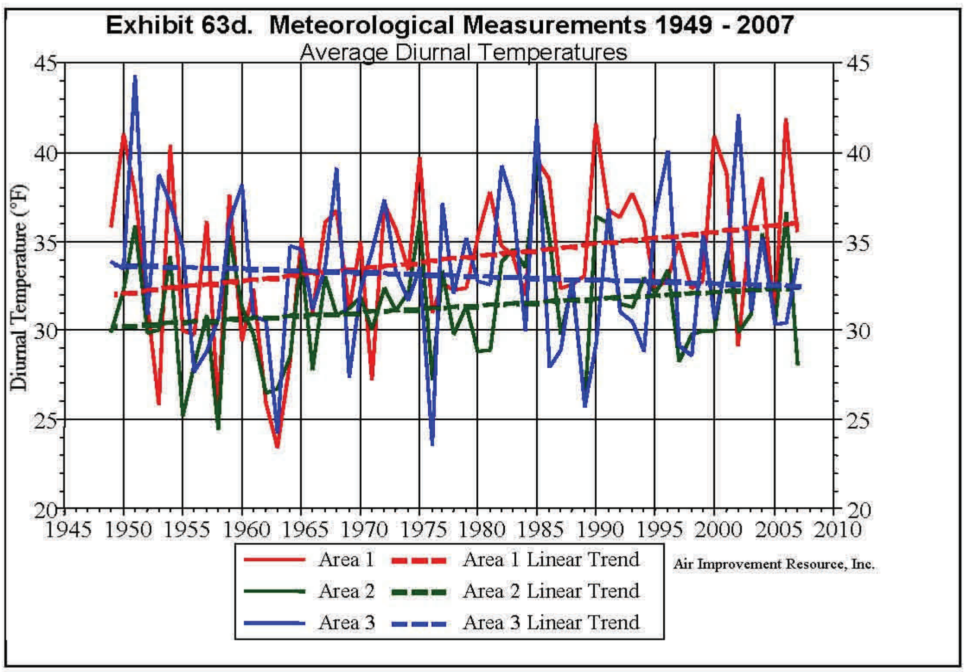


Exhibit 63d. Meteorological Measurements 1949 - 2007
Average Diurnal Temperatures
Diurnal Temperature (°F)
45
40
35
30
25
20
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
Area 1
Area 1 Linear Trend
Area 2
Area 2 Linear Trend
Area 3
Area 3 Linear Trend
Air Improvement Resource, Inc.

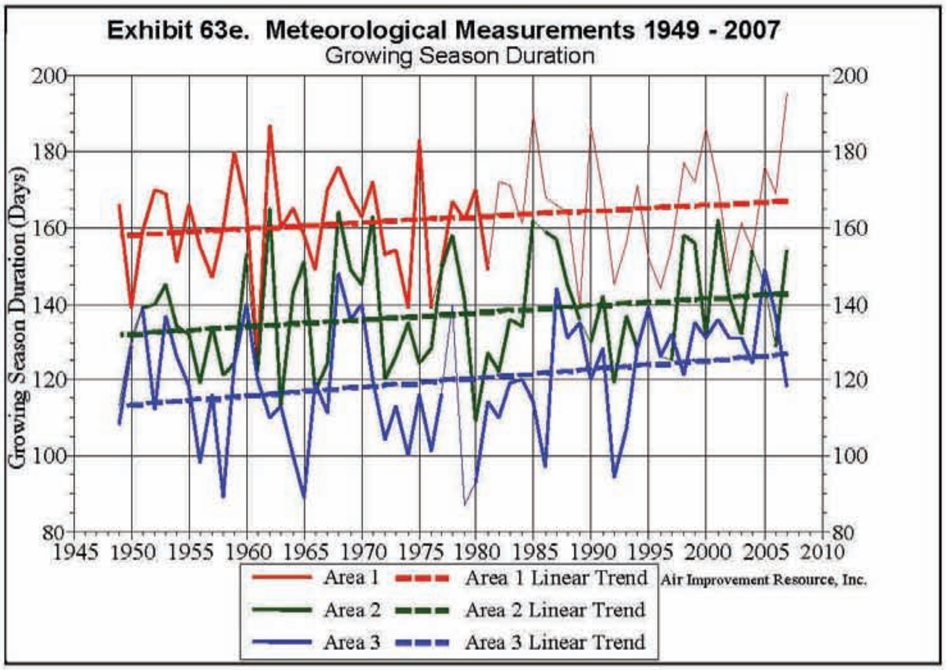


Exhibit 63e. Meteorological Measurements 1949 - 2007
Growing Season Duration
Growing Season Duration (Days)
200
180
160
140
120
100
80
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
Area 1
Area 1 Linear Trend
Area 2
Area 2 Linear Trend
Area 3
Area 3 Linear Trend
Air Improvement Resource, Inc.

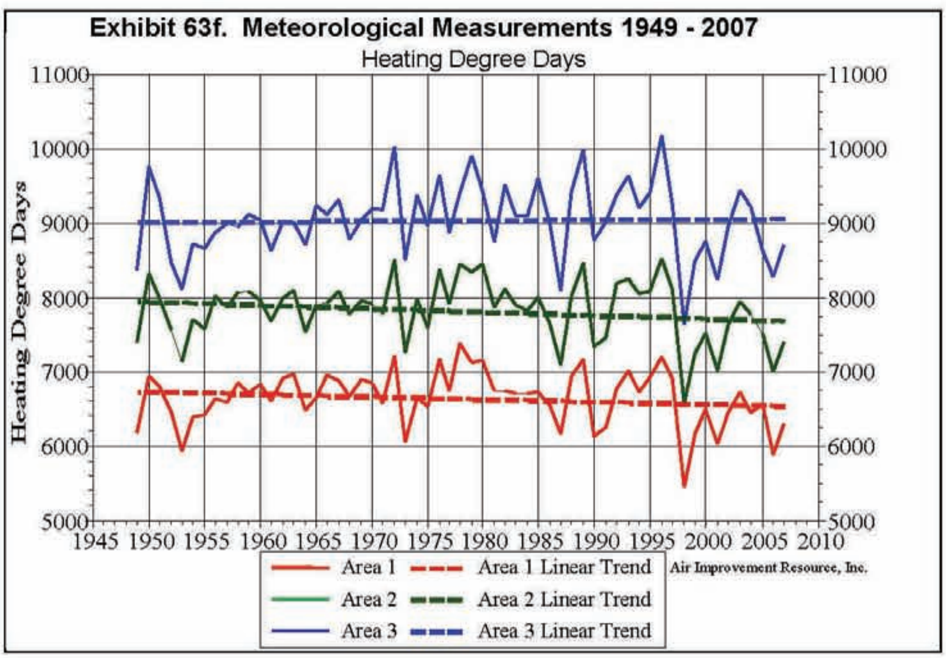


Exhibit 63f. Meteorological Measurements 1949 - 2007
Heating Degree Days
Heating Degree Days
11000
10000
9000
8000
7000
6000
5000
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
Area 1
Area 1 Linear Trend
Area 2
Area 2 Linear Trend
Area 3
Area 3 Linear Trend
Air Improvement Resource, Inc.

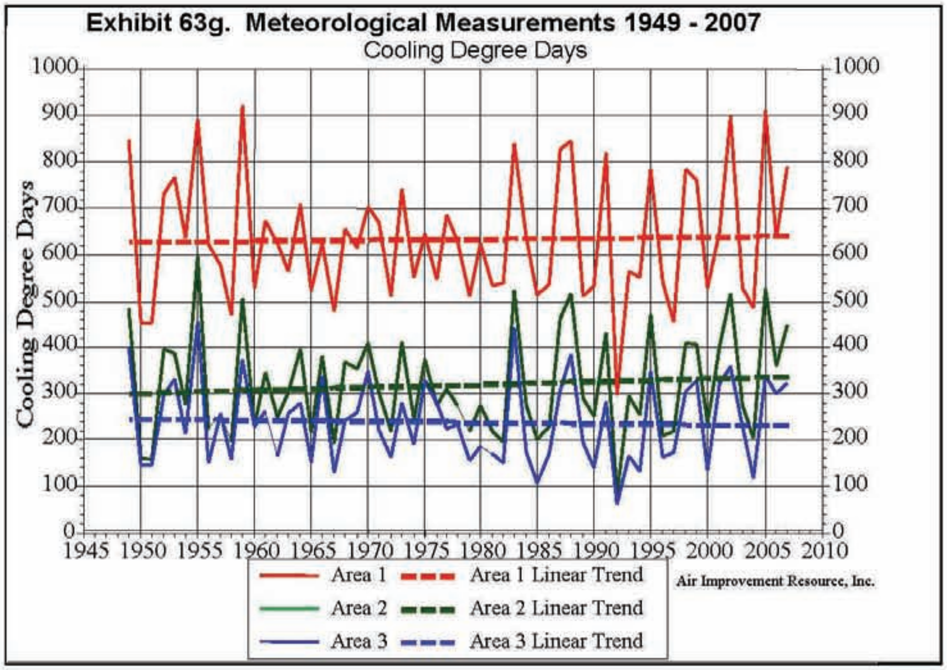


Exhibit 63g. Meteorological Measurements 1949 - 2007
Cooling Degree Days
Cooling Degree Days
1000
900
800
700
600
500
400
300
200
100
0
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
Area 1
Area 1 Linear Trend
Area 2
Area 2 Linear Trend
Area 3
Area 3 Linear Trend
Air Improvement Resource, Inc.

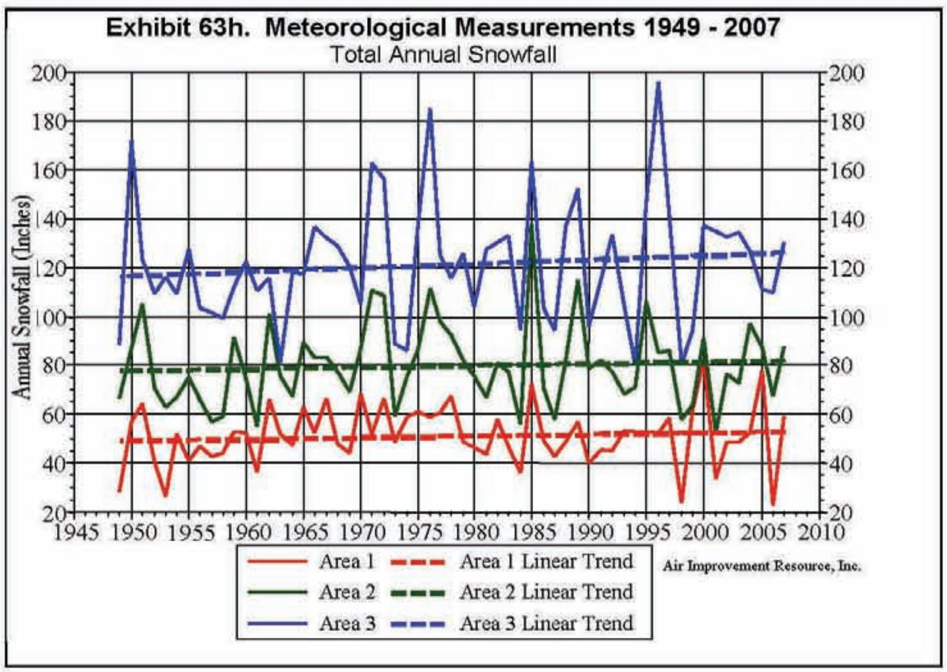


Exhibit 63h. Meteorological Measurements 1949 - 2007
Total Annual Snowfall
Annual Snowfall (Inches)
200
180
160
140
120
100
80
60
40
20
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
Area 1
Area 1 Linear Trend
Area 2
Area 2 Linear Trend
Area 3
Area 3 Linear Trend
Air Improvement Resource, Inc.

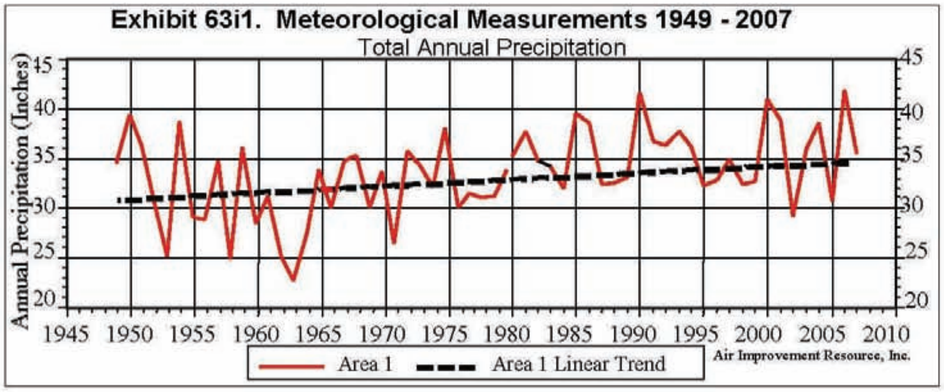


Exhibit 63i1. Meteorological Measurements 1949 - 2007
Total Annual Precipitation
Annual Precipitation (Inches)
Area 1
Area 1 Linear Trend
Air Improvement Resource, Inc.

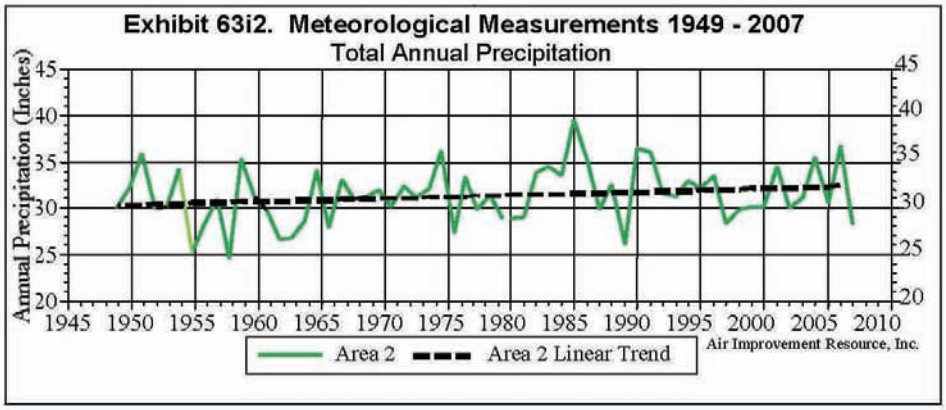


Exhibit 63i2. Meteorological Measurements 1949 - 2007
Total Annual Precipitation
Annual Precipitation (Inches)
Area 2
Area 2 Linear Trend
Air Improvement Resource, Inc.

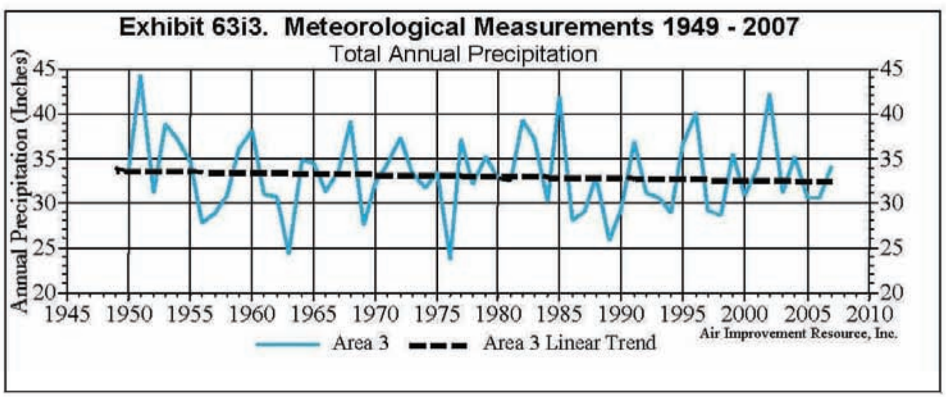
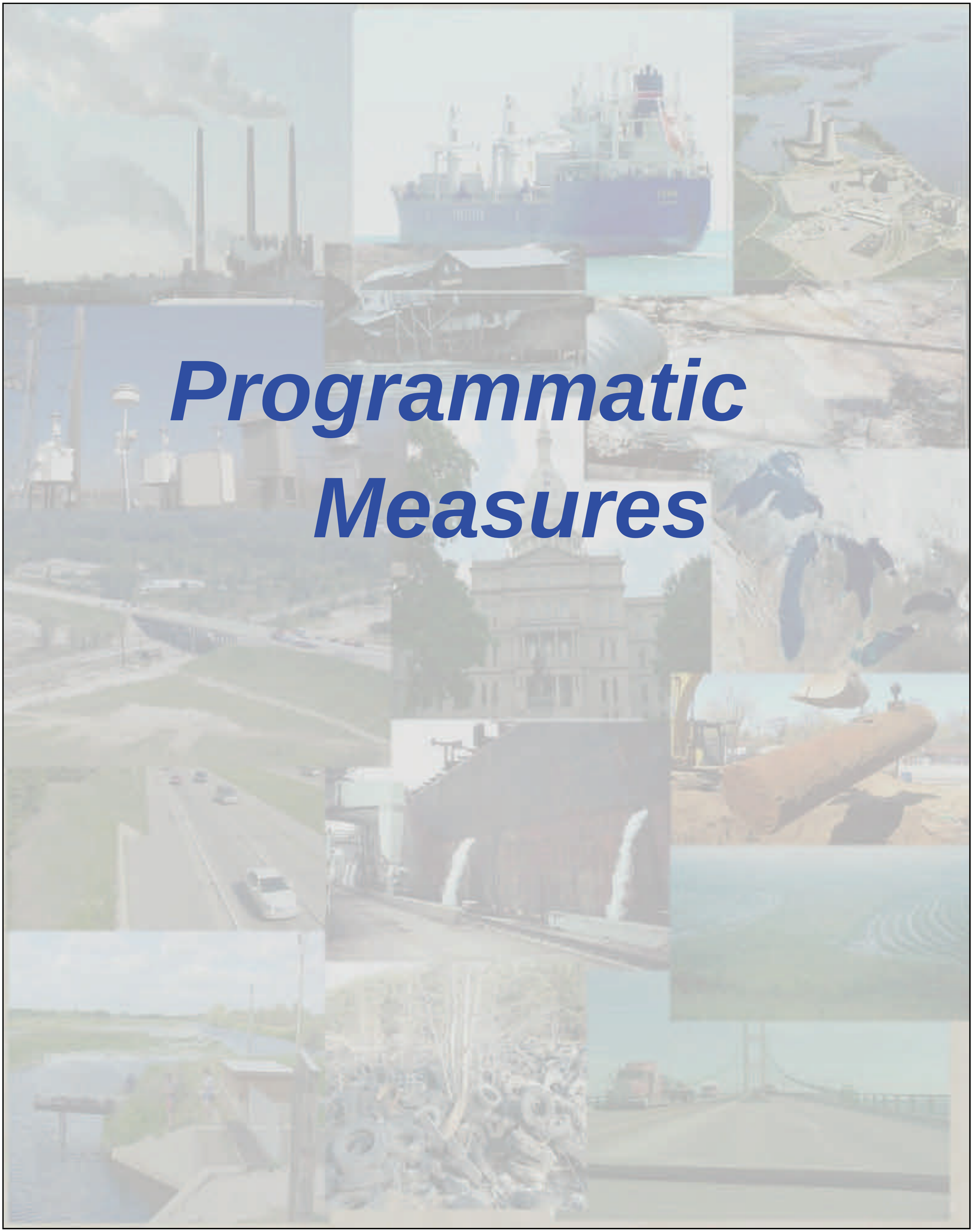


Exhibit 63i3. Meteorological Measurements 1949 - 2007
Total Annual Precipitation
Annual Precipitation (Inches)
Area 3
Area 3 Linear Trend
Air Improvement Resource, Inc.



