Recommended Environmental Indicators Program for the State of Michigan

(A Science Report to Governor John Engler)

Prepared by
Michigan Environmental Science Board
Environmental Indicators Investigation Panel

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JULY 2001

MICHIGAN ENVIRONMENTAL SCIENCE BOARD
Environmental Indicators Investigation Panel

MICHIGAN ENVIRONMENTAL SCIENCE BOARD

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(FIRST PRINTING)

Manufactured in the United States of America

Copies of this report may be obtained free of charge by either writing to the Michigan Environmental Science Board or downloading from the Michigan Environmental Science Board's Home Page at: http://www.mesb.org

1st Printing (July 2001): 1000 Copies $3,870.00
(Cost per Copy: $3.87)

Printed by Authority of Executive Orders 1992-19 and 1997-3

<u>Correct Report Citation:</u>

Premo, B.J., D.T. Long, R.J. Huggett, D. Premo, W.W. Taylor, G.T. Wolff and K.G. Harrison. 2001. *Recommended Environmental Indicators Program for the State of Michigan*, July 2001. Michigan Environmental Science Board, Lansing. x + 88p.

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PREFACE

Michigan Environmental Science Board

The Michigan Environmental Science Board (MESB) was created by Governor John Engler by Executive Order 1992-19 on August 6, 1992. The MESB is charged with advising the Governor, the Natural Resources Commission, the Michigan Department of Natural Resources and other state agencies, as directed by the Governor, on matters affecting the protection and management of Michigan's environment and natural resources. The MESB consists of nine members and an executive director, appointed by the Governor, who have expertise in one or more of the following areas: engineering, ecological sciences, economics, chemistry, physics, biological sciences, human medicine, statistics, risk assessment, geology, and other disciplines as necessary. Upon the request of the Governor to review a particular issue, a panel, consisting of MESB members with relevant expertise, is convened to evaluate and provide recommendations on the issue. The MESB is neither a state policy body nor an advocate for or against any particular environmental or public health concern.

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Recommended Environmental Indicators Program for the State of Michigan

Major Findings and Conclusions

An environmental indicator is a measure, an index of measures, or a model that characterizes the environment or one of its critical components. An indicator may reflect biological, chemical, or physical attributes of the environment. Environmental indicators are used to characterize the current status and to track or predict significant change within the environment. They may also be used to identify potential environmental stress. Environmental indicators should provide information relevant to specific assessment questions, which are developed to focus monitoring resources and data on environmental management issues. Properly chosen indicators should be able to not only identify changing trends, but also to measure the need for and performance of public programs that protect the environment at the state and national levels.

To date, there have been several attempts at the state and national levels to identify and track environmental change and to develop meaningful ways to measure change and/or the degree of success of programs designed to protect the environment. However, most of these varied approaches have resulted in a patchwork of disjointed programs and measurements, many of which have little direct scientific meaning, are incapable of being integrated into a comprehensive understanding of the impact of human-related degradation or mitigation activities on the natural environment, and/or are incapable of differentiating anthropogenic from natural change.

Within the state, the Michigan Department of Environmental Quality (MDEQ) has prepared two annual Environmental Quality reports (1999 and 2000). Shortly after the 1999 MDEQ report was published, Public Act 195 of 1999 (Environmental Indicators Act) was signed into law by Governor John Engler. The law requires the MDEQ to work with the Michigan Department of Natural Resources (MDNR) to prepare a biennial report on the quality of the environment, based on scientifically supportable environmental indicators and using sound scientific methodologies. The first report is to be produced in October 2001, followed by additional reports every two years.

On January 28, 2000, the Michigan Environmental Science Board (MESB) was charged by Governor Engler to review the environmental indicators proposed by the MDEQ and MDNR for use in the legislatively mandated report to determine whether they have a sound scientific basis, and also to determine if change in the quality of the environment can be ascribed to observed changes in indicator values from one reporting period to the next. On May 1, 2000, an Environmental Indicators Panel (Panel), composed of four MESB members and three guest scientists, was formed to begin the investigation. The investigation consisted of the accumulation and evaluation of peer-reviewed and some non peer-reviewed background literature on the subject. In addition, a meeting was held on July 20, 2000 at which testimony and supportive documentation on proposed state environmental quality indicators were presented by the MDEQ, MDNR, interested environmental organizations, and concerned citizens. The major findings and conclusions of the MESB report are summarized below.

- Two general themes are considered in the Panel's review of the state's proposed indicators. First, in addition to evaluating the proposed environmental measurements individually, the Panel evaluated the indicators collectively from the standpoint of their being able to be developed into an integrated, adaptive, and informative program capable of identifying and monitoring statewide environmental trends. Second, the Panel advanced the concepts of biodiversity as an important guiding principal in the selection of ecological indicators and the need to establish a sound biodiversity information baseline for these measurements.

- Of a total of 23 environmental indicators proposed for consideration by the MDEQ and MDNR, the Panel recommends that 20 be included into a statewide environmental indicators program. The recommended indicators are based on a review of the environmental measurements that are currently being monitored or, in the case of three indicators (Ambient Levels of Air Toxic Contaminants, Persistent and Bioaccumulative Air Toxics, and Mammalian Populations), proposed to be monitored in the future.

The Panel's recommended list includes one additional indicator (Climate and Weather Change) that neither the MDNR nor MDEQ is currently tracking, but would be needed to be taken into consideration in the state's evaluation of all the other indicators (Table 1).

Table 1. Recommended Michigan Environmental Indicators.

Ecological Indicators:	Land Cover
	Breeding Bird Abundance
	Trends in Habitat of Interior and Edge Bird Species
	Trends in Game Fish Populations
	Trends in Fish and Benthic Macroinvertebrate Populations
	Trends in Frog and Toad Populations
	Invasive Species
	Forest Acreage, Mortality, Growth and Removals
	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 Mammalian Populations
Optional Indicator:	Contaminant Levels in Bald Eagles

♦ The Panel found that several of the state's environmental measurements were often times not systematically and consistently collected in terms of location and methodology. Consequently, the Panel recommends that the state employ the use of a protocol for sample collection, referred to as *Master Station*s and described in the report, from which it can systematically and consistently collect biotic, chemical, and physical information on the state's environment. The Master Stations would need to be: permanent to provide long-term trend analyses, incorporate a distributed sampling grid, intensively monitored, and integrated and optimized with the existing state monitoring programs.

♦ The reporting frequency outlined in the state's Environmental Indicators Act is every two years. Given the number and variety of different environmental indicators recommended, the different degrees of development of baseline information for each of the indicators, and the individual natural biological and physical dynamics of each indicator, the Panel concluded that a two year reporting period may not be sufficient to accurately determine a change in the quality of the environment for many of the recommended indicators. Many of the recommended environmental indicators will require a much longer time frame before trends and changes to trends can be discerned. The Panel offered suggestions for several of the state's proposed environmental indicators to improve the quality and interpretation of the data collected. It is recommended that the state address the various issues raised by the Panel to explicitly delineate, where needed, what can and cannot be derived from the data collected from the recommended indicators. In addition, the Panel suggests that after the state's environmental indicators program has been instituted, periodic, systematic reviews be conducted by the state to determine whether the recommended environmental indicators are achieving the underlying objectives of tracking environmental quality.

♦ Finally, in making the various recommendations throughout this report, the Panel was cognizant of the fact that most state environmental monitoring programs described by the MDEQ and MNDR were designed initially to fulfill a specific state or federal regulatory mandate for information rather than to generate specific ecological information. Consequently, the Panel recognizes that several of its recommendations may need to be evaluated further by the state before they can be fully implemented. Given this recognition, the Panel recommends that the state not try to institute all of the suggestions made by the Panel before its first legislatively required report in October 2001. Rather, it would be more productive for the state to incorporate the suggested changes and report on what it can currently and to take the additional time needed to carefully develop the more involved Panel recommendations (e.g., development of Master Stations).

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Recommended Environmental Indicators Program

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Introduction

An environmental indicator is a measure, an index of measures, or a model that characterizes the environment or one of its critical components. An indicator may reflect biological, chemical, or physical attributes of the environment. Environmental indicators are used to characterize the current status and to track or predict significant change within the environment. They may also be used to identify potential environmental stress (USEPA, 2000a). According to the U.S. Environmental Protection Agency's (USEPA) *Framework for Ecological Risk Assessment* (USEPA, 1992), indicators should provide information relevant to specific assessment questions, which are developed to focus monitoring resources and data on environmental management issues. Properly chosen indicators should be able to not only identify changing trends, but also to measure the need for and performance of public programs that protect the environment at the state and national levels. In addition, they should fit within the context of national and global requirements to address major environmental policy questions (NRC, 2000).

To date, there have been several attempts at the state and national levels to identify and track environmental change and to develop meaningful ways to measure change and/or the degree of success of programs designed to protect the environment (GLC, 2000; NCSE, 2000; NRC, 2000; USEPA, 2000a; 1996; Bertram and Stadler-Salt, 1999; ECOS, 1999; 1997; Hayward, Scholar and Fowler, 1999; Batie, 1995; Noss, 1990). However, most of these varied approaches have resulted in a patchwork of disjointed programs and measurements, many of which have little direct scientific meaning, are incapable of being integrated into a comprehensive understanding of the impact of human-related degradation or mitigation activities on the natural environment, and/or are incapable of differentiating anthropogenic from natural change. One attempt, in particular, was the creation of the National Environmental Performance Partnership System by the USEPA and the Environmental Council of the States (ECOS - an organization of state environmental agency heads) (ECOS, 1999; 1997). A key element of the partnership was a voluntary commitment to increase the use of environmental goals and indicators in the administration of environmental statutes. The USEPA and ECOS developed a three-tiered approach which incorporates program outputs to count specific items (such as the number of permits issued, enforcement actions taken, etc.), program outcomes to assess how well individual programs operate, and environmental indicators to directly measure change in the environment. Several state environmental agencies have adopted this approach, while most have chosen to incorporate only portions of it.