Programmatic Measures

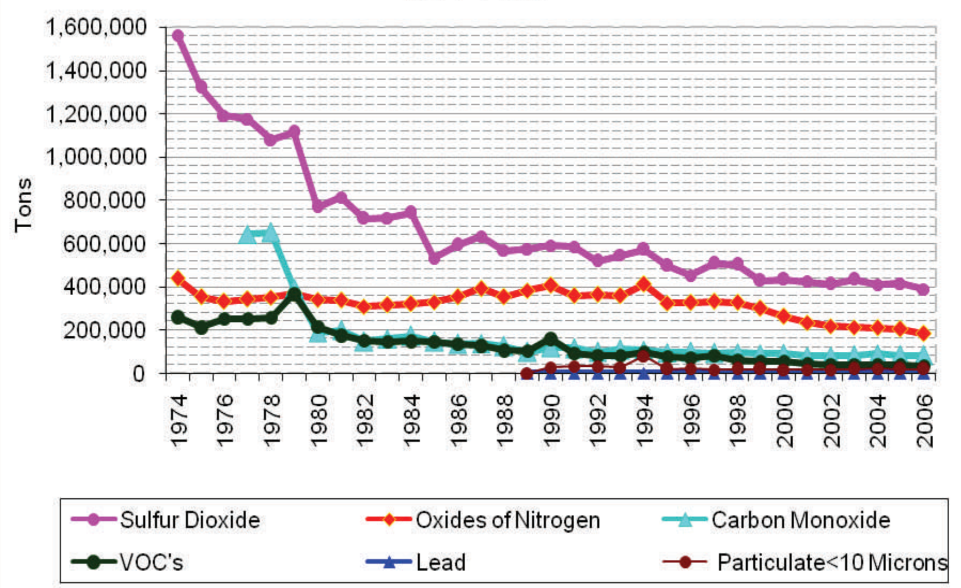
Programmatic Measures

Air Quality

Air Emissions Estimates

The federal Clean Air Act requires states to prepare and maintain inventories of emissions from major pollutant sources. Emissions from large stationary sources are calculated for particulates, sulfur dioxide, nitrogen oxides, carbon monoxide, volatile organic chemicals (VOCs), and lead. The MDEQ compiles information from over 1,800 facilities. In 2001, the USEPA required states to report PM_{10} rather than total particulate matter when reporting to the USEPA. The MDEQ then began collecting PM_{10} emissions data from stationary point source facilities that report annually and began estimating PM_{10} emissions for all other source categories. Exhibits 64 presents a summary of this information for the six contaminants.

Exhibit 64. Pollution Emission Inventory Trends 1974 - 2006



Air pollutant emission sources are categorized as mobile sources, large facility point sources, and area sources (small industries, boats, farm equipment, etc.). The relative percentage that these sources contributed to the overall emissions of VOCs and nitrogen oxides is shown in Exhibits 65 and 66, respectively (based on 2002 emission data, the latest available). Motor vehicles contributed 32 percent of the VOC emissions and 46 percent of the nitrogen oxides. Photochemical reactions between nitrogen oxides and VOCs form ground level ozone.

Greenhouse Gas Emissions Inventory

Naturally occurring greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Excluding water vapor, the combined greenhouse gases make up less than one percent of the chemical composition of the Earth's atmosphere. These gases are vital for life systems on Earth because they absorb and reemit the infrared radiation (felt as heat) that the Earth emits as a result of radioactive heating by the sun. Without greenhouse gases in the atmosphere, the Earth's temperatures during nighttime hours would drop below a level that would allow for survival of terrestrial life.

The current concern of increased greenhouse gases and global climate change can be described as the *enhanced greenhouse gas effect* where due to the increased concentrations of CO_2, N_2O, CH_4, and other greenhouse gases, more heat is retained in the atmosphere. With greater heat energy in the atmosphere, dramatic changes are more likely to occur in the coming decades concerning the earth's global climate and oceanic circulation system.

In April 2005, the first inventory report of Michigan greenhouse gas emissions (*Michigan Greenhouse Gas Inventory 1990 and 2002*) (Inventory Report) was released. The Inventory Report provides estimates of anthropogenic (human-caused) greenhouse gas emission sources and sinks in Michigan in 1990 and 2002. The purpose of the inventory is to establish an emissions baseline and begin to look at trends across economic sectors within the state. The Inventory Report estimated that total greenhouse gas emissions in Michigan during 2002 amounted to 62.59 million metric tons carbon equivalent (MMTCE) (Exhibit 67). This amounted to a nine percent increase over the 1990 emissions baseline of 57.42 MMTCE.

Exhibit 65. Estimated Levels of Volatile Organic Compound Emissions by Source Category

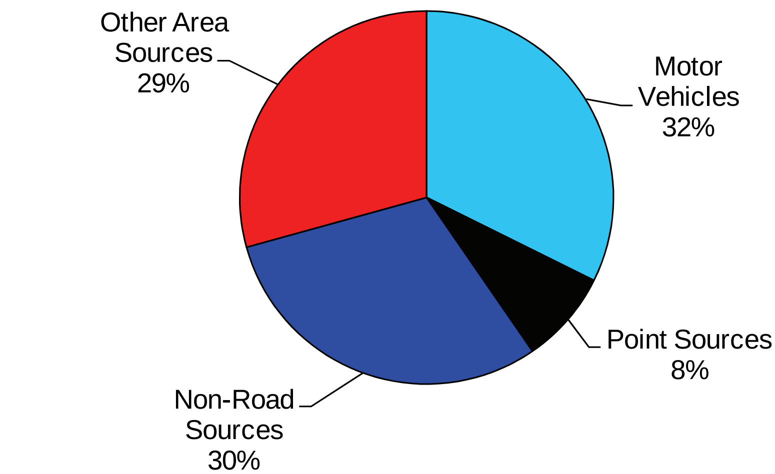
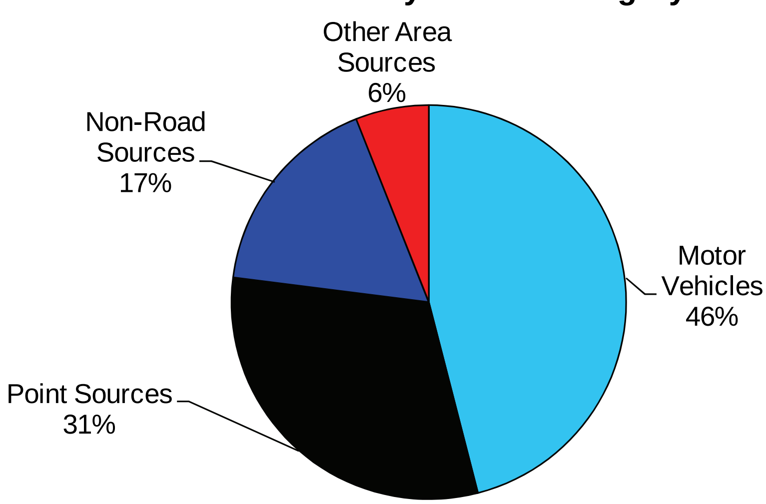


Exhibit 66. Estimated Levels of Nitrogen Oxides Emissions by Source Category



Carbon dioxide is the dominate greenhouse gas emission in Michigan, accounting for 87 percent of all the estimated greenhouse gas emissions in 2002. Electricity generation, the largest contributor, accounted for 33 percent of the total emissions in 2002 (Exhibit 68). The transportation sector was the second largest contributor. Additional information on the inventory can be found on the Internet at www.michigan.gov/deqair.

On November 14, 2007, the Governor signed Executive Order 2007-42 establishing the Michigan Climate Action Council (MCAC). The purpose of the MCAC is to assist Michigan in identifying the best opportunities to mitigate and adapt to climate change, reduce costs associated with climate change activities, and foster economic growth in Michigan. A comprehensive climate action plan will be addressed in the final report of the MCAC, which is due December 31, 2008.

One of the charges to the MCAC under the Executive Order is to produce an updated inventory and forecast of greenhouse gas sources and emissions for the period 1990 - 2020. Work on this inventory and forecast is well underway. Additional information on the MCAC, including a draft inventory and forecast, is available on the Internet at www.miclimate change.us/.

Exhibit 67. Summary of Estimated Michigan Greenhouse Gas Emissions and Sinks (Excluding Forestry) 1990 and 2002

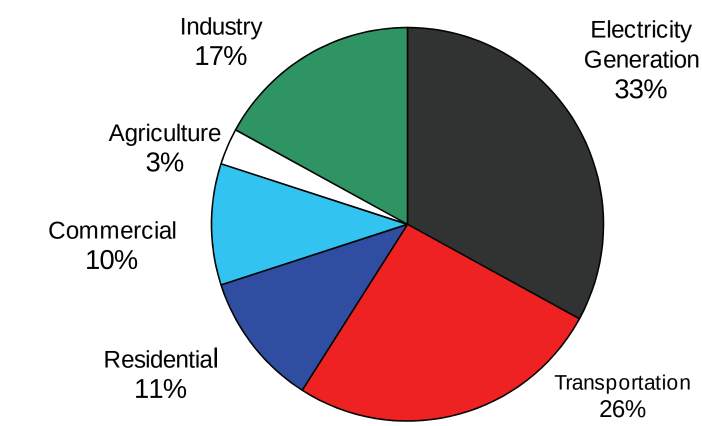
Gas/Activity	Million Metric Tons Carbon Equivalent 1990	Million Metric Tons Carbon Equivalent 2002
Carbon Dioxide	49.58	54.15
Methane	5.16	5.18
Nitrous Oxide	2.12	2.13
Hydrofluorocarbons, Perfluorocarbons, and Sulfur Hexafluoride	0.30	1.13
Total	7.42	62.59
Net Emissions (Sources & Sinks[1])	57.07	62.48

1. Sinks are calculated as 0.35 and 0.11 Million Metric Ton Carbon Equivalent for 1990 and 2002, respectively, and are included in the Net Emissions (Sources and Sinks) values.

Air Toxics Release Inventory

Air releases of toxic chemicals are reported annually as required by the federal Emergency Planning and Community Right-to-Know Act of 1986. Under this law, facilities in designated industrial sectors are required to report their process-related releases to air and other media and wastes of specific toxic chemicals. Only facilities that exceed activity thresholds for manufacturing, processing, or otherwise use of chemicals on the registry are required to report. Reports must be sent to the state and the USEPA, which compiles the information into the Toxics Chemical Release Inventory and makes it available to the public.

Exhibit 68. Distribution of Michigan Greenhouse Gas Emissions by Economic Sector 2002



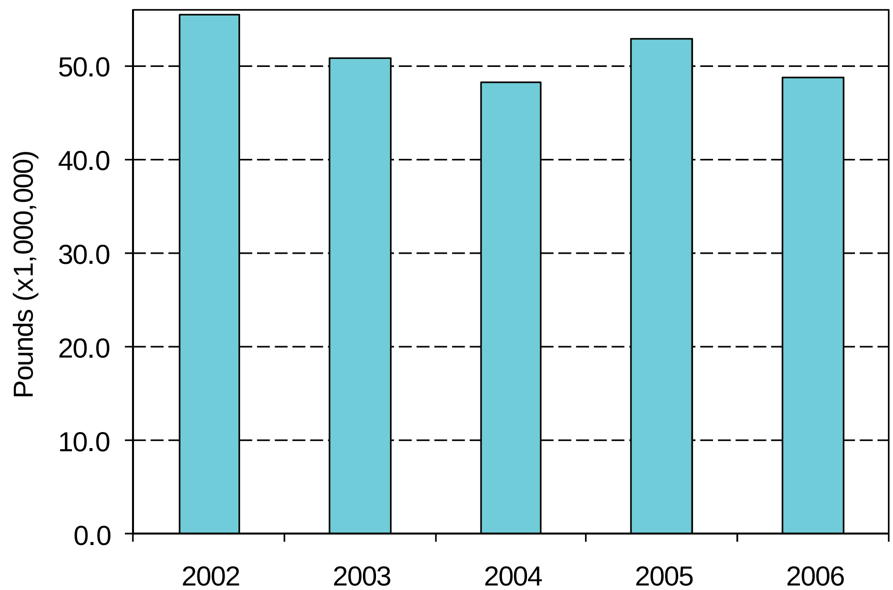
The Air Toxics Chemical Release Inventory information frequently is used to provide trends on particular media releases because of its availability and its longevity. For 2006, reported air releases in the state totaled 49 million pounds, which is a decrease of eight percent compared to 2005. Exhibit 69 shows an average of 50 million pounds of toxic air releases since the 2002 high of 56 million pounds.

The Toxics Chemical Release Inventory information presented in this Triennial Report is a statewide total of the data for specific reporting years and does not indicate upward or downward trends for individual pollutants or facilities. Caution also must be used with this measurement because the values are self-reported, may be estimates rather than actual measurements, and are not inclusive of all Michigan industries. Air toxics release data cannot be used to infer relative risks, absolute risks, or temporal trends for risk. Additional information on individual chemicals and facilities, including historical information, is available on the MDEQ Internet site (www.michigan.gov/deqsara).

Air Radiation Monitoring

The MDEQ is responsible for monitoring the

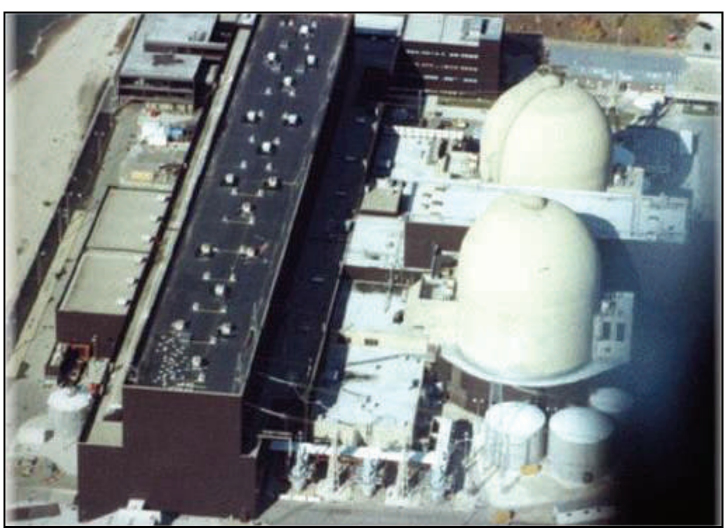
Exhibit 69. Air Toxics Release Inventory 2002 - 2006



environment may be obtained by contacting the MDEQ.