In 1996, the National Research Council (NRC), at the request of the USEPA, established a committee to conduct a critical scientific evaluation of indicators to monitor environmental change (NRC, 2000). The committee evaluated ecological indicators on the basis of their ability to quantify and simplify information about complex phenomena. Based on that evaluation, the committee came up with a series of questions that it felt should be taken into consideration when selecting environmental indicators:

1. Does the indicator provide information about major environmental changes?

2. Is the indicator based on a well-understood and generally accepted conceptual model?

3. Has past experience demonstrated the reliability of the indicator?

4. Does the indicator provide information about spatial or temporal changes?

5. Can the indicator detect signals above the noise of normal environmental variation?

6. How many and what kinds of data are required for the indicator to detect a trend?

7. What technical and conceptual skills must the collectors of data for an indicator possess?

Within the state, the Michigan Department of Environmental Quality (MDEQ) has prepared two annual Environmental Quality reports (MDEQ, 2000a; 1999b). Both documents have reported on a series of parameters best classified, using the USEPA - ECOS classification, as environmental indicators and program outcome measures. Shortly after the 1999 MDEQ environmental quality report was published, Public Act 195 of 1999 (Environmental Indicators Act, 1999), was signed into law by Governor John Engler (Appendix 1) further defining the manner in which Michigan's environment quality was to be reported. The law requires the MDEQ to work with the Michigan Department of Natural Resources (MDNR) to prepare a biennial report on the quality of the environment, based on scientifically supportable environmental indicators and using sound scientific methodologies. The first report is to be produced in October 2001, followed by additional reports every two years.

Charge to the Michigan Environmental Science Board

On January 28, 2000, the Michigan Environmental Science Board (MESB) was charged by Governor Engler to review the environmental indicators proposed by the MDEQ and MDNR for use in the legislatively mandated report to determine whether they have a sound scientific basis, and also to determine if change in the quality of the environment can be ascribed to observed changes in indicator values from one reporting period to the next (Engler, 2000, see Appendix 2).

Michigan Environmental Science Board Response

On May 1, 2000, an Environmental Indicators Panel (Panel), composed of four MESB members and three guest scientists, was formed to begin the investigation. The investigation consisted of the accumulation and evaluation of peer-reviewed and some non peer-reviewed background literature on the subject. In addition, a meeting was held on July 20, 2000 at which testimony and supportive documentation (Appendices 3 and 4) on proposed state environmental quality indicators were presented by the MDEQ and MDNR (Harrison, 2000). The MDEQ and the MDNR presented a total of 23 environmental indicators for consideration by the MESB (Table 1).

Table 1. Michigan Departments of Natural Resources and Environmental Quality Proposed Environmental Indicators.

Michigan Land Use
Michigan Breeding Bird Abundance
Trends in Habitat, Interior Versus Edge Bird Species
Trends in Deer Populations
Trends in Game Fish Populations
Trends in Fish and Benthic Macroinvertebrates
Trends in Frog and Toad Populations
Invasive Species
Forest Acreage and Timber Volume, Mortality, Growth and Removals
Vegetation Structure and Diversity
Lichen Communities
Ambient Levels of Criteria Air Pollutants
Emission Rates of Criteria Air Pollutants
Pollutant Standard Index
Ambient Levels of Air Toxic Contaminants (Future Indicator)
Emission Rates of Toxic Air Pollutants
Rates of Deposition of Persistent and/or Bioaccumulative Air Toxics (Future Indicator)
Stream Flow
Inland Lake Water Quality
Contaminant Levels in Bald Eagles
Contaminant Levels in Native Whole Fish
Contaminant Levels in the Sediments of Inland Lakes
Contaminant Levels in the Connecting Channels, Saginaw Bay, Grand Traverse Bay, and Major Tributaries

During the testimony and the later, more extensive literature research segments of the investigation, it became obvious to the Panel that it would be of little benefit to comment solely on the efficacy of the state's proposed environmental indicators without also looking at how the measurements could be integrated to present a comprehensive and meaningful understanding of the changing environment. Taking into consideration the request from the Governor and the recommendations of the NRC (2000), it was determined that the most productive approach to the MESB assignment would be to present an evaluation of the proposed state indicators in a manner that could result in the development of an integrated, adaptive, and informative program capable of identifying and monitoring statewide environmental trends. Consequently, the following MESB evaluation has been divided into two main sections. The first section describes important ecological factors (such as land cover, biological diversity, and inland lake productivity) that should be taken into consideration in a statewide environmental indicator program, while the second provides an evaluation of the important physical/chemical factors (such as air and water quality, fish, sediment contaminants, and stream flow). A series of conclusions and recommendations follow this discussion.

It must be recognized that most state environmental programs are designed to fulfill a specific state or federal regulatory mandate for information and that oftentimes the information generated may not be readily adaptable to a different purpose (e.g., such as serving as a basis for discerning and evaluating ecological change). In addition, it also must be recognized that the development of a set of indicators that will provide meaningful trend information may require a period of time to develop a scientifically defensible set of baseline data before interpretations can be made. The Panel, in its evaluation of the proposed environmental indicators, has tried to be cognizant of both of these limitations and recognize that some of its recommendations may need to be refined further by the state before they can be fully implemented.

Review of Proposed Ecological Indicators

Biological Diversity, Ecological Health, and Establishing a Baseline. The Panel suggests that an overarching theme can guide the selection and assessment of ecological indicators. An appropriate theme is the ecological concept of biological diversity (also known as biodiversity). Measurements of biodiversity are often considered indicative of the health of biological systems (NCSE, 2000; Spellerberg, 1991c; Norse, 1990). Norse (1990) states that, *"… measurement of biological diversity could provide an effective and economical indicator of overall ecological health*." The ecological indicators proposed by the state as gauges of environmental health are all components of biological diversity and, therefore, biological diversity is a useful organizing construct for this aspect of environmental monitoring. Biological diversity has a high public and scientific profile as evidenced by the recent report of the NRC (2000) that identified *biological diversity and ecosystem functioning* as one of four *grand challenges* in need of immediate funding by the National Science Foundation (Schoen, 2001).

One of the most encompassing definitions of biodiversity comes from the Office of Technology Assessment (OTA, 1987):

> *Biodiversity is the variety and variability among living organisms and the ecological complexes in which they occur*.

By this definition, biodiversity includes the variety of living organisms in all forms - microorganisms, plants, and animals - and at all levels of organization. These organizational levels are on a continuum that encompasses molecular and genetic diversity, the numbers and frequency of species themselves (species diversity), the variety and frequency of communities of organisms and their associated physical surroundings (ecosystem diversity) (Nigh *et al*., 1992; Falk, 1990; Norse, 1990; McNeely, 1988; Norse *et al*., 1986; Hair, 1980), as well all intermediate levels (Hunter, 1990; Wilson, 1988). Biodiversity, however, is not simply the temporal and spatial composition of genetic material, species, communities, or ecosystems; it is also processes. Processes such as nutrient cycling, energy flows, carbon sequestration, productivity, successional pathways, genetic drift, and gametic exchange are important, but often unrecognized aspects of biodiversity (Hansson and Angelstam, 1991).

Although the concept of ecological health is mentioned throughout resource management and policy documents, it has rarely been clearly defined (Haskell, Norton and Costanza, 1992), and there is thoughtful critique of its validity as a metaphor (Suter, 1993). Despite these concerns, protecting and restoring ecological health is often a unifying theme of resource management (Haskell *et al*., 1992; Barrett, 1981). One of the most frequently cited aspects of ecological health is stability. Ecologists have traditionally posited that diverse biological systems are more stable than simple systems, and that stability is a component of system health. Elton (1958) empirically observed that communities with many species were more resistant to introductions and invasions than communities with fewer species. His early observations have been supported by a subsequent review of species introductions to islands and continents (Diamond and Case, 1986). At one level, the *diversity begets stability* axiom is intuitive. For example, the American elm was a large part of the tree community in northern hardwood forests of the western Upper Peninsula of Michigan. Dutch elm disease virtually removed this component, but the impact on the forest was less dramatic than if the forests had included only one or two tree species. Some measures of ecological change, the converse of stability, can, therefore, be a way of monitoring environmental health within the state of Michigan.

Loss of biodiversity has been documented throughout the world. Most of this documentation shows a decrease in both variety and absolute numbers of organisms (Falk, 1990; Ehrlich, 1988). Less frequently documented, but of equal concern, is the associated decrease in complexity and integrity of processes in the environment (Norse 1990). Much of the loss of biodiversity is related to the expanding human population and its related support systems (Ehrlich, 1988). It manifests itself as loss or degradation of entire ecosystems, loss of individual species, and loss of genetically unique components of populations. According to Ehrlich (1988), the primary cause of loss of biodiversity is the habitat destruction that accompanies human population growth and the related expansion of human activities. Norse (1990) identifies six proximate human-related threats to biodiversity: (1) direct population reduction of plants and animals (both intentional and incidental taking), (2) physical alteration of habitat (the most severe threat), (3) chemicals and waste products affecting land, water, and air, (4) global atmospheric change, (5) introduction of alien species, and (6) interactions between one or more of these stressors. Of these six threats, activities by land and resource managers can most directly address direct population reduction, physical habitat alteration, and introduction of alien species.

If measures of biodiversity are to be used as indicators of environmental health, there needs to be a baseline of biodiversity information against which scientists and resource managers can interpret monitoring data. In fact, initial monitoring years should be designed to help assemble the baseline of biodiversity information both from existing sources and from new data to be collected. The baseline requires information on both common and rare species and ecosystems.

Compilation of a working inventory of biodiversity is a significant task. Existing data are scattered through a variety of sources. Up-to-date, accurate records are often scarce, particularly in a region of sparse human population, such as Michigan's Upper Peninsula. Museums and herbaria contain a wealth of data on species' distributions, often commencing at the turn of the 20th Century or before and continuing to the present time. The computerization of these records is proceeding, making ready access in the future much more feasible (Allen, 1993).

The MDNR's Michigan Natural Features Inventory (MNFI) represents one source of information on biodiversity of the state. This program focuses on species with official status under state and federal endangered species legislation or rare vegetative communities. This focus makes the MNFI less likely to be a source of information on ecologically significant species that lack protected status (i.e., common species and ecosystems). The MNFI database relies heavily on volunteer contributions with the result that the greatest amount of effort occurs in the areas of highest human population and development activity. Thus, users of these data must be cautioned that absence of element occurrence records (especially in remote areas) does not necessarily mean an absence of a rare organism.

Other sources are published state and regional floras, faunas, and natural histories that address historic and contemporary information on life histories, habitats, and distributions of Michigan plants and animals. Universities are the primary publishers of such topical publications. Broad-spectrum published lists of biota such as Harding (1997); Voss (1996; 1985; 1972); Kurta (1995); Benyus *et al.* (1992); Patton (1992); Brewer, McPeek and Adams (1991); Albert, Denton and Barnes (1986); Barnes and Wagner (1982); and Hubbs and Lagler (1958) are excellent starting sources of information on distributions of vertebrates. Regional and local experts, both professional and amateur, represent another source of information rarely tapped, but potentially invaluable.