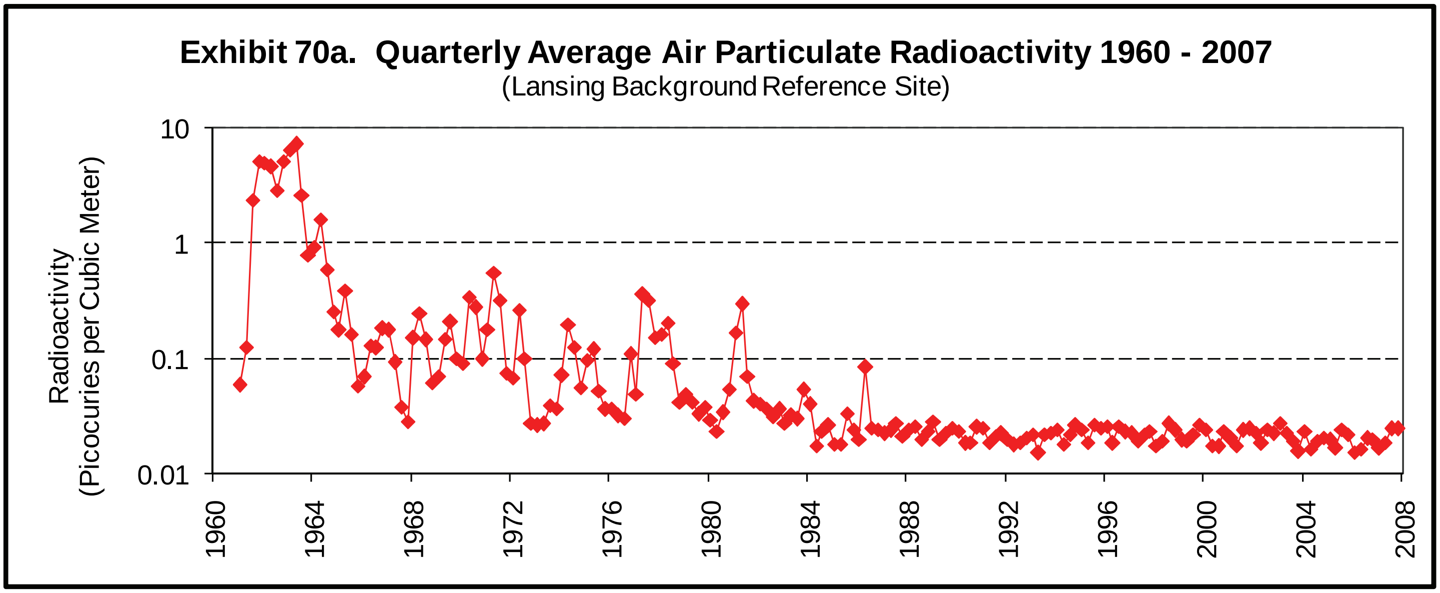
Since the inception of the program in the early 1980s, a general trend of decreasing levels of radioactive fallout from atmospheric testing of nuclear weapons has been observed, with the radioactivity associated with air particulates. A brief exception to this downward trend was observed in 1986 as a result of radioactive fallout from the Chernobyl Nuclear Power Plant accident in the former Soviet Union. Since 1986, the quarterly 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 quarterly

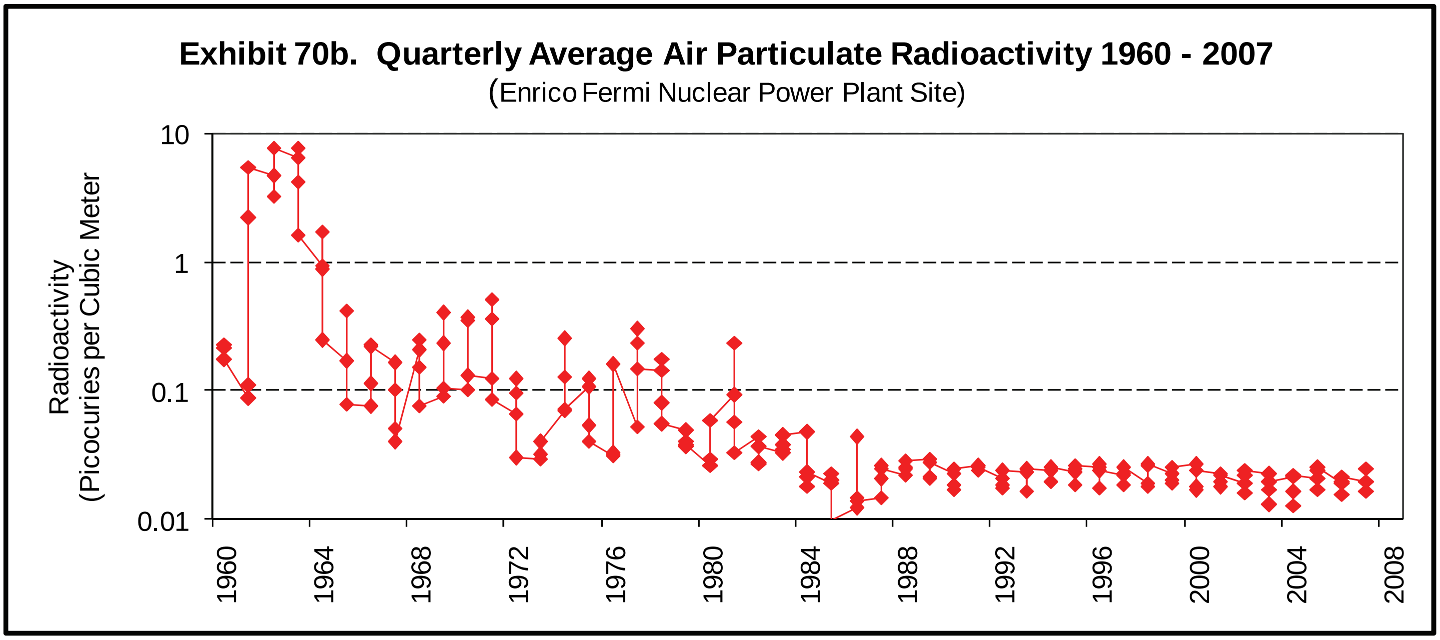
potential for environmental impact due to the operation of nuclear power plants in Michigan. Baseline radiological data for the four nuclear power plant sites in Michigan (Enrico Fermi, Big Rock Point, Palisades, and D.C. Cook) were established a minimum of one to three years prior to plant operation, 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 MDEQ include 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



average exceeding 1 picocurie per cubic meter or several consecutive quarters exceeding 0.1 picocurie per cubic meter. A total of five sites are monitored throughout the state. Exhibits 70a and 70b present measurements for the Lansing Background Reference and the Big Rock Nuclear Power Plant sites, respectively, and may be considered representative for the other three monitoring locations. Data for 2007 from the monitoring locations demonstrate that radioactivity levels have continued to remain at natural background levels.

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





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

Exhibits 71a and 71b 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 MDEQ has worked closely with municipalities to eliminate untreated sewage discharges from combined, sanitary, and storm water sewer systems. As a result, all cities have

Exhibit 71a. Annual Average Cesium-137 Radioactivity in MIlk 1963 - 2007
(Monroe Milk Station)

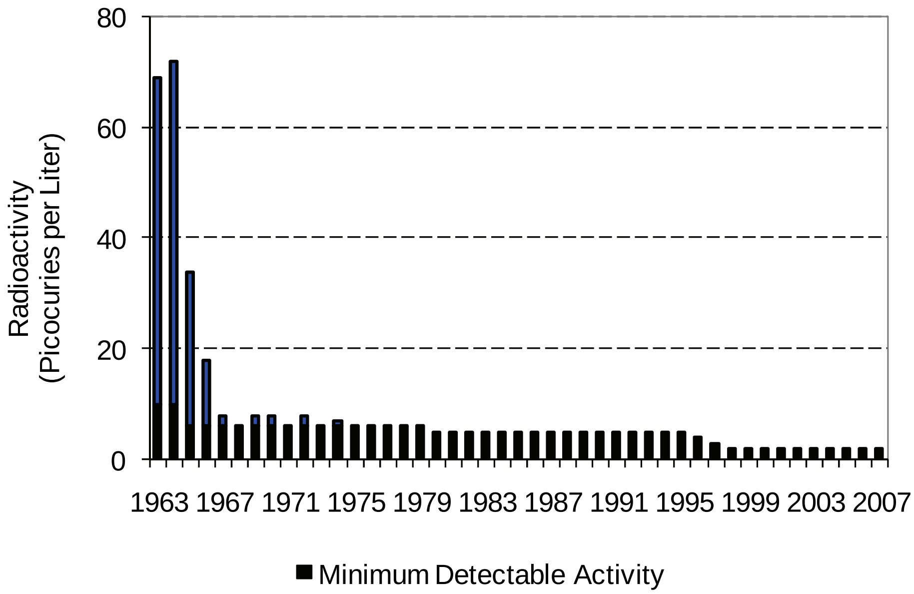
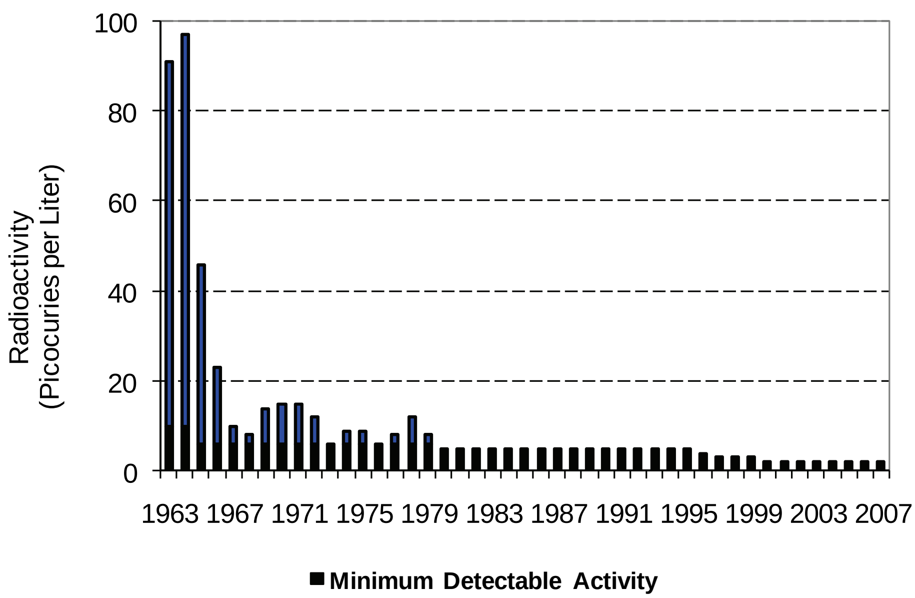


Exhibit 71b. Annual Average Cesium-137 Radioactivity in Milk 1963 - 2007
(Lansing Milk Station)



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 MDEQ 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.

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 MDEQ identified municipalities throughout the state that experienced discharges of sanitary sewage into waters of the state. In May 2000, the MDEQ 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 MDEQ adopted a statewide sanitary sewer overflow policy statement for implementation to accomplish these goals.

The MDEQ 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. The reporting of the discharge of untreated or partially treated sewage and the public posting are required by state statute.

Dischargers also are required to promptly notify local county health departments, potentially impacted neighboring municipalities, and the local media of such incidents. The MDEQ 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 MDEQ's Internet site (www.michigan.gov/deq).

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 October 31. In Michigan, a water body is considered suitable for total body contact recreation when the number of the indicator bacteria, *Escherichia coli* (*E. coli)*, per 100 milliliters of water is less than or equal to 130, as a 30-day average. The MDEQ 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 MDEQ awards federal grants to local health departments to support *E. coli* monitoring at public beaches located along the Great Lakes shoreline. A summary of grant awards and monitoring information for Great Lakes beaches is shown in Exhibit 72a. On average, 203 Great Lakes beaches are monitored each year in the state with these federal grants.

The MDEQ also awards state funds from the CMI-Clean Water Fund 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 Exhibit 72b. On average, 250 inland lake beaches are monitored each year in the state with the CMI-Clean Water Fund monies.

Beach monitoring data for *E. coli* are reported by local health departments to the MDEQ's Beach Monitoring Internet site (www.deq.state.mi.us/beach/). The percentage of daily samples exceeding daily standards averaged three percent over the past five years. Since 2003, an average of 21 percent of the monitored beaches reported at least one exceedance per year (Exhibit 72c).

Conservation Reserve Enhancement Program

The MDEQ has been working closely with the MDA and MDNR 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 three critical watersheds (Saginaw Bay, Macatawa, and River Raisin) 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 MDEQ has agreed to supply CMI-Clean Water Fund 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.

There are currently over 65,750 acres of conservation practices that are either under contract or pending in Michigan. With recently secured CMI-NPS funds, Michigan will reach 85,000 acres of CREP practices in the four watersheds. Over $7.5 million in CMI funds were awarded to acquire permanent conservation easements on over 4,000 acres of the CREP practices, with 3,405 acres currently under permanent conservation easements. The success of the CREP will be measured in reduced sediment, phosphorus, nitrogen, pesticide, and pathogen inputs to surface waters resulting in improved water quality in Michigan and by increased production of wildlife as indicated by waterfowl and ring-necked pheasant populations.

Exhibit 72a. Summary of Great Lakes Beach Monitoring 2004 - 2008

Year	Number of Grants Awarded	Total Award Amounts	Number of Counties that Monitored	Number of Beaches Monitored
2004	19	$ 244,873	33	204
2005	21	$ 278,157	36	197
2006	23	$ 212,766	37	207
2007	23	$ 212,766	38	205
2008	23	$ 245,719	*To be determined*	*To be determined*

Exhibit 72b. Summary of Inland Lake Beach Monitoring 2004 - 2008

Year	Number of Grants Awarded	Total Award Amounts	Number of Counties that Monitored	Number of Beaches Monitored
2004	9	$ 100,000	41	290
2005	11	$ 100,000	33	209
2006	10	$ 117,576	40	233
2007	13	$ 100,000	38	269
2008	13	$ 100,000	*To be determined*	*To be determined*

Exhibit 72c. Summary of *Escherichia coli* Beach Monitoring Program 2003 – 2007

Description	2003	2004	2005	2006	2007
Number of Counties with Beach Monitoring Programs	38	53	52	58	58
Number of Daily Mean *E. coli* Samples Samples Collected	4418	6701	4677	5609	5476
Number of Samples that Exceeded the Daily Standard	123	213	143	200	145
Percent of Samples that Exceeded the Daily Standard	2.8	3.2	3.1	3.6	2.6
Number of Beaches with *E. coli* Samples Collected	392	494	406	440	474
Number of Beaches with Samples that Exceeded the Daily Standard	86	123	82	99	77
Percent of Beaches with Samples that Exceeded the Daily Standard	21.9	24.9	20.2	22.5	16.2

Water Toxics Release Inventory

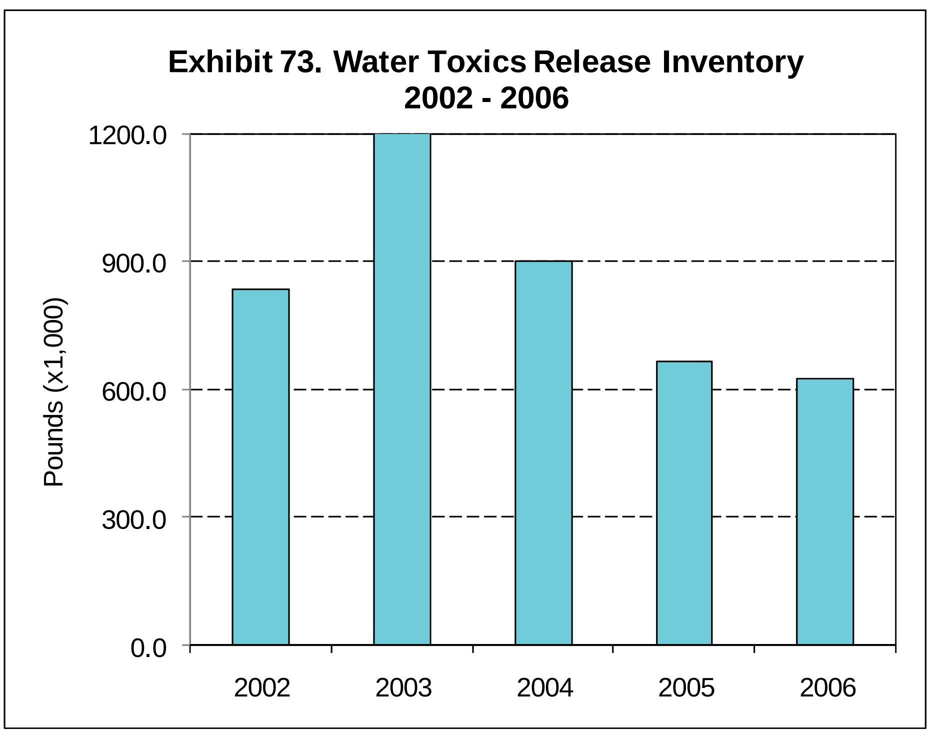
The federal Emergency Planning and Community

Right-to-Know Act of 1986 requires facilities in designated industrial sectors to annually report their process-related releases of specific toxic chemicals to surface waters and other media.

Only those facilities that exceed activity thresholds for manufacturing, processing, or otherwise use of chemicals on the registry are required to report. Reports must be sent to the state and the USEPA, which compiles the information into the Toxics Chemical Release Inventory and makes it available to the public.

The water Toxics Chemical Release Inventory information frequently is used to provide trends on particular media releases because of its availability and its longevity. For 2006, releases of toxic chemicals to surface waters in the state totaled 625,000 pounds, slightly less than the 2005 total of 665,000 pounds. Since 2003, the reported annual toxic chemical releases to surface waters have been decreasing. Exhibit 73 shows statewide water releases since 2002.

The Toxics Chemical Release Inventory information presented in this Triennial Report is a statewide total of the data for specific reporting years and does not indicate upward or downward trends for individual pollutants or facilities. Caution also must be used with this measurement because the values are self-reported and may be estimates rather than actual measurements, and are not inclusive of all Michigan industries. Water toxics release data cannot be used to infer relative risks, absolute risks, or temporal trends for risk. Additional information on individual chemicals and facilities, including historical information, is available on the Internet (www.michigan.gov/deqsara).

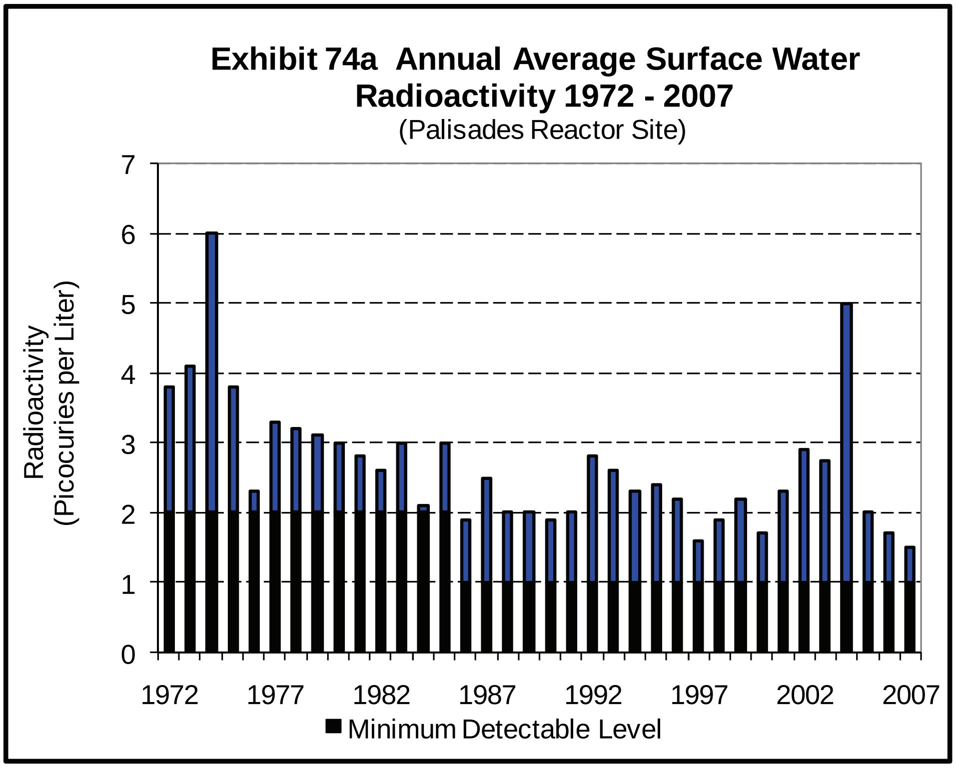


Surface Water Radiation

The MDEQ is responsible for monitoring the potential for environmental impact due to 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 1 to 6 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. Exhibits 74a and 74b present the annual radioactivity measurements for the monitoring stations near the Palisades and Fermi Nuclear Power Plants, respectively. These results are representative of what has been measured at the two other nuclear power plant locations in Michigan. Annual reports on the overall quality of the radiological environment may be obtained by contacting the MDEQ.