An accounting of information and data that have been collected by the state over the years on organisms such as furbearers, fishes, and aquatic insects would be a valuable starting point for establishing a baseline. This information resides in many forms and repositories and should be consulted for what it can offer in establishing a baseline of biodiversity information.

Michigan Land Use. The first ecological indicator proposed by the state is *Michigan Land Use* (Appendix 3). The Panel suggests that *Michigan Land Cover* rather than *Michigan Land Use* would be a more appropriate title for this measurement since *land cover* is both a measure of human use of the landscape as well as the natural cover. Detection of change in the ecosystem patches that comprise the Michigan landscape is an important way of characterizing and tracking potential stressors to biodiversity and predicting future impacts to environmental quality. As this indicator is developed, it is likely that a somewhat finer resolution of cover types than the major categories outlined in Appendix 3 eventually would be needed. A discussion of spatial and temporal scales appropriate to the question(s) of concern also should be developed. For example, wetlands would be a prime candidate for this treatment given the importance of these ecosystems to plant and animal communities and their role in such ecological processes as carbon sequestration and water storage.

Several potential data sources were mentioned in the MDNR description for this indicator (Appendix 3) and these need to be researched as to their scales, attributes, and compatibility. Several of these sources were oriented toward resource commodities (such as timber) and would have to be carefully scrutinized as to their value for monitoring environmental quality. It seems desirable to select and test landscape monitoring data within the context of *Master Stations* (discussed later in this report). In this way, data and analyses can be assessed as to their ability to answer specific questions. Finally, a stronger argument could be made for this indicator if several specific questions were articulated so that monitoring design suits the problem at hand. With these considerations addressed, the Panel recommends that this indicator be included as one of the environmental quality measurements.

Birds. Two of the state's proposed ecological indicators, *Michigan Breeding Bird Abundance* and *Trends in Habitat of Interior Versus Edge Bird Species* address birds (Appendix 3). Birds are often selected as a subject of biodiversity studies for several compelling reasons: (1) relative ease of census, (2) inherent diversity, (3) demonstrated correlation between habitat structure and bird diversity, (4) position at all levels of the food web, (5) sensitivity to environmental stressors, and (6) aesthetic appeal (birds are popular with the public) (Rogers and Premo, 1992). Counting birds has a long tradition and bird counts have been the basis for many discoveries in ornithology and ecology (Ralph and Scott, 1981). There are many methods used to estimate bird numbers and they vary considerably in their precision and accuracy. It is important to know how variations in methods, observers, training of observers (or lack thereof), species, habitats, and other environmental variables affect the outcomes of bird counts in order to have a reliable tool for monitoring. In the context of monitoring environmental quality in Michigan, it is important to understand and evaluate these factors in the specific data sets proposed for use. For example, in the description of the proposed indicator, *Michigan Breeding Bird Abundance*, it is suggested that *"… relative abundance of breeding bird populations in selected habitat types …"* be monitored by using data from the annual Breeding Bird Survey (Appendix 3). This would provide insight only at a very crude habitat level (such as forested land or open land) because each listening point is not strictly tied to habitat since the listener can detect birds from a greater distance than he/she can easily assess habitat. Again, specific questions should be designed to accommodate the kind of data that is available for analysis.

The Panel suggests that the term *versus* be dropped from the proposed state ecological indicator entitled, *Trends in Habitat, Interior Versus Edge Bird Species*, as it implies a positive and negative value on groups of birds. An edge species grouping only makes sense if there is a need to construct a grouping of birds tolerant of human activities. Otherwise, many classic edge species (in an ecological sense) are currently experiencing population declines as old-field habitat is developed or succeeds to forest and fire is strictly controlled. The Panel suggests that the approach of tracking habitat-specific groups of birds (dry coniferous forest birds, grassland birds, deciduous forest birds, etc.) makes sense. Ecological edge species guilds also could be an important category to monitor (with some of the same caveats as outlined above) as well as a grouping of those species tolerant of humans. The Panel recommends that species groupings be reviewed by a team of ornithologists (professional and amateur) from various parts of Michigan. The Panel recommends the inclusion of both proposed indicators.

Mammals. The state proposed indicator, *Trends in Deer Population* (Appendix 3), was offered for consideration as a possible indirect measure of habitat quality using population trends of white-tailed deer. Deer populations are estimated annually in Michigan by the MDNR. Two methods, based on statistics, are used to estimate populations: sex/age/kill ratio estimates and pellet count surveys.

The MDNR cautiously offered this measure as a possible indicator due to the number of limitations associated with deer population estimates and the highly managed nature of the population by humans. Another limitation of using deer population estimates as an indicator of habitat quality is the limitations of the estimators themselves. The only statewide estimator of populations is the sex/age/kill ratio estimator since pellet surveys are not conducted in southern Michigan. The sex/age/kill ratio is largely derived from the annual buck kill. The annual buck kill can vary yearly for many reasons unrelated to the change in deer populations, including weather, hunter pressure, and corn harvest in southern Michigan.

Pellet survey estimates are less susceptible to annual fluctuations for reasons other than population changes; however, as indicated above, these surveys are not conducted statewide. Often these data analyses cannot be completed until after the regulations for that year have to be set. Therefore, the long-term use of this population estimator by the MDNR may be uncertain.

The Panel concurs with the various limitations and concerns expressed by the MDNR and suggests that MDNR's highly managed *Trends in Deer Population* measurement would be better classified and reported as a program measure rather than an environmental indicator. The MDNR may wish to consider some other mammalian species or suite of species that it maintains population data on and that are not as actively managed as the deer population to serve as an environmental indicator. A couple of suggestions are presented later in this report (see Potential Gaps Among the Ecological Indicators).

Amphibians. The state proposed that *Breeding Frog and Toad Populations Trends* be used as an indirect indicator of habitat degradation (Appendix 3). Breeding frogs and toads have been counted annually for the past four years throughout Michigan as part of the MNFI Frog and Toad Survey. The Panel believes that amphibians offer an excellent opportunity for monitoring environmental quality in Michigan; however, this is a relatively new indicator for Michigan and there are few historic data to compare with the four years of survey data to determine long-term trends. In addition, in its evaluation of the indicator (Appendix 3), the MDNR has expressed concerns regarding the availability of sufficient volunteers with varying abilities to identify species and estimate numbers in the survey areas and to ensure sufficient coverage statewide in all survey years. The Panel concurs with this assessment.

The MDNR description did not provide information on how, where and by whom the breeding amphibians census would be conducted (Appendix 3). Several monitoring protocols exist depending on the area being surveyed and the purpose of the survey (Bertram and Stadier-Salt, 1999); however, as with any census program, the development of a sound and consistently used survey methodology is critical to the utility of the data and the reliability of any subsequent trend analysis. The Panel suggests that, in the absence of a consistently used protocol, the MDNR may wish to review Heyer *et al*. (1994) to formulate a basis for using amphibians as ecological indicators and for ideas regarding methodology for surveys and evaluating survey data. In addition, the MDNR should consult with professional and amateur herpetologists in Michigan for advice on monitoring strategies.

Despite the apparent limitations noted for this proposed indicator, the Panel suggests that this indicator is one that should be continued to be pursued and refined by the state.

Fish and Benthic Macroinvertebrates. Both the MDNR and the MDEQ monitor fish populations. Probably the single largest difference between the two departments' efforts is that the MDNR's program focuses primarily on game species, while the MDEQ's program is not as exclusive and also focuses on nongame fish species and benthic macroinvertebrates.

According to Alimov *et al.* (1979) and the National Academy of Sciences (NAS, 1979), environmental indicators of aquatic ecosystem health should provide a measure of progress towards achieving water quality goals and objectives and demonstrate trends in water quality and aquatic ecosystem health. In addition to providing a reflection of water quality and ecosystem health, use of environmental indicators should allow for the development of comparable methods and a means for replication across a broad range of habitat conditions and temporal scales (Couillard and Lefebvre, 1985; NAS, 1979). Some attributes of using fish as an environmental indicator include:

1. Fish are generally easy to collect and easily identifiable in the field making them a relatively inexpensive and easily accessible tool for environmental assessment (Karr, 1981);

2. Some fish species have large ranges and are less affected by natural microhabitat differences than smaller organisms. This makes fish extremely useful for assessing regional and macrohabitat differences (Jackson, 1991; Hesselberg *et al*., 1990; DeVault, Willford and Hesselberg, 1985);

3. Most fish species have long life spans (2 to 10+ years) and can reflect both long-term and current water resource quality (DeVault, Willford and Hesselberg, 1985); and

4. Distribution, life histories, and tolerances to environmental stresses of many species of North American fish are documented in the literature.

The purpose of the MDNR's *Trends in Game Fish Populations* indicator is to evaluate specific fish populations and fish community structure as a relative measure of the ecological integrity of the water body. Information about flow and temperature are also monitored to improve the understanding of the relationship between these dynamic natural conditions and biological responses. Changes in fish communities and fish conditions are used to assess changes in environmental quality (Appendix 3).

Some of the limitations noted by the MDNR with its measurement include: (1) changes observed in fish populations and/or fish community structure are site specific and can be difficult to extend for statewide trend analysis, (2) data collection schedules and methods have been varied in the past (the MDNR currently has plans in place to improve conformity in future assessments), (3) fisheries management practices (stocking, harvest regulations, removal treatments) have established and/or sustained fisheries and are not necessarily indicative of local environmental quality, (4) potential relationships between environmental conditions and fish communities are not well understood (e.g., changes in the fishery due to climactic or other natural causes may be difficult to discern from land use or water quality changes), and (5) fish populations have wide natural variability and trends may not be evident (or reliable) on an annual basis (Appendix 3).

The MDEQ's *Trends in Fish and Benthic Macroinvertebrates* program routinely collects data on the relative abundance of fish and benthic macroinvertebrates in wadable streams and rivers. These surveys are a major component of the MDEQ's watershed assessments program and are conducted on a 5-year cycle to support the National Pollution Discharge Elimination System and nonpoint source protection regulatory programs. The sampling method, known as Procedure 51, is a rapid assessment protocol designed to quickly determine stream condition and aquatic life conditions. The MDEQ samples a stream reach to identify the fish and benthic macroinvertebrate species present and determine their relative abundance. Nine benthic invertebrate metrics (e.g., total number of taxa, number of mayfly taxa, percent caddisflies, etc.), which are based upon reference conditions, are used to calculate an overall metric score. The overall metric score is rated as excellent, acceptable, or poor. There are ten fish metrics for warmwater streams. For coldwater streams, if greater than one percent of the fish collected are salmonids, the site is considered meeting water quality standards for fish (Appendix 4).