Drinking Water

Microbiological, chemical, and radiological contaminants can enter water supplies. These contaminants may be produced by human activity

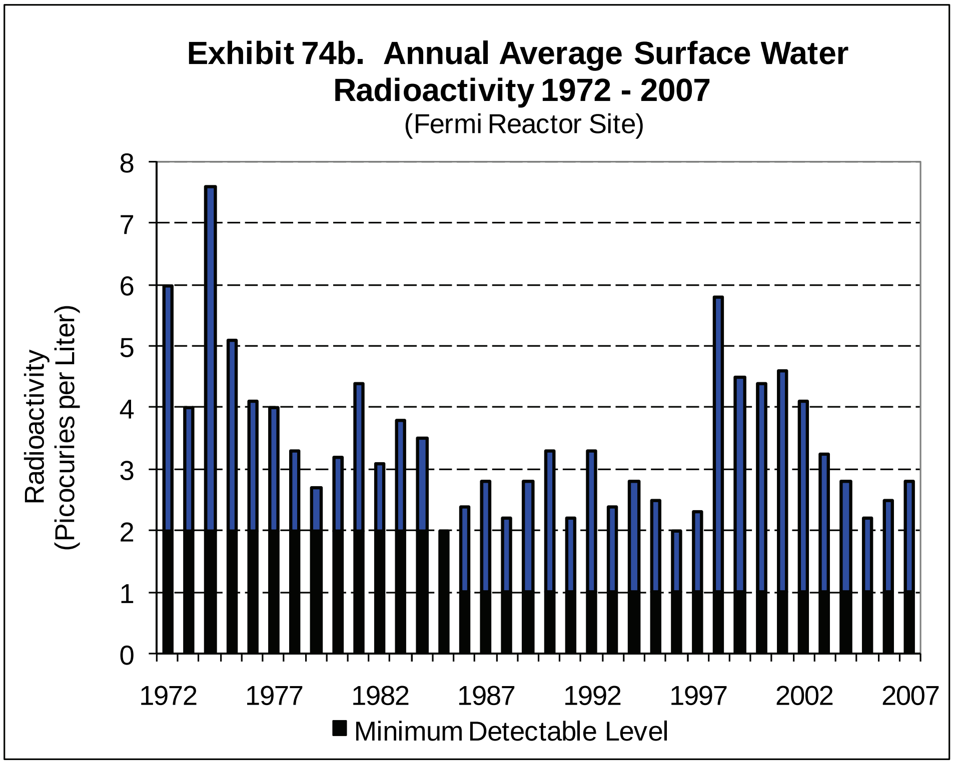


or occur naturally. For instance, chemicals can migrate from disposal sites or underground storage systems and contaminate sources of drinking water. Animal wastes, pesticides, and fertilizers may be carried to lakes and streams by rainfall runoff or snow melt. Nitrates from fertilizers also can be carried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

Effects of exposure to contaminants in drinking water will 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 2008, approximately 91 contaminants are regulated in drinking water under the federal Safe Drinking Water Act. Additional contaminants also are regulated by drinking water standards that require 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 from animal activity within a watershed, treatment methods such as disinfection and filtration become mandatory. These treatment techniques also remove a wide number of other microbiological contaminants that could impact public health.

The MDEQ oversees 11,700 *community* and *noncommunity* public water systems by emphasizing prevention and 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 persons, 60 days or more per year and include campgrounds, restaurants, schools, churches, child care centers, and business with their own water supply. Sanitary surveys of these public water systems are conducted routinely to assess the condition of water supply facilities, including source, treatment, distribution, and storage. The operation, maintenance, and security of the system also are evaluated. Conclusions and recommendations are then provided to the system operator and schedules to complete needed improvements are developed and implemented. The MDEQ also establishes monitoring requirements for drinking water systems based on vulnerability and source water assessments.

The MDEQ 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. The Michigan inventory consists of approximately 1,420 community water systems, including municipal systems, mobile home parks, nursing homes, public institutions, and housing developments, such as subdivisions and condominiums. Since the first quarter of 2000, the percentage of the population served by community



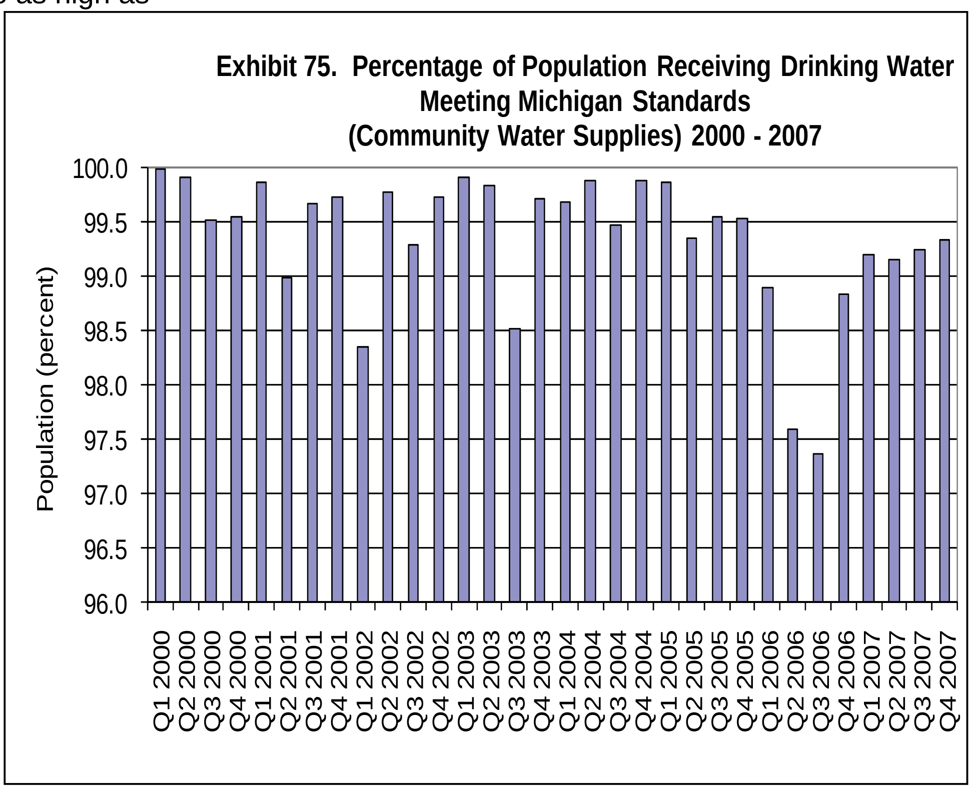
water systems meeting all health based standards ranged from a low of 97.3 percent to as high as 99.9 percent (Exhibit 75). Inspection, permitting, monitoring oversight, and enforcement of the 10,300 noncommunity water systems are delegated by the MDEQ to local health departments.

Each year the MDEQ spends millions of dollars providing safe drinking water to families or businesses with tainted private water wells when no viable, liable party is able to address the contamination. Since 1985, the MDEQ has spent about $100 million providing safe drinking water to Michigan residents whose well water is contaminated or threatened. The MDEQ actions at such sites have included:

1. Supplying affected homes/ businesses with bottled water;
2. Sampling, monitoring or replacing impacted drinking water wells;
3. Providing hook-ups to municipal water when multiple private wells are tainted; and
4. Helping to build new municipal water supply systems when no other 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 from a few days to multiple years to fully address the problems, and have impacted anywhere from one family to thousands of people.

Arsenic. One contaminant that has presented a significant challenge recently 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 is inorganic arsenic. The most common form of human exposure to arsenic is from ground water used for drinking or cooking.



The manner in which 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 January 2001, the USEPA promulgated a revised arsenic standard, reducing the maximum contaminant level for drinking water from 50 to 10 micrograms per liter. The effective date for this revised standard was January 2006. Michigan has a relatively high number of public systems impacted by this revised arsenic standard, ranking second among all states.

Based on compliance monitoring conducted in 2005, 108 community water systems exceeded this revised standard, with all but a couple 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 2008, 56 of these community systems have returned to compliance by replacing their source, consolidating with an adjacent system, or constructing treatment facilities. The vast majority of the remaining systems are still following a compliance schedule established in a consent order and periodically providing public notice to remind customers about the health threat. One hundred noncommunity water systems installed treatment to comply with the new arsenic standard and 70 small systems are participating in a alternative to treatment that allows the use of bottled water in accordance with an enforceable compliance agreement.

Exhibit 76 presents ground water arsenic levels from Michigan counties. More precise locations of the sample locations within each county may be found on the MDEQ's Internet site (www.deq.state.mi.us/documents/deq-wd-gws-ciu-as.htm). 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. Nitrate is 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 that are located in rivers and lakes that are subject to agricultural runoff and discharges of untreated sewage. Typical sources of nitrate contamination include:

1. Wastes from livestock operations;
2. Septic tank/drainfield effluent;
3. Crop and lawn fertilizers;
4. Municipal wastewater sludge application; and
5. 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 addressed immediately 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 milligrams per liter. Michigan has adopted these standards.

Private water supply owners 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, initially, 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.

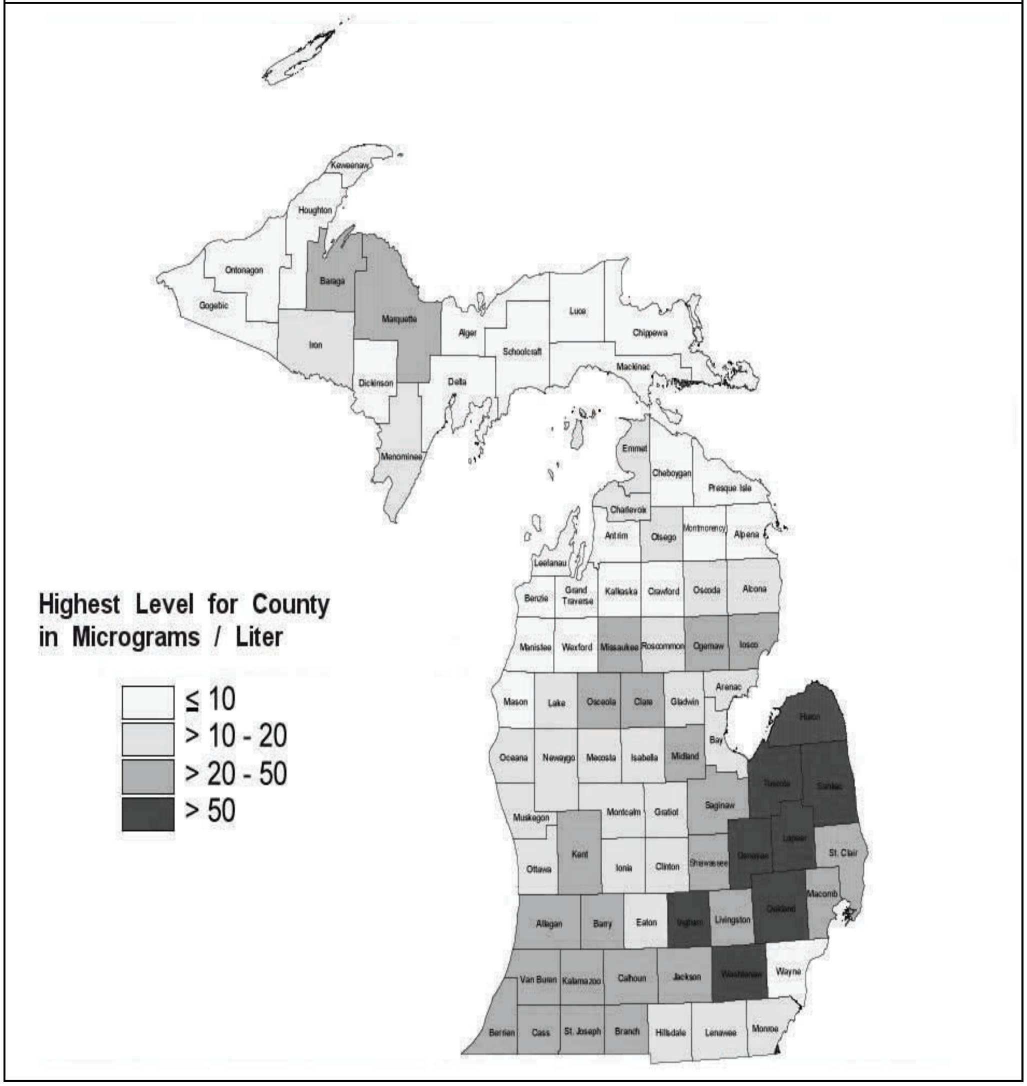
Exhibit 77 graphically presents averaged nitrate levels in ground water from Michigan counties. More precise locations of the sample locations within each county may be found on the Internet (www.deq.state.mi.us/documents/deq-wd-gws-ciu-no3.htm).

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

Twenty-one VOCs that can pose a physical and/or biological risk to drinking water resources are currently monitored by the MDEQ. Exhibit 78 presents the location of ground water 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 Internet (www.deq.state.mi.us/documents/deq-wd-gws-ciu-voc.htm).

In 2006, the MDEQ completed a two-year project to inventory and map ground water resources in Michigan. The MDEQ partnered with the USGS and MSU to produce maps that depict ground water yielding capabilities for glacial and bedrock aquifers, ground water dependant surface water features, users of large quantities of ground water, and other valuable ground water information. This mapping report, mandated and funded through legislation (2003 Public Act 148), was submitted to the state's Ground Water Conservation Advisory Council for its use in analyzing the need for water legislation. The council submitted its report to the Legislature in February 2006 . The generated maps are available on the Internet (www.gwmap.rsgis.msu.edu).

Exhibit 76. Arsenic Levels in Michigan Ground Water by County



Concern for Michigan's water resources has led to new legislation to regulate large quantity water users and assist in management of Michigan's vast water resources. The legislation, which became effective February 28, 2006, amended Parts 327 and 328 of the Natural Resources and Environmental Protection Act, as well as the Michigan Safe Drinking Water Act. The amendments:

1. Redefine the requirements for water use registration and water use reporting;

2. Identified environmental standards for the assessment of large quantity water withdrawals;
3. Established permit requirements for large quantity withdrawals from groundwater and surface water that are over two million gallons per day; and
4. Established new standards for the approval of bottled water operations.

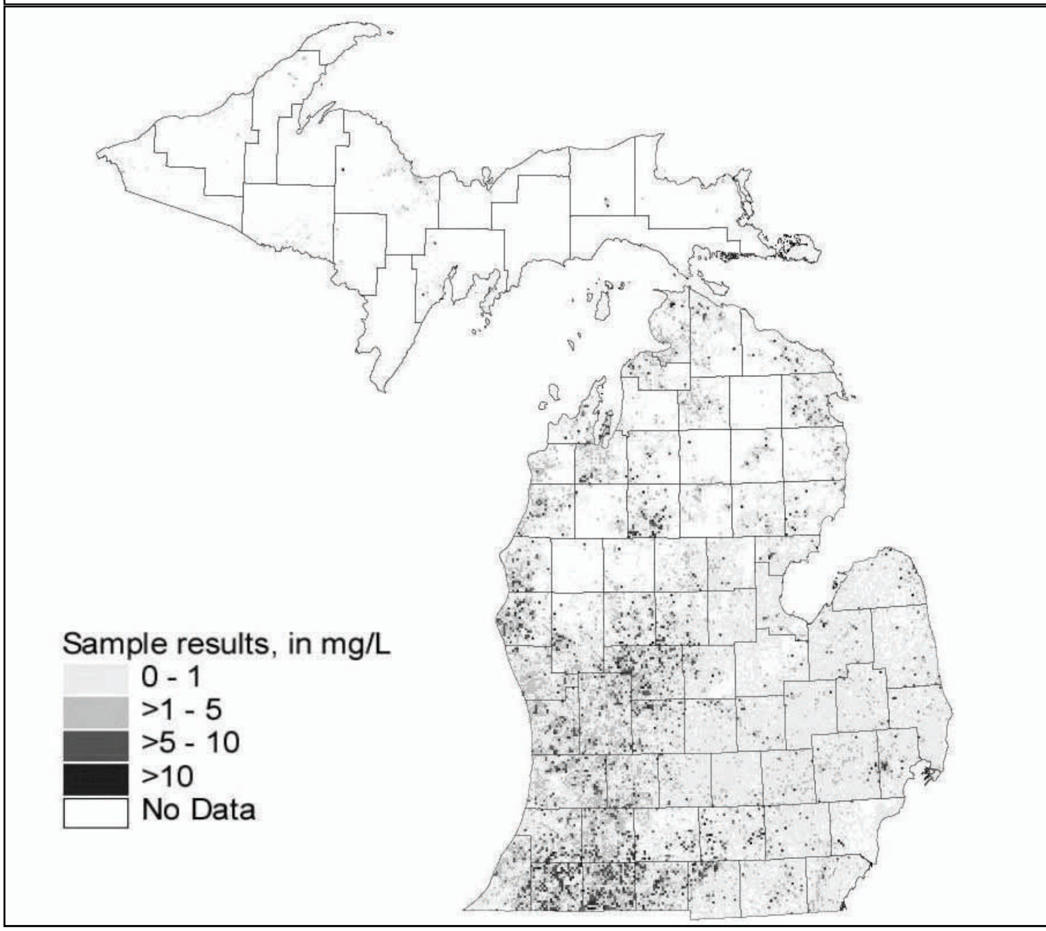
Water Diversions and Consumptive Use

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 five 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 December 13, 2005, the Great Lakes Governors and Premiers signed agreements that will 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 will be implemented in Ontario and Québec through Provincial laws, and in the States, through the Great Lakes-St. Lawrence River Basin Water Resources Compact (Compact).