Because Procedure 51 is a rapid assessment technique, it is qualitative rather than quantitative (i.e., the percentage of each taxa based on the total number of individual organisms is recorded). The program does not generate quantitative, statistical measures for each species, such as population densities (e.g., numbers per square meter) or production rates, which are much more time-intensive. This limits the use of these data as long-term, consistent water quality indicators. Another limitation is that the program does not use fixed sites that are monitored for fish and benthic macroinvertebrates on a regular basis. Rather, different watersheds are sampled each year during a 5-year cycle. Consequently, a given site likely will not be sampled more than once every five years. The MDEQ recently released an Invitation to Bid on a project to develop a procedure to measure long-term trends in aquatic life at fixed stations. The focus of the project will be on benthic invertebrate communities, but also may encompass fish as well (Appendix 4).

The Panel concurs with both the MDNR's and MDEQ's assessments regarding the limitations of their respective programs, but suggests that several of the noted limitations could be lessened if the two department monitoring protocols could be coordinated. In addition, both programs could benefit from the adoption of the Master Station concept described later in this report. The Panel recommends that both the MDNR and MDEQ measures be included in the state's environmental indicators program.

Invasive Species. The Panel agrees with the state that monitoring *Invasive Species* in Michigan would be a useful tool to evaluate environmental quality (Appendix 3). Simply defined, an alien invasive organism is "… *a foreign taxon that enters an established ecosystem and contaminates it …*" (McKnight, 1993). In this context, *contaminate* can mean anything from a relatively benign organism that becomes a naturalized component of the ecosystem to an organism that spreads and multiplies and seriously upsets the system (McKnight, 1993). What the MDNR outlined in its description for this indicator represents progress toward a baseline of information rather than a field monitoring technique. The Panel urges that this ecological indicator be developed toward a field monitoring program and, where needed, a control and restoration program. As part of the baseline effort summarized by the MDNR, the species should be ranked by attributes such as: (1) threat to the environment, (2) opportunities for control, and (3) current distribution. Another approach would be to target several species to track over a period of years or decades. For example, Eurasian milfoil (an aquatic plant), purple loosestrife (a wetland plant), and spotted knapweed (an upland plant) are all invasive species with ecological impacts. Field monitoring could be stratified by land cover type and region. It could also fit well into a concept of Master Stations (described later).

Forests. The state recommended that *Forest Acreage and Timber Volume, Mortality, Growth and Removals* measurement be used to monitor changes in forest types (and related habitats), and the sustainability of forest resources (Appendix 3). The MDNR description for this ecological indicator appears to assert that wood fiber extraction is the primary forest use of public concern (Appendix 3). If correct, this assertion, however, would set the stage for a proposed indicator that focuses more on extraction of resources than quality of the environment. Terms such as *under-utilized* and *over-mature* have little to no meaning in an ecological context. Also, the data proposed as a source of information for this indicator fail to treat the forest as an ecosystem. Given that the goal of the monitoring program is to evaluate environmental quality, ecology-based, rather than economy-based measures, need to be used. The reporting on the volume of timber removed from Michigan's forests provides little information about the health of the ecosystem because the focus is on what has been taken from the forest rather than on what has been left behind. The Panel recommends that for purposes of reporting on environmental quality that data on time timber volume be excluded from this indicator and that the MDNR carefully review its forest indicator in the context of current ecological knowledge about forest health and sustainability (for examples and references, see Hunter, 1990). It might be appropriate to identify both unmanaged and managed reference sites in Michigan against which appropriate measures of forest health can be evaluated.

In addition, the Panel suggests that consideration be given to specifically incorporating the recommendations of the NRC (2000) for local and regional ecological indicators for forests. Included among these are productivity and tree species diversity, soils, light penetration, foliage-heights profiles, crown condition, and physical damage to trees. The use of such measures, according to the NRC (2000), can provide early warning of adverse trends in productivity, species diversity, and structural diversity.

Vegetation Structure and Diversity. Another forest health index proposed by the state is the U.S. Department of Agriculture (USDA) Forest Service's Forest Health Monitoring (FHM) Program *Vegetation Structure and Diversity* indicator (Appendix 3). This indicator was developed in 1983 and its purpose is to assess forest ecosystem health in terms of (1) the composition and diversity of native vascular plant species, (2) the composition, abundance, and rate of change on non-native vascular plant species, and (3) the vertical layering of vegetation within a forest. The composition, diversity, and structure of vascular plants in a forest are important indicators of chronic stresses such as disturbance and pollution. These stresses can change the composition of species and lead to the decline or local eradication of sensitive species, as well as the increase and dominance of opportunistic species, such as many weedy non-native plants.

A field guide has been developed by the USDA Forest Service (2001d) to help standardize data collection. Data are collected by qualified botanists with regional knowledge to provide optimum field identification of plant species at each site, and preferably with the ability to identify locally rare species and invasive species from Europe, Asia, Africa, and Australia. In addition, specimens of all measured plants that cannot be confidently identified to the species level are collected off-plot and submitted to herbaria for subsequent identification.