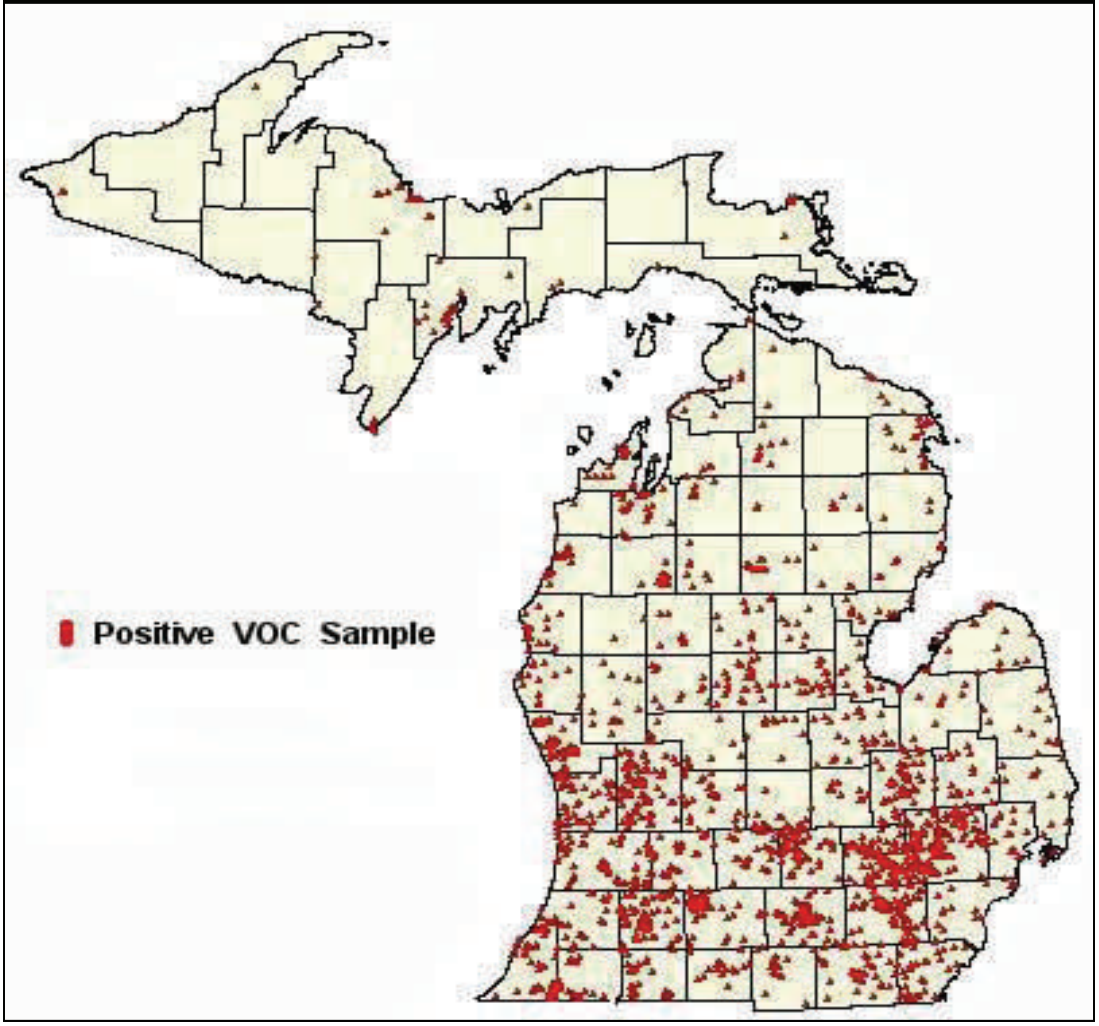
The Compact includes the following points:
1. Sustainable use and responsible management of Great Lakes Basin waters;
2. Banning (with some limited exceptions) of new diversions of water from the Great Lakes Basin;
3. Use of a consistent standard to review proposed uses of Great Lakes Basin water;
4. 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.

Exhibit 77. Averaged Nitrate Levels in Ground Water from Michigan Counties



On July 9, 2008, the Great Lakes States completed ratification of the Compact. In order to become law, it was necessary for the United States Congress to provide its consent. Federal consent legislation was introduced in both the United States House of Representatives and Senate. The Compact was approved by the US Senate in August and the US House of Representatives in late September. It then was sent to the President who signed the legislation into law.

Exhibit 78. Positive Volatile Organic Chemical Ground Water Sample Locations in Michigan

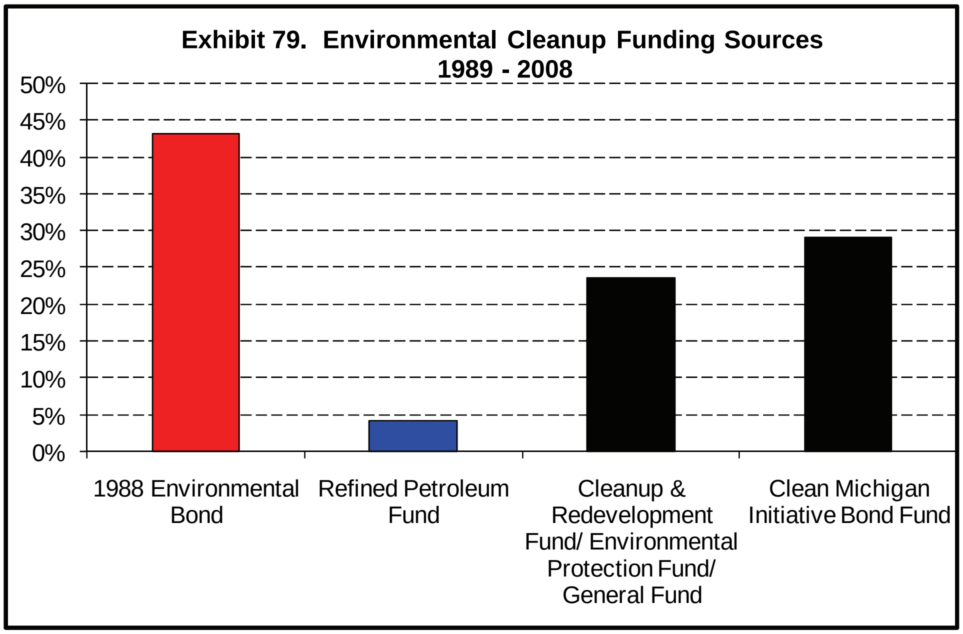


Land Quality

Environmental Cleanups

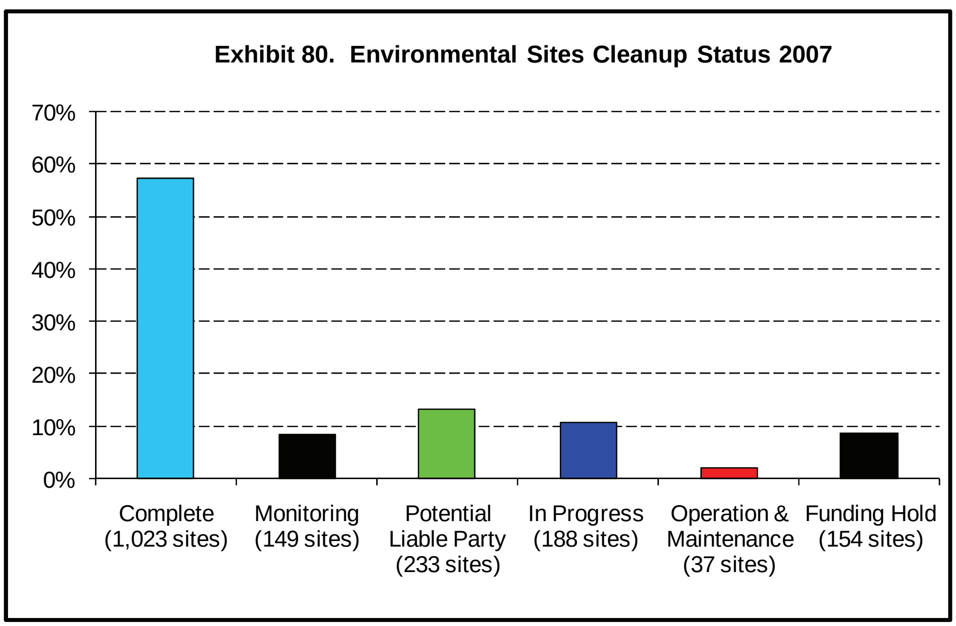
Remediation (cleanup) of environmentally contaminated land is accomplished through state-funded actions and through actions conducted by liable parties and property owners. The sources of public funds that have been used for cleanup since 1989 are shown in Exhibit 79. Prior to passage of the CMI in November 1998, the MDEQ cleanup program was funded primarily by an Environmental Bond approved in 1988. Most of the 1988 Environmental Bond money was directed at performing cleanups to protect public health and the environment. Under the 1998 CMI, the primary focus was and continues to be preparing contaminated sites for redevelopment. Monies from the Cleanup and Redevelopment Fund and the CMI Fund have supported the majority of the cleanups since 1998.

A total of $335 million has been earmarked from the CMI Fund for cleanup of environmentally contaminated sites, including leaking underground storage tank sites. To date, $144 million has been appropriated for work on 589 redevelopment related projects. The MDEQ's goal is to complete projects within 18 months after they are initiated. A portion of the $335 million is set aside to address serious health and environmental problems at contaminated sites that do not have redevelopment potential. A total of $97 million has been appropriated for action at 213 sites in this



category. Eight million dollars of the $335 million will be used for local units of government to address municipal landfills on the federal Superfund National Priorities List (NPL) and to clean up sites where a specific redevelopment proposal exists. Seventy-five million dollars will be used for Brownfield Redevelopment Grants to local units of government. The remaining $11 million of the $335 million will be used for administrative support costs. In addition to the $335 million, another $50 million from the CMI Fund was awarded for 62 projects through a competitive grant process for waterfront improvements to promote economic development. Part of the work that has been conducted in Michigan includes cleanups at federal Superfund sites on the NPL. Since Michigan began listing sites on the NPL, the use of 10 percent state-matching dollars secured approximately $260 million in federal monies for cleanups.

A total of 1,784 sites has been targeted for cleanup with public funds, beginning with the 1988 Environmental Bond program. At 233 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 presented in Exhibit 80.



Cleanup activities are complete at 1,023 sites. At 149 additional sites, monitoring is being conducted to assure that further state-funded actions are not required. The two categories combined represent 66 percent of the sites where work has been undertaken. Cleanup systems have been constructed and operation and maintenance activities are ongoing at 37 sites. Cleanup work is in progress at 188 additional sites. Due to funding restraints, 154 projects are on hold until additional funds are secured.

In 1995, Michigan's cleanup law was changed. One of the goals of the change was to promote redevelopment of contaminated property (referred to as *Brownfield sites*). Up until the time of the 1995 changes, any person who owned or operated contaminated property was responsible for cleaning up the contamination, regardless of whether they caused the problem. This was a 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. In an effort to reduce this problem and to put contaminated property back into productive use, liability for property owners was changed to a *causation standard*. Under the 1995 changes to the state cleanup law, the person who caused contamination, rather than the person who buys or owns the contaminated property, is responsible for conducting the cleanup. In addition to cleanups conducted by these liable parties, 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.

Another change established in the 1995 amendments to the state cleanup law was the creation of risk-based cleanup criteria that are linked to land use. 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. Site-specific cleanups allow the MDEQ and property owners to account for special circumstances at a site. The MDEQ has approved cleanup plans for 2,030 sites in land use categories other than residential. The 2005 Biennial Report noted that 164 sites met this criterion. That number, however, did not include leaking underground storage tank sites, whereas the 2,030 number represents all sites. Cleanups meeting residential criteria have been completed at many more sites, including sites where spill response activities undertaken by liable parties have eliminated unacceptable risks to public health and the environment. Property owners and other liable parties have conducted cleanup work at additional sites for which the MDEQ does not maintain statistics.

In the 2001, 2003, and 2005 Biennial Reports, information on the amount of private investment and the number of jobs created at brownfield properties was based on surveys conducted by the MDEQ at 33 communities between 1996 and 2002. The 2005 Biennial Report mentioned that additional surveys would be performed and that the results would be updated in the next version. The MDEQ conducted a survey of Brownfield Redevelopment Authorities in 2007, but the survey focused on finding out what redevelopment tools communities use rather than on acquiring information regarding amounts of private investments and jobs created. Beginning with this Triennial Report, information regarding amounts of private investment (Exhibit 81) and jobs created (Exhibit 82) at brownfield sites will be based on numbers gained through the MDEQ review of work plans submitted by local Brownfield Redevelopment Authorities in accordance with the Brownfield Redevelopment Financing Act, 1996 Public Act 381, as amended.

Michigan currently has a total of 140 municipal solid waste, industrial waste, and construction and demolition waste landfills. 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. Seventy-six of these landfills have been found to be contaminating ground water. Of these, 51 landfills (68%) have been cleaned up or have a corrective action ongoing. Corrective action sites fall into one

Exhibit 81. Investment in Brownfield Properties 1998 - 2007

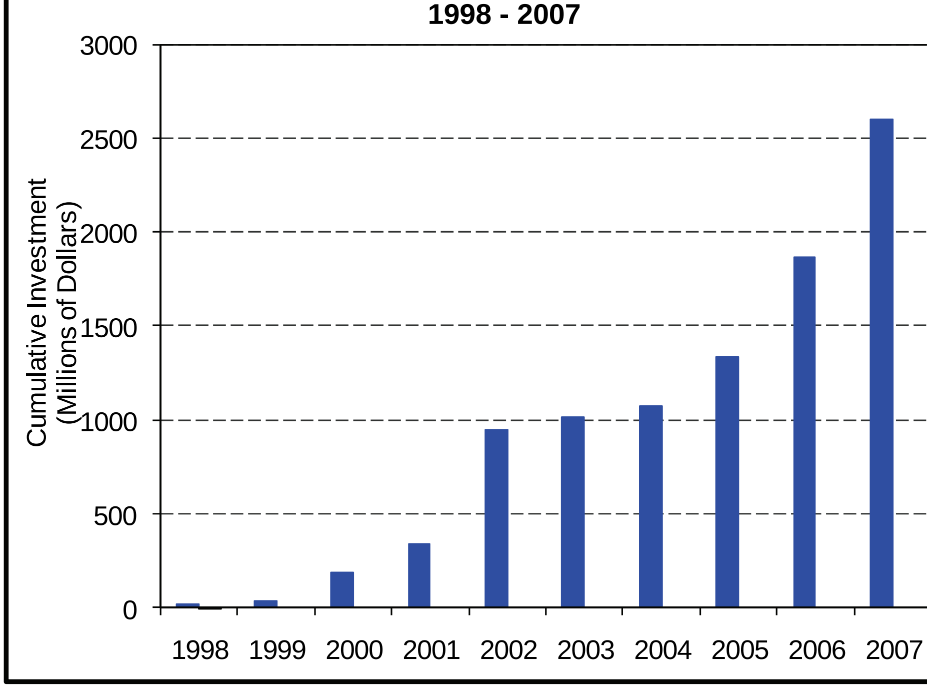
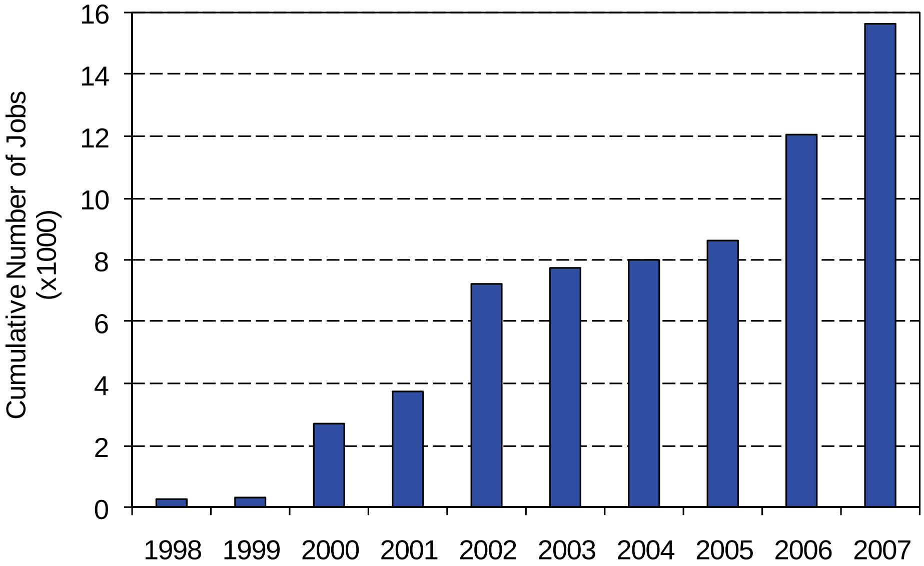


Exhibit 82. Number of Jobs Created at Brownfield Properties 1998 - 2007



of two categories: either the MDEQ is using enforcement authorities to force the landfill owner/operator to address ground water contamination or the MDEQ is using public funds to clean up the site because a liable party is no longer available. This leaves 25 sites (33%) at which no actions to correct ground water contamination are underway. All of the latter sites are closed and no longer operating. Exhibit 83 shows the cumulative number of ground water contaminated landfills returned to compliance since 1990.

State-Owned Sites Cleanups

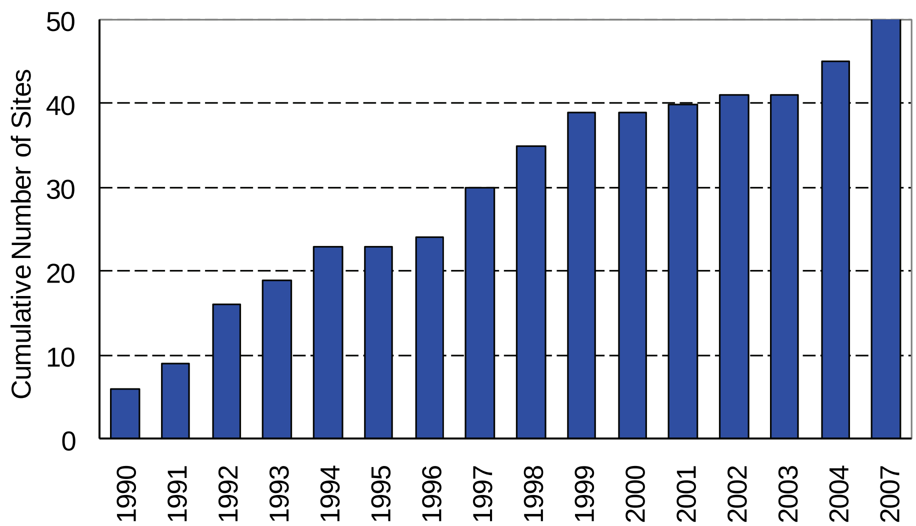
In addition to ensuring the cleanup of contaminated sites of others, the state is responsible for the cleanup of sites that it has contaminated as a result of its own operations. The state has identified a total of 170 such sites where it is responsible, as either the owner or operator, for environmental remediation. Of the 170 sites, 128 are underground or above ground storage tanks; 18 are old landfills, dumps, or storage pits; 7 are shooting ranges; 10 are surface spills; 2 involve either asbestos removal or radioactive license decommissioning; and 5 have multiple sources of contamination.

In July 1996, a States Sites Cleanup Fund was established, into which a total of $30,965,100 was made available to help the state fulfill its own environmental cleanup responsibilities. Currently, 127 of the 170 sites have been funded. Of the 170 funded sites, 92 have been cleaned up and closed; 19 have been cleaned up and are in the process of being closed; 26 are into long-term treatment to reduce the level of contamination; 12 are being investigated or are in the process of having a treatment design developed; and 21 sites are partially cleaned, but currently inactive due to lack of available funding (Exhibit 84).

Hazardous Waste Treatment, Storage, and Disposal Sites

Two hundred thirty-two hazardous waste treatment, storage, and disposal sites in Michigan

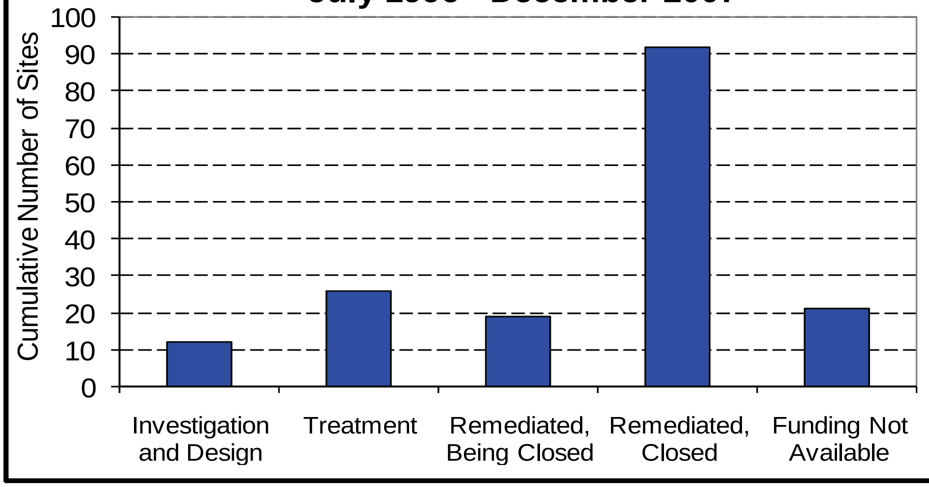
Exhibit 83. Ground Water Contaminated Solid Waste Landfills Returned to Compliance 1990 - 2007



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 MDEQ 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, 66 have been ranked as *high priority* (i.e., sites having the worst contamination or risks). The environmental contamination problems at the remaining 166 sites are not as significant as those at the 66 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 such that there remains no unacceptable human health risk (51 sites), eliminating or controlling ground water contamination (48 sites), or completing the cleanup such that no further corrective action is required (10 sites) (Exhibit 85).

Exhibit 84. Status of Funded Cleanups at State-Owned/Operated Sites July 1996 - December 2007



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 and 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 renamed

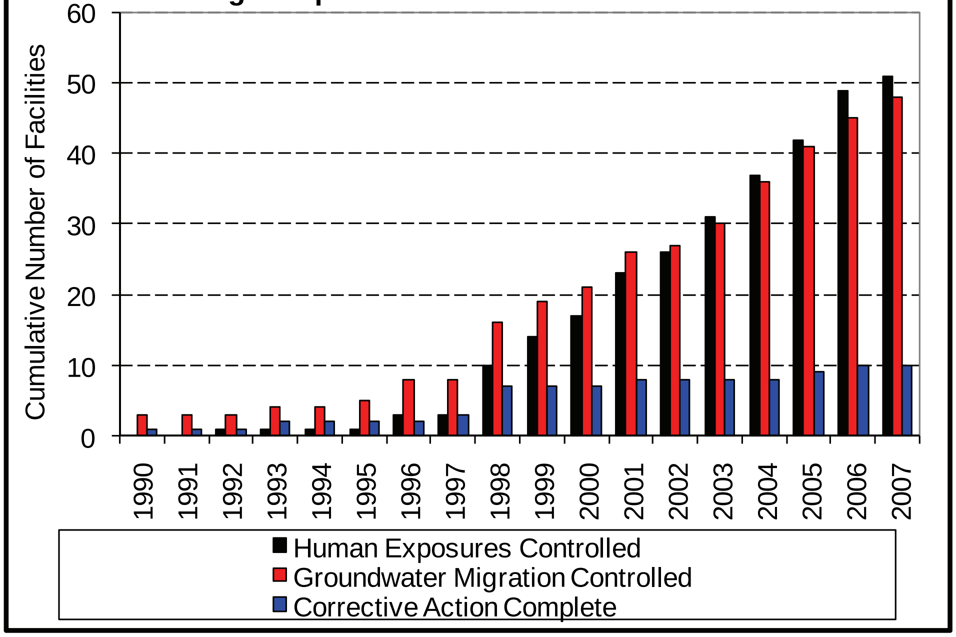


Exhibit 85. Corrective Actions Taken at High Priority Hazardous Waste Management Treatment Storage Disposal Facilities 1990 - 2007

the Refined Petroleum Fund. The 2004 legislation entrusted an advisory council to develop

recommendations on the final form of a Refined Petroleum Cleanup Program; however, the advisory council legislation expired before final program recommendations were made.

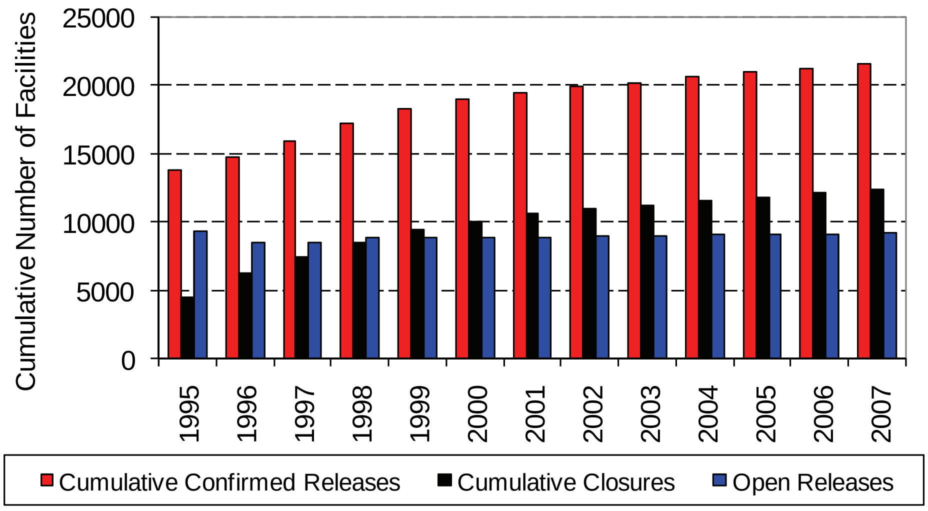
The cumulative closure of releases has increased from 4,530 in 1995 to 12,380 by the end of 2007 (Exhibit 86). However, since 1997 the number of unaddressed releases from underground storage tanks has been slowly increasing from about 9,000 releases to almost 9,200 releases, due to new releases being discovered at a faster rate than old ones are being cleaned up. In fact, more than 60 percent of confirmed releases are over 10 years old. It is estimated that about half of all open releases will require the use of state cleanup funds due to non-viable and recalcitrant owners/ operators. The program is currently at a crossroads due to the recognition that current funding levels are not adequate to address the risks to the public and environment posed by petroleum releases. Program funding is not sufficient to provide adequate human resources to assist owners and operators by providing information, training, and compliance assistance, or to adequately deter noncompliance. The cost estimated to address only the orphan sites is estimated to exceed $1.5 billion. By contrast, since publication of the 2005 Biennial Report, only $14 million has been made available to the Leaking Underground Storage Tank Program (from 2005 through 2007), even though the Refined Petroleum Fee collected $167 million in that same time period. The program is currently undergoing internal re-prioritization of tasks as well as considering alternative deployment options for shrinking staff resources to adjust to decreasing funding levels.

State and federal rules require that owners/ operators of underground storage tank systems comply with new 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

Exhibit 86. Number of Leaking Underground Storage Tank Releases 1995 - 2007



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 ground water 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 10 years, the MDEQ has required monitoring for MTBE at underground storage tank release sites. At sites where levels exceed safe concentrations, the MDEQ has taken action to address the contamination. Michigan instituted a ban on MTBE in June 2003. The acceptable level of MTBE in ground water at sites of contamination is 40 parts per billion (ppb), based on aesthetic criteria of taste and odor. The aesthetic criterion is significantly lower than the health-based criterion of 240 ppb. Consequently, an individual would taste or smell the MTBE before it posed a health risk.

Abandoned Oil and Gas Wells

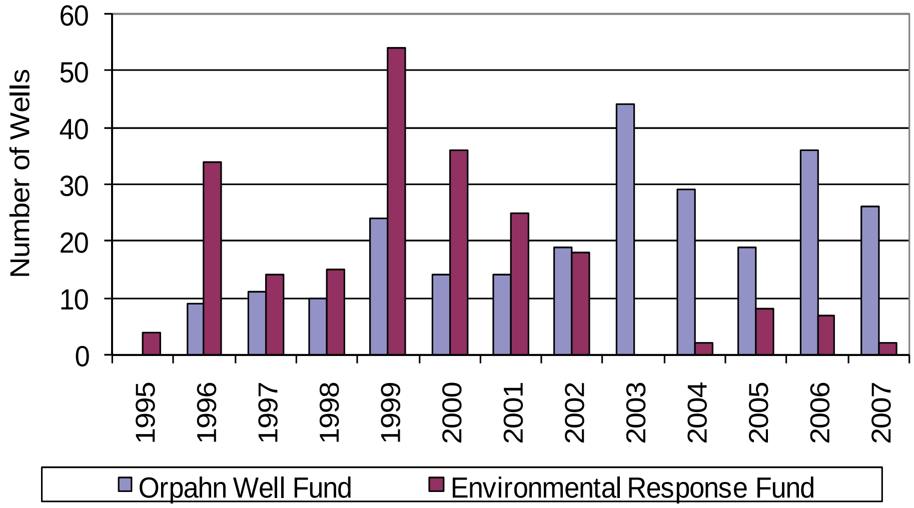
Since commercial oil and gas production began in Michigan in 1925, over 56,000 oil and gas wells have been drilled. Approximately 18,000 of these wells are in use today producing 25 percent of the natural gas and four percent of the oil used within the state. One thousand five hundred and seventy new wells were drilled during 2005 through 2007.

The MDEQ regulates oil and gas 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 2005 through 2007, the MDEQ issued 117 rulings increasing the size of the tract assigned to a well. This allows fewer wells to drain an oil and gas reservoir and provides more flexibility for locating a well to protect the environment. The MDEQ also issued eight orders establishing secondary recovery projects, where gas or fluids are injected into a partially depleted oil or gas reservoir, to increase the ultimate production from existing wells. Three of those orders provided for injection of carbon dioxide, a beneficial use of this greenhouse gas. In addition, there were eight orders issued that increased the size of prescribed drilling units.

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 MDEQ 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 MDEQ may plug the

Exhibit 87. Oil and Gas Wells Plugged 1995 - 2007



legislation has been introduced that could drastically reduce the amount of Canadian waste entering into Michigan.

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. The MDEQ has plugged 474 abandoned wells since 1995 (Exhibit 87).

Solid Waste Imports

During the period 1995 - 2007, solid waste imports have ranged between 12.2 and 30.7 percent of the total amount of solid waste disposed of into Michigan landfills. During Fiscal Year 2004, the bulk of these imports, approximately 64 percent, came from Canada. The remaining out-of-state wastes come into Michigan from such nearby states as Indiana, Illinois, Ohio, and Wisconsin, as well as some more distant states such as New Jersey and New York.

Solid waste imports decreased slightly in 2007 (Exhibit 88), but still made up almost 30 percent of all waste disposed of in Michigan (The overall amount of waste disposed in Michigan landfills from all sources also decreased). Michigan still continues to be one of the largest importers of waste due to the relatively close proximity of Michigan landfills to other states and Canada, and the continuing inability of the state, due to federal interstate commerce rules, to restrict the import of waste from outside the state. Federal legislation has been introduced that could drastically reduce the amount of Canadian waste entering into Michigan.

Hazardous Waste Imports and Exports

During the period from 1992 to 1999, the importation of hazardous waste to Michigan for disposal rose from 301,000 tons per year to 630,000 tons per year. Since then, it has declined to approximately 372,000 tons per year in 2007 (Exhibit 89). A portion of the observed reduction in waste importation between 2001 and 2002 is due in part to MDEQ's improved data collection procedures, which filters out extraneous data on liquid industrial waste and PCB waste. During the last five years, the quantity of hazardous waste exported by Michigan has declined from approximately 253,000 tons per year in 2002 to approximately 168,000 tons per year in 2007 (Exhibit 90).

Comparing the import amounts to the export amounts, it can be seen that since 2002, the amount of hazardous waste imported has increased (approximately 318,000 tons per year in 2002 to approximately 372,000 tons per year in 2007), while the amount of waste exported has declined (approximately 253,000 tons per year in

Exhibit 88. Annual Solid Waste Imports to Michigan 1995 - 2007

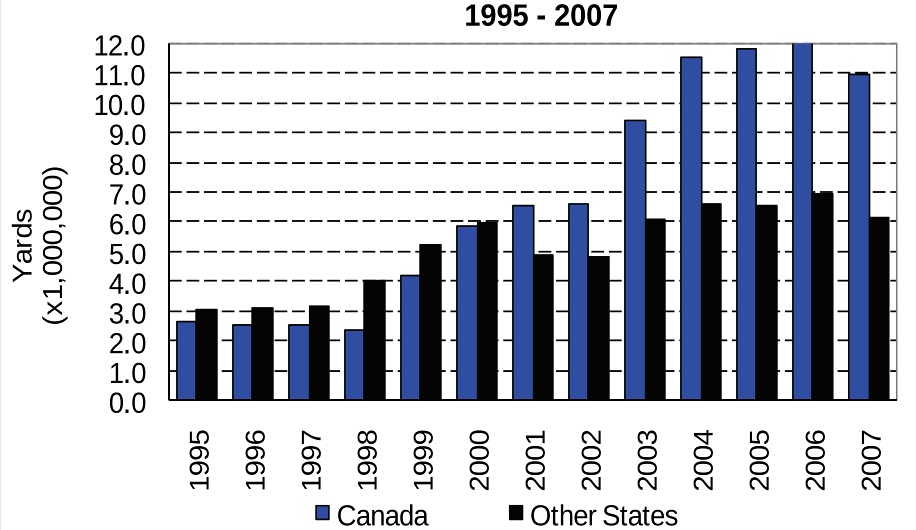
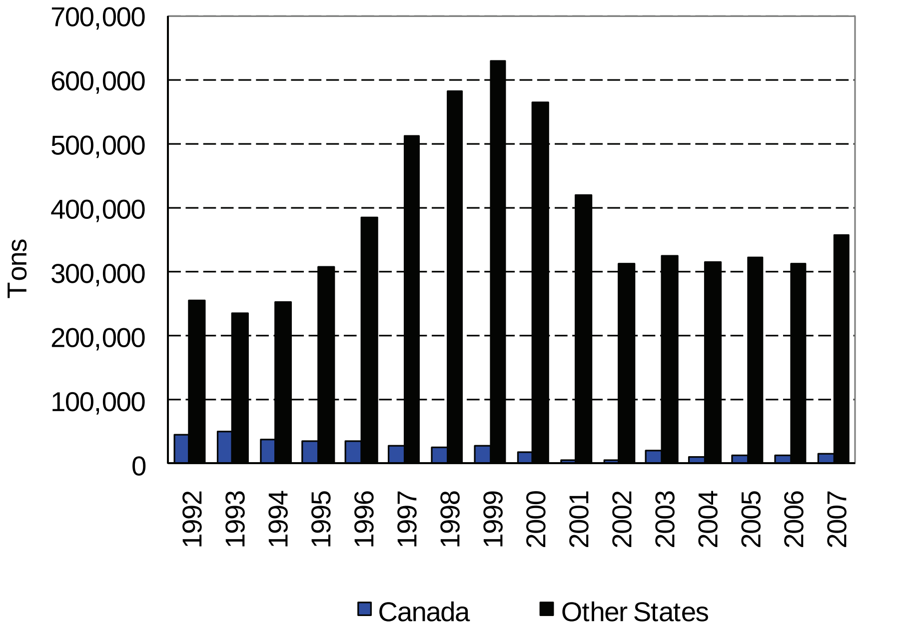


Exhibit 89. Annual Hazardous Waste Imports to Michigan 1992 - 2007



2002 to approximately 168,000 tons per year in 2007). In 2007, Michigan remained a net importer of hazardous waste, by approximately 204,000 tons per year.