The indicator measures the following forest ecosystems attributes:

1. Vegetation diversity;
2. Number and abundance of forest-dependent species;
3. Number of native species;
4. Number of exotic species; and
5. Vertical structure.

The degree of disturbance and percent cover by various microhabitat variables (litter/duff, rocks, dead wood, live roots/bole, etc.) are also estimated.

The USDA Forest Service (2001) suggests that the abundance (i.e., cover) and layering of vegetation is a good predictor of wildlife habitat and the severity of damage that might occur when fire occurs. The individual species themselves are important indicators of a site's potential productivity, and wildlife forage and shelter. While the Panel generally agrees with these statements, it is concerned that without periodic and accurate census of the forest ecosystem's animal components (e.g., birds, mammals, amphibians, reptiles, etc), any interpretation as to the nature and extent of these components would be limited.

The MDNR has indicated that a primary advantage of the use of this indicator is that it is an established index measured by the USDA Forest Service's FHM program across many states (Appendix 3). The Panel agrees with the MDNR assertion, but suggests that this indicator could be improved further by also incorporating the recommendations of the NRC (2000) for local and regional ecological indicators for forests.

Lichens. The state recommended that the USDA Forest Service's FHM program's *Lichen Communities* indicator be used as one of several measures to assess the health of Michigan's forests and landscapes (Appendix 3). According to the USDA Forest Service (2001b), the lichen communities indicator program was developed in the Southeast in 1990 – 1993. The premise for the use of lichens as an environmental indicator is that since epiphytic lichens rely totally on atmospheric sources of nutrition, a close relationship exists between lichen communities and air pollution, especially sulfur dioxide and acidifying or fertilizing nitrogen and sulfur-based pollutants (McCune, 2000; Muir and McCune, 1988). In addition, lichens serve an important biological roles in temperate forests including winter forage for mammals, arthropod forage, and habitat for nesting materials for birds, and are important in nutrient cycling, especially nitrogen fixation in moist areas (USDA Forest Service, 2001b). Consequently, lichens may be used as an indicator of air quality and also of forest productivity and biodiversity (USDA Forest Service, 2001a).

The MDNR description provided for this indicator did not specifically reveal what or how data are to be collected (Appendix 3). Initially, the Panel expressed some reservation with the utility of this indicator since most lichen species are difficult to identify in the field; with identification oftentimes requiring intensive hand lens and microscope examination as well as chemical tests. However, further research of the USDA Forest Service program revealed contingencies to counter this concern with its employment of an extensive training plan (Neithlich and Will-Wolf, 1999) and its development of a field guide for the collection, preservation, storage, and mailing of samples for later identification by trained lichenologists (USDA Forest Service, 2001a; b; c). The Panel recommends that this indicator be further developed and included in the state's environmental indicators baseline database. As with previous ecological indicators, the inclusion of this indicator in the Master Station concept (described later) also should be explored.

Stream Flow. According to the state, *Stream Flow* is an indicator of amount and type of habitat available for fish and other aquatic organisms. It is also an indirect indicator of water quality in streams, and in lakes and reservoirs occurring in stream systems. Flow patterns are expected primarily to reflect changes in runoff from land, groundwater level, water extraction, discharge from upstream reservoirs (if present), and climatic change (Appendix 3). The Panel agrees that stream flow patterns seem a useful tool for evaluating environmental quality, but suggests that this would need to be compared to some historic measure of what is normal or expected for a given region. Also, it may be difficult to extract the hoped for causal meanings from these data unless it is possible to couple the data with land cover and attributes of the riparian zone. Consequently, the Panel suggests that the MDNR consider broadening this indicator to include some measures of the riparian zone condition. For example, the U.S. Bureau of Land Management has devised a set of measures referred to as *proper functioning condition* to monitor the quality of riparian habitat. In addition, it would be useful to coordinate this effort with the collection of water quality data that the MDEQ obtains for connecting channels and major tributaries (Appendix 4). Such an approach would provide useful and needed riparian or watershed information. This indicator also lends itself to the Master Station approach outlined later in this report.

Inland Lake Productivity. The state recommended that assessment of *Inland Lake Productivity* trends as measured by trophic status classification should be used as a water quality environmental indicator (Appendix 4). Lake water quality can serve as a valuable indicator of nutrient runoff and biological production. As more people live and work around lakes, their activities induce sedimentation and increased inputs of phosphorus and nitrogen. The higher nutrient levels stimulate higher plant production and change the trophic state of a lake. Oligotrophic lakes are clear, low in nutrients and generally low in weeds and algae. Eutrophic lakes are high in nutrients and support high levels of biomass. They are subject to algae blooms and are quite weedy. Mesotrophic lakes lie somewhere between the oligotrophic and eutrophic stages. A natural aging process occurs in all lakes; however, human activities have greatly increased the rate of eutrophication by allowing nutrients from agriculture, lawn fertilizers, streets, septic systems, and urban storm drains to enter lakes (Shaw, Mechenich and Klessig, 1996). The eutrophication of lakes can destroy their recreational, fisheries, and aesthetic values. The measure of change in trophic state of lakes can be used as a measure of the success of land management, runoff and sedimentation control practices, and landowner environmental education programs.

Relatively simple and commonly used measurements