Scrap Tires

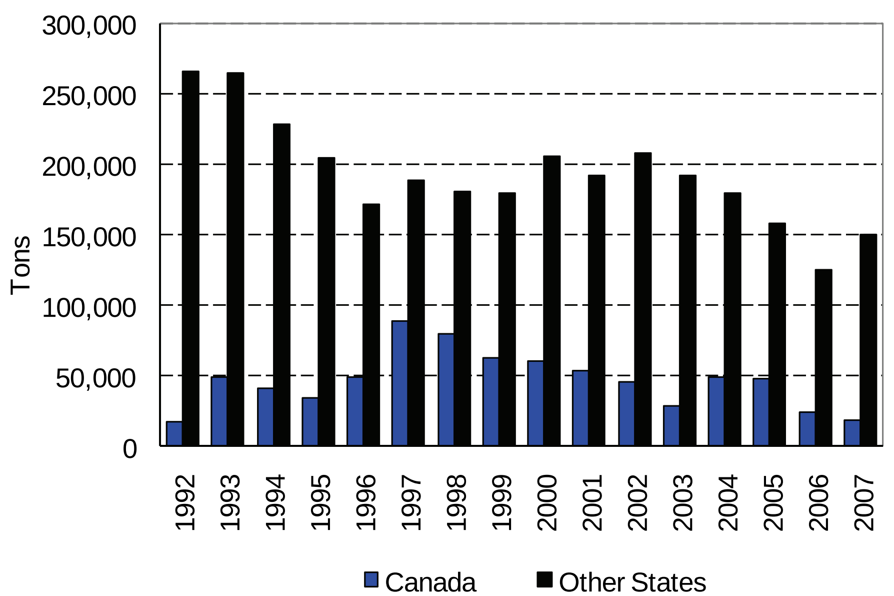
Over 290 million scrap tires are generated each year in the United States. Michigan contributes ten million scrap tires annually to that waste stream. In the past, millions of these scrap tires were abandoned or illegally stockpiled each year on vacant lands and inner-city back alleys. The illegal accumulations 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. 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 MDEQ

discovers additional collection sites that are regulated by law 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. Consequently, the documented number of scrap tires stockpiled in identified noncompliant sites has increased since 1991. The number of tires reported as being removed also may change over time due to improved tracking and data quality methods.

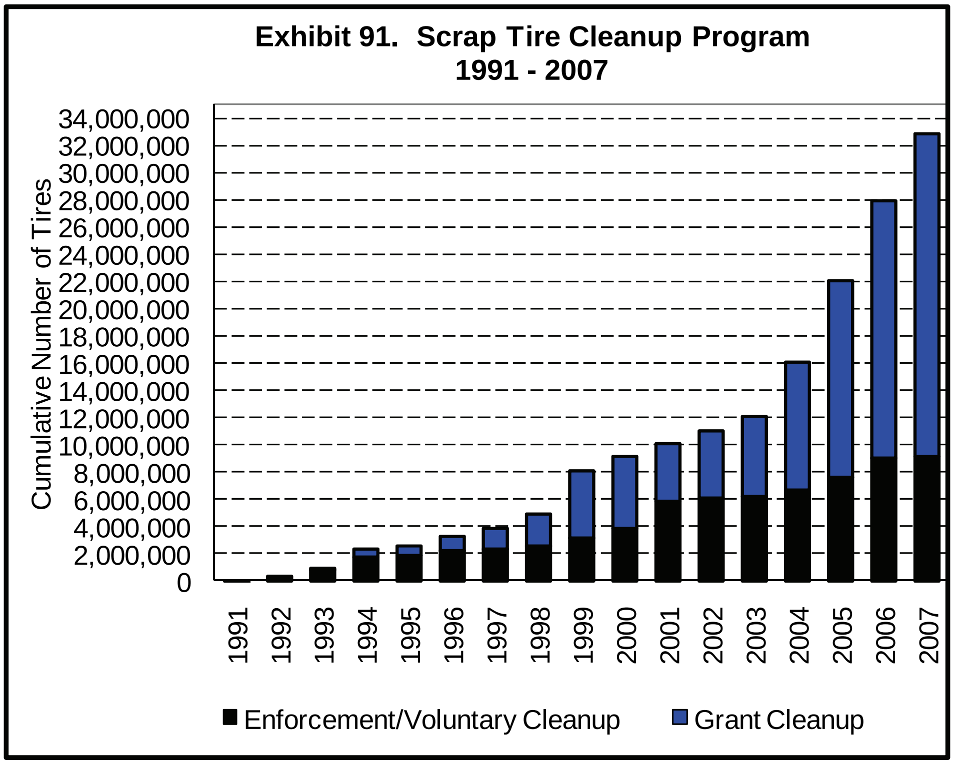
State law requires the MDEQ to help ensure that all abandoned scrap tires accumulated at

Exhibit 90. Annual Hazardous Waste Exports from Michigan 1992 - 2007



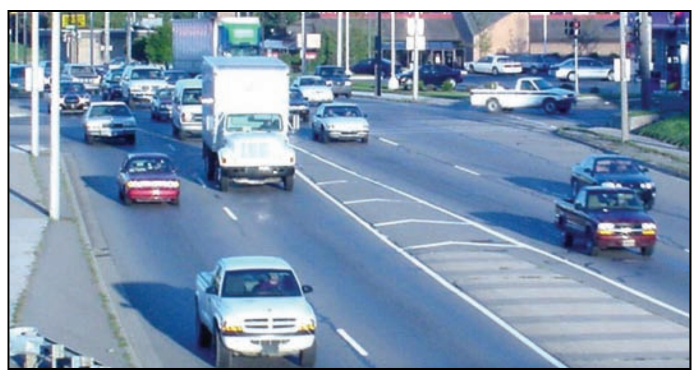
collection sites prior to January 1, 1991 are cleaned up or collected by September 30, 2009. Additionally, the USEPA established a group of individuals representing various stakeholders to formulate a strategy for addressing scrap tires. The group established a recommended goal for mitigation of 55 percent of the known stockpiled scrap tires in the United States by 2008.

Whole motor vehicle tires have been prohibited from disposal in Michigan landfills since March 2004. While portions of tires (e.g., tire shreds) can still 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.



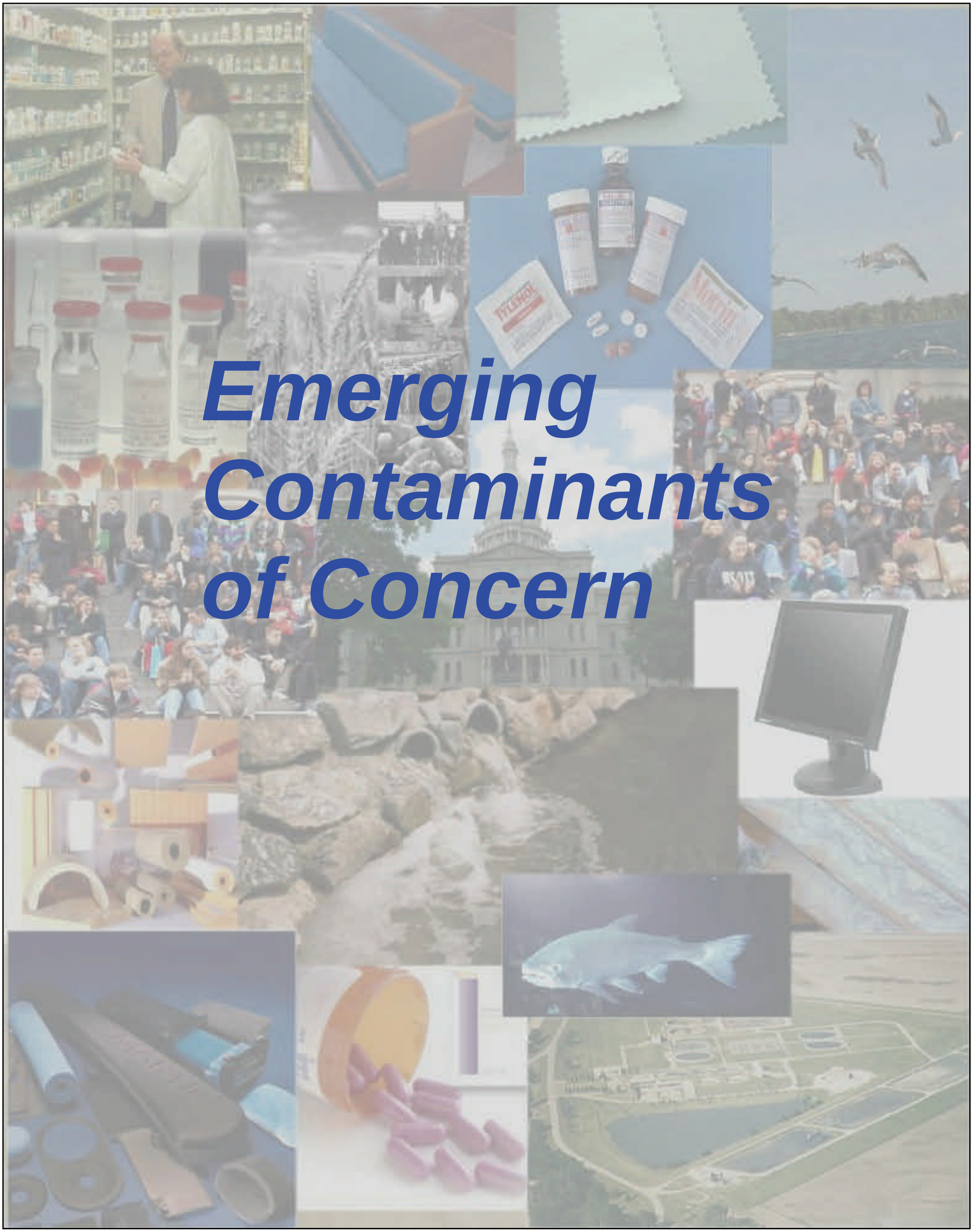
Much of the reduction in illegal stockpiles is due to Scrap Tire Cleanup Grants. Since the Legislature first appropriated funding in 1993, more than $22.6 million in public funds have cleaned up approximately 23.8 million passenger tire equivalents (PTEs) from the Michigan landscape. Approximately nine million additional PTEs have been cleaned up through compliance and enforcement efforts. 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 91 shows the cumulative totals of tires removed by the MDEQ grant program and those removed voluntarily or through enforcement actions. The current estimate of scrap tires remaining in illegal stockpiles around the state is approximately 7.5 million, just over 2 million pre-1991 scrap tires plus over 5.4 million post-1991 tires at collection sites posing an imminent threat to public health, safety, welfare, or the environment.

The Scrap Tire Program is funded by a $1.50 tire disposal surcharge on each motor vehicle certificate of title that is collected by the state



pursuant to Section 806 of the Michigan Vehicle Code, 1949 PA 300, as amended, and deposited into the Scrap Tire Regulatory Fund. These fees provide money for cleanup, market development, and end-user grants and administration of the program. Amendments to the Motor Vehicle Code in December 2006 extended the sunset for the program funding to December 31, 2012.

Emerging Contaminants of Concern



Emerging Contaminants of Concern

Introduction

The USEPA defines an emerging contaminant as *a chemical or material that is characterized by a perceived, potential, or real threat to human health or the environment or a lack of published health standards*. A contaminant also may be "emerging" because a new source or a new pathway to humans has been discovered or a new detection method or treatment technology has been developed.

Fourteen contaminants are described in this section of the report (Exhibit 92). The first six contaminants (Polybrominated diphenyl ethers, Pharmaceuticals and Personal Care Products, Perfluorooctane sulfonate, Polychlorinated naphthalenes, Tetrahydrofurans, and Alkylphenol ethoxylates) were previously identified as emerging contaminants of concern in the 2005 Biennial Report. The next five contaminants (1,2,3-Trichloropropane, N-Nitrosodimethylamine, Tungsten, Perchlorate, and 1,4-Dioxane) were recently identified by the USEPA as emerging contaminants of concern in 2008. The remaining three emerging contaminants of concern (Manganese, Nanomaterials, and Ethylenediaminetetraacetic acid) are discussed for the first time in this Triennial Report.

Exhibit 92. Identified Emerging Contaminants of Concern

1. Polybrominated diphenyl ethers
2. Pharmaceuticals and Personal Care Products
3. Perfluorooctane sulfonate
4. Polychlorinated naphthalenes
5. Tetrahydrofurans
6. Alkylphenol ethoxylates
7. 1,2,3-Trichloropropane
8. N-Nitrosodimethylamine
9. Tungsten
10. Perchlorate
11. 1,4-Dioxane
12. Manganese
13. Nanomaterials
14. Ethylenediaminetetraacetic acid

Identified Contaminants

Polybrominated Diphenyl Ethers

Polybrominated diphenyl ethers (PBDEs) are a family of chemicals used as flame-retardants. PBDEs are added to plastics and textile coatings and are found in a variety of consumer products such as computer monitors, televisions, textiles, and cushion and upholstery foams. Commercial production of PBDEs began in the 1970s. Three commercial PBDE mixtures have been produced: decabromodiphenyl ether (Deca-BDE), octabromodiphenyl ether (Octa-BDE), and pentabromodiphenyl ether (Penta-BDE). While Deca-BDE has accounted for more than 80 percent of the PBDE production, Penta-BDE (Congeners 47, 99, and 100) and Octa-BDE (Congeners 153, 154, and 183) appear to be the two formulations of greatest concern to human health and the environment.

PBDEs are persistent and bioaccumulate in the environment. They do not dissolve easily in water and, therefore, are not found at high levels in water. PBDEs adsorb strongly to particles and can remain in sediments and soils for many years because they do not readily break down. PBDEs have been detected in air, sediments, house dust, food, animals, and humans. They have been found in aquatic and terrestrial biota around the world with levels in North American animals being greater than European animals. PBDEs are

present in herring gulls (and their eggs), fish and sediments in Michigan.

In humans, PBDEs usually are found in blood, breast milk, and body fat. Levels in people from the United States have been increasing and are higher than in people living in other parts of the world. People are likely to receive most of their exposure to PBDEs from food and through the inhalation of contaminated particles including indoor dust. PBDE-contaminated dust in indoor air is generated from computers, televisions, mattresses, and furniture.

When laboratory animals are exposed to PBDEs, adverse impacts to the liver, neurodevelopmental effects in developing animals, and reductions in thyroid hormones have been reported. The lower brominated congeners and mixtures are more toxic than the higher brominated compounds.

A background paper on PBDEs was prepared in 2004 by the MDEQ. In 2005, legislation was passed in Michigan that placed restrictions on Penta-BDE and Octa-BDE due to their persistence, bioaccumulation, and toxicity. The legislation prohibited the manufacture, processing, and distribution of products containing more than one tenth of one percent of Penta-BDE or Octa-BDE beginning June 1, 2006. The legislation did not apply to original equipment manufacturer replacement service parts or the processing of recyclables containing Penta-BDE or Octa-BDE.

The sole United States manufacturer of Penta-BDE and Octa-BDE has ceased production of these two substances.

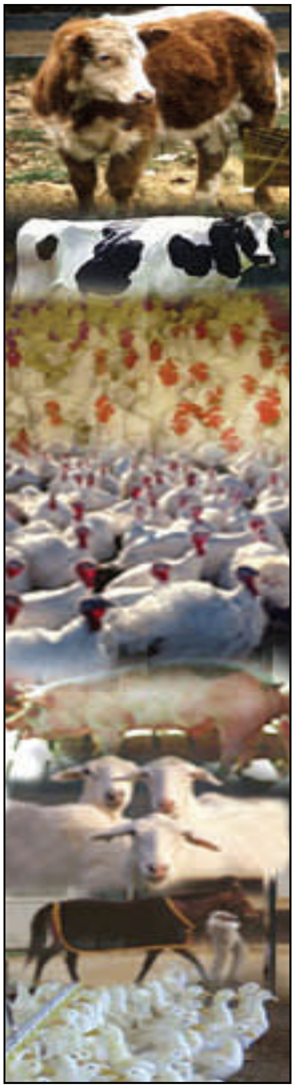
At the time of the Penta-BDE and Octa-BDE ban, data were insufficient to make a similar recommendation for Deca-BDE. In 2007, the MDEQ report was updated with attention focused on Deca-BDE. The report entitled, *Polybrominated Diphenyl Ethers: A Scientific Review with Risk Characterization and Recommendations*, was released in August 2008.

Pharmaceuticals and Personal Care Products

PPCPs comprise a diverse collection of thousands of chemical substances, including prescription and over-the-counter therapeutic drugs, veterinary drugs, fragrances, and cosmetics. PPCPs refer in general, to any product used by individuals for personal health or cosmetic reasons or used by agribusiness to enhance growth or health of livestock. PPCPs have been found at trace levels in some drinking water supplies throughout the country, including Michigan. 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 pathways that PPCPs have made their way into drinking water supplies is through discharges from sewage treatment plants. These facilities currently are not designed to remove these compounds. As a result, many PPCPs that enter the sewage 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.

Water treatment plants typically do not perform analyses for PPCPs, and the MDEQ currently does not require drinking water treatment plants to



test for them. Current research suggests that granular activated carbon, powdered activated carbon, and ozone may be effective treatment processes in removing many PPCPs from the water. These treatment processes currently are in use by some drinking water treatment plants in Michigan.

The presence PPCPs in the environment has gained considerable attention since the 2005 Biennial Report. The Associated Press released a story in March 2008 identifying numerous PPCPs that were detected in the water systems of several cities across the country. In December 2007, the USEPA published a standardized method for the analysis of some PPCPs. Presently, the USEPA is processing fish tissue samples for PPCP residue and plans to have those data available at the end of 2008.

A grant funded through the CMI-Clean Water Fund provided data regarding the presence of PPCPs in some Michigan waters. In 2004, the city of Ann Arbor collected samples from raw source water, finished drinking water, untreated wastewater influent, and treated wastewater effluent. A similar study was conducted in 2005 in the cities of Ann Arbor, Grand Rapids, and Monroe. PPCPs were detected in the part per trillion to part per billion range in all samples. The highest concentrations of PPCPs were found in untreated wastewater influent, followed by treated wastewater effluent, raw source water, and finished drinking water.

Many states have started pharmaceutical take-back programs to discourage the continued flushing of unused medications as a means of disposal. Also relevant to this issue, the MDEQ co-sponsored a workshop in April 2008 on proper disposal of unwanted medication. Additional information regarding the many issues surrounding PPCPs as an environmental contaminant may be found on the USEPA Internet site (www.epa.gov/nerlesd1/chemistry/pharma/).

Perfluorinated Compounds

The 2005 Biennial Report referenced only perfluorooctane sulfonate, but this category has been expanded to cover the range of perfluorinated compounds (PFCs). PFCs are surface active compounds that are found in hundreds of commercial products because of their ability to impart stain, water, and flame resistance. PFCs have been the subject of considerable research over the past few years. Attention has been focused on two compounds, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS), but nearly 200 PFCs exist. Researchers are currently attempting to determine if the chemical precursors to and the degradation products of PFOS and PFOA are also cause for concern.

The half-life of PFCs generally is measured in terms of years, thus they are persistent compounds. Researchers throughout the Great Lakes Basin 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. The biomagnification potential of PFOA is lower than that for PFOS.

Minnesota, which is home to one of the largest manufacturers of PFCs, promulgated Health Risk Limits (HRLs) for PFOS and PFOA in 2007. An HRL is the concentration of a substance in water that poses little or no appreciable risk when ingested. It is unclear whether there is industry in Michigan that would use or manufacture these compounds in sufficient quantity to require regulation. Additionally, there is some debate as to the relevance of the data from animal toxicological studies to humans, and it is not known if the most sensitive toxicological endpoint has been determined.

Polychlorinated Naphthalenes

Polychlorinated naphthalenes (PCNs) are a group of compounds that are used as cutting oils; engine oil additives; insulation; water repellents; and some wood, paper, and fabric preservatives. PCNs are persistent and tend to 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. In a 2000 study, PCNs were measured in fish whole body and fillets collected from Michigan waters, including the Great Lakes, during 1996 to 1997. PCNs were found in all the fish analyzed. Concentrations of total PCNs in fish ranged from 19 to 31,400 picograms per gram (wet weight). In a joint study involving the MDEQ, Yokohama (Japan) National University, and MSU, sediment from the upper Detroit and lower Rouge Rivers in southeast Michigan, and sediments from a nonpoint source location in Lake Michigan were analyzed. PCNs were found in all sediments from all locations with their concentrations ranging from 0.08 to 190 nanograms per gram. PCNs recently were added to the list of parameters monitored as part of the state/federal Chinook and Coho Salmon Trend Monitoring Program, and the USEPA's Whole Fish Trend Monitoring Program.

Tetrahydrofurans

Tetrahydrofuran (THF) is a manmade solvent used in the production of resins, adhesives, coatings, inks and polymers (particularly polyvinyl chloride), and as an intermediate in chemical synthesis. THF may be emitted to air or the waste stream and is a common contaminant found at landfill sites in Michigan. THF is water-soluble and highly mobile in soil. It biodegrades in aerobic environments and can form peroxides when exposed to air. THF is more resistant to biodegradation in anaerobic environments. Once it enters the body, THF is rapidly absorbed and excreted with little potential for bioaccumulation.

THF was identified as an emerging contaminant in the 2005 Biennial Report based on its potential for carcinogenicity. The USEPA's human health assessment for THF was released in May 2008 for external peer review. Chronic oral and inhalation criteria and a cancer risk factor are proposed. A final draft is expected later this year. The MDEQ currently regulates THF as a carcinogen based on evidence of liver tumors in experimental animals. Occupational studies and case reports have identified irritation of mucous membranes and the upper respiratory tract, sedation, and adverse liver and kidney effects in humans. The public may be exposed through contaminated air or drinking water.

Alkylphenol Ethoxylates

Alkylphenol ethoxylates (APEs) are a broad class of compounds used primarily as surfactants, detergents, emulsifiers, and wetting and dispersing agents in numerous industries as well as a range of consumer products, including contraceptives. They are strictly manmade chemicals with no natural sources and are released into the environment by way of industrial effluent and wastewater treatment processes. APEs that are not fully degraded during sewage treatment may become concentrated in the sewage sludge.

Nonylphenol and octylphenol ethoxylates are the largest produced members of this class in the United States. A number of alkylphenols and their ethoxylates are currently under review as part of the USEPA's high-production volume chemicals program. This voluntary program is aimed at providing health and environmental effects information on chemicals manufactured or imported into the United States in excess of one million pounds per year. There are no regulatory standards specific to APEs. Although there are analytical techniques to detect APEs in groundwater and sediments, there currently are no monitoring programs in Michigan for these compounds.

APEs are expected to be moderately persistent but the larger alkyl substituted class members have the potential to bioaccumulate. Toxicity data relevant to human health is very limited. Potential for dermal irritation appears to be low and APEs are not skin sensitizers. Aquatic toxicity has been widely reported for nonylphenol and lower ethoxylates. Some alkylphenols can bind to estrogen receptors and mimic estrogenic effects in fish. Endocrine disrupting chemicals are of concern because they can produce effects at low doses.

1,2,3-Trichloropropane

1,2,3-Trichloropropane (TCP) is exclusively a man-made chlorinated hydrocarbon chemical. TCP has been used as an industrial solvent, a cleaning and degreasing agent, an extractive agent, and in the production of pesticides. It is used currently as a chemical intermediate in the manufacture of other chemicals.

TCP is typically detected at industrial and hazardous waste sites. It is only slightly soluble in water and will likely leach from soil into groundwater where it may persist. TCP is likely to readily volatilize from water and more slowly from soils. Once released to the atmosphere, TCP will readily break down in sunlight. TCP is not expected to undergo significant degradation in soil or groundwater.

Animal studies suggest that long-term exposure to TCP may result in adverse effects to the kidneys. TCP is recognized by California as a human carcinogen. Non-occupationally exposed humans would most likely be exposed to TCP through ingestion of contaminated drinking water and soils.

N-Nitrosodimethylamine

N-Nitrosodimethylamine (NDMA) currently is not produced in pure form or commercially used, except for research purposes at laboratory scale. It formerly was used in the production of liquid rocket fuel, antioxidants, and softeners for copolymers. NDMA may be produced as a chemical by-product from manufacturing processes involving alkylamines, nitrogen oxides, nitrous acid, or nitrite salts. Industrial sources of these by-products may include tanneries, pesticide and rocket fuel manufacturing plants, rubber and tire manufacturers, fish processing facilities, foundries, and dye manufacturers.

NDMA is highly mobile in soil, with potential to leach into groundwater. When NDMA is released into the atmosphere, sunlight breaks it down in a matter of minutes. Environmental monitoring data for NDMA is minimal.

The USEPA has listed NDMA as a priority pollutant, but no federal standards have been established for drinking water. The public may be exposed to NDMA through ingestion of food containing nitrosamines, such as smoked or cured meats and fish, beer, contaminated drinking water, and inhaling cigarette smoke. Exposure to high levels of NDMA may cause liver damage in humans. NDMA is a probable human carcinogen.

Tungsten

Tungsten is a naturally occurring element that is used extensively in producing tungsten carbide and tungsten alloys for use in welding and oil drilling, and in the electrical and aerospace industries. Tungsten metal also is used to produce lamp filaments, x-ray tubes, dyes, and paints for fabrics. These industries can contribute to air emissions and wastewater releases of tungsten to the environment, especially in urban areas where these industries are more likely to be located. A significant percentage of tungsten is recycled.

Tungsten alloy alternatives have replaced lead shot ammunition for migratory waterfowl hunting subsequent to the 1991 ban on lead shot in the United States. Approximately 50,000 people hunted waterfowl in Michigan during the 2005 and 2006 waterfowl seasons. It is unclear what volume of tungsten-based shot may have been introduced into the environment through such annual hunting activities. The United States Department of Defense (USDD) has used tungsten alloys to produce various munitions. Tungsten was detected in groundwater above baseline levels at the Massachusetts Military Reservation subsequent to the transition from lead to tungsten-nylon bullets for small arms training. Currently, 200 million tungsten bullets are produced annually, using an ounce of tungsten each.

There are very limited data on adverse effects of tungsten in humans. Tungsten has not been classified for potential carcinogenic effects by any United States or international agency.

The amounts of tungsten in drinking water are generally not known and there is no federal drinking water standard for tungsten.

Perchlorate

Perchlorate is a persistent contaminant of concern. While naturally occurring, perchlorate salts are commonly manufactured for use as an oxidizer in solid propellants, munitions, fireworks, airbag initiators for automobiles, matches, and signal flares. Approximately 90 percent of the domestically produced perchlorate has been estimated to be used in the defense and aerospace industries in the form of ammonium perchlorate. Perchlorate has been used by the USDD as an oxidizer in munitions and missiles since the 1940s. Perchlorate has been detected at defense sites where historic manufacture, maintenance, use, and disposal of ammunition and rocket fuel have occurred.

Perchlorate is highly soluble and relatively stable in water, and as a result, perchlorate groundwater plumes can be extensive. As a salt, perchlorate easily migrates from the soil to the groundwater. However, perchlorate is not expected to volatilize to ambient air. The primary route of human exposure to perchlorate is ingestion of contaminated food and drinking water. Once ingested, perchlorate competes with iodine for uptake into the thyroid gland. As a result, excessive exposure can potentially alter thyroid homeostasis.

The USEPA has not established a federal drinking water standard for perchlorate. The states of Massachusetts and California, however, have established drinking water standards of 2 and 6 micrograms per liter, respectively.

1,4-Dioxane

1,4-Dioxane is a colorless, volatile liquid and is completely miscible in water and organic solvents. 1,4-Dioxane is used as a solvent for chemical processing in such products as cleaning and detergent preparations, lacquers, varnishes, cosmetics, and adhesives. It also has been used as an extraction medium of animal and vegetable oils and as a laboratory reagent. In the past, it was used primarily as a stabilizer in chlorinated solvents, particularly 1,1,1-Trichloroethane.

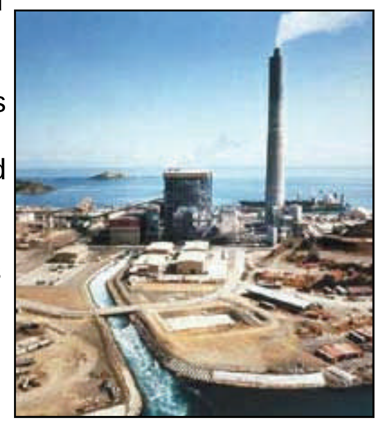
1,4-Dioxane is unstable at elevated pressures and temperatures and is potentially explosive if

exposed to light or air. In groundwater, it can migrate quickly, typically ahead of other contaminants, and it does not volatilize. 1,4-Dioxane is only weakly retarded by its adsorption to soil particles, and as result, it may move rapidly from soil to groundwater. It does not bioconcentrate in the food chain and does not readily biodegrade.

The most common route of exposure in humans is inhalation. 1,4-Dioxane is easily absorbed through the lungs, skin, and gastrointestinal system. Short-term exposure to high air concentrations in humans has resulted in damage to the liver and kidneys and also has caused death. Other symptoms include eye, nose, throat, and lung irritation, drowsiness, vertigo, headache, and anorexia. Chronic exposures may cause dermatitis, eczema, dry and cracked skin, and possible liver and kidney damage. Various routes of exposure in animals result primarily in damage to the liver and kidneys. Lifetime exposure to 1,4-Dioxane in the drinking water of rats and mice resulted in liver cancer; the rats also developed cancer inside the nose. 1,4-Dioxane is regulated as a human carcinogen in Michigan.

Manganese

Manganese is a naturally occurring element and an essential nutrient for growth and development. It is used as an additive in the steel manufacturing process and is emitted from sources burning fossil fuels such as coal-fired electric utilities. Manganese exists in ambient air primarily as particulates of manganese oxides and also is present in soil as manganese salts. There are several sites in Michigan where manganese is present in air and soil at levels exceeding current regulatory standards. Manganese is the focus of several state initiatives and has been identified by the USEPA as a priority pollutant.



Intake of manganese by way of ingestion is tightly regulated by the gut, but intake by way of inhalation represents a potential route for accumulation and adverse effects. Occupational studies have found that manganese is neurotoxic at high concentrations typical of work place exposures, affecting fine motor skills such as eye-hand coordination. Newer studies in experimental animals have observed reproductive effects and a potential for manganese to accumulate in the brain. The relevance of this phenomenon to humans is unknown. It also is unknown whether these adverse effects can result from chronic low-level environmental exposure to manganese in the general population.

Nanomaterials

Nanoscale science involves the engineering of materials from elements such as carbon, zinc, gold, and iron scaled down to 100 nanometers or less into various structures (rods, tubes, spheres) which impart useful properties. These materials are already in use in literally hundreds of consumer products including tennis rackets, clothing, electronics, sunscreen, and cosmetics. Nanomaterials also have many promising applications in the biomedical field as sensing and imaging devices as well as practical applications in the field of environmental bioremediation.

Toxicity information on nanomaterials is quite limited considering their widespread use. It generally is believed that surface area and surface properties (the physics) are more important to toxicity than composition (the chemistry). A study published in May 2008 suggests that carbon nanotubes behave similarly to asbestos fibers when injected into mice. Nanoparticles, like other ultrafine particulates, are more easily transportable deep into the lung. Inhalation exposure is most likely to occur in the occupational setting. Environmental inhalation exposure is uncertain, but expected to be low because most products currently in use contain nanomaterials embedded in a solid matrix.

Nanomaterials are expected to persist in the environment; therefore, the entire life cycle poses multi-media issues. Currently, there is no state or federal regulation of manufacture or use of nanomaterials, although the USEPA requires that nanomaterials that make claims of antimicrobial properties be registered under the Federal Insecticide, Fungicide, and Rodenticide Act. The USEPA also has established a voluntary program, the Nanoscale Materials Stewardship Program, to collect data on environmental and human health risks and benefits. Regulation of nanomaterials is quite problematic because pollutants are generally tracked and regulated by mass, which is not a practical measure for nanomaterials. It is unclear how introduction of nanomaterials into the environment could be controlled or measured. This, coupled with their unknown potential for toxicity, underscores the importance of toxicity testing and regulatory goals for nanomaterials.

Ethylenediaminetetraacetic Acid

Ethylenediaminetetraacetic acid (EDTA) is a chelating agent that binds with metal ions to form metal-EDTA complexes. The metals that usually are most strongly bound to EDTA are iron, copper, zinc, calcium, and sodium. In the United States, it is utilized in various applications including sanitizing solutions, colognes, cosmetics, food additives, and in medical treatment for heavy metal poisoning.

EDTA can be present in the environment as an acid or as a salt. Its ability to form complexes with metals poses a concern for groundwater. At several Michigan sites, EDTA has entered groundwater and mobilized a variety of metals that are normally bound to soil. The dissolved metals may then move with groundwater and contaminate drinking water wells.

Notes

PHOTOGRAPH AND EXHIBIT CREDITS

Animals: ***Bear, Frog*** - MDNR; ***Toad, Chickadee*** – Linda Albro Sparks; ***Bald Eagle*** - USEPA Great Lakes National Program Office; ***Juvenile Bald Eagle, Canadian Lynx, Asian Carp*** - USFWS; ***Kirtland's Warbler*** - Ron Austing; ***Emerald Ash Borer*** – Michigan Technological University; ***Zebra Mussel*** - Dave Brenner; ***Herring Gulls*** - Chris Gregerson.

Plants: ***Lichen*** - MDNR; ***Trillium in Woods*** - Corey Sparks; ***Frogbit, Purple Loosestrife*** - Dave Brenner.

Air: ***Air Monitors, Factory*** - MDEQ; ***Traffic*** - Linda Albro Sparks; ***Satellite Image of Michigan*** - NOAA/NASA; ***Three Stacks with Smoke*** - William Taft; ***Fermi Nuclear Plant*** - www.NukeWork.com; ***Three Smoke Stacks*** - Corey Sparks.

Water: ***Ionia Forest Stream*** - Michael Zander; ***Ice Breaker*** - US Coast Guard; ***Wetland, Road Construction, Angler on Shore, Sewer Overflow, Stream Assessment, Waste Water Treatment Plant*** - MDEQ; ***Grand River Forest, Boys on Beach, Ambassador Bridge, Detroit River Beach*** - Corey Sparks; ***Angler in Boat, Au Sable River*** - Lawrence R. LaMere; ***Boys at Fountain, Beach with Kids*** - Linda Albro Sparks; ***Angler with Fish*** - Amy Butler; ***Freighter "Irma," Little Girl on Beach*** - Jesse Harrold; ***Freighter Releasing Ballast*** - MIT Sea Grant for Coastal Resources; ***Freighter and Tugboat; Sediment Sampler*** - USEPA; ***Great Lakes Map, Lake Michigan High and Low Water*** - NOAA; ***Cook Nuclear Plant*** - www.NukeWork.com.

Land: **Michigan Envirothon Logo** - Teresa Salveta; ***Conifer Forest*** - MDNR; ***Conservation Filter Strip*** - USEPA; ***Road Construction, Truck at Landfill, Labeled Hazardous Waste, Hazardous Waste Treatment Facility, Oil Well, Old Tires*** - MDEQ; ***Underground Storage Tank Removal*** - Michael Charbonneau; ***Confined Animal Feedlot Operation*** - USEPA; **Monitor, Pills, Foam Cushion, Insulation, Tire, Gun Ammunition, Insecticide, Can of Varnish** - Internet.

Collages: ***Title Page, Ecological Measures, Programmatic Measures and Emergent Contaminants*** - Linda Albro Sparks, Corey Sparks, David Kenyon, Keith Harrison, USEPA, USFWS, MDNR, MDEQ, and Internet.

Exhibits: ***Exhibit 1*** - Michigan Environmental Science Board; ***Exhibits 32 and 33*** - Michigan Natural Features Inventory***; Exhibit 5*** - Public Sector Consultants; ***Exhibit 6*** - Michigan Land Use Leadership Council and MDEQ; ***Exhibits 2, 3, 4, 8 - 18, 21 - 28, 35, and 59 -*** MDNR; ***Exhibits 7, 19, 20, 28, 29 - 31, 38 - 58, and 64 - 91*** - MDEQ; ***Exhibit 34*** - National Oceanic and Atmospheric Administration and Michigan Technological University's Center for Exotic Species; ***Exhibit 36*** - Anthony Ricciardi; ***Exhibit 37*** - Edward Mills; ***Exhibit 60*** - US Army Corps of Engineers; ***Exhibit 61*** - SOLEC; and ***Exhibits 62 and 63*** - Air Improvement Resource, Inc.

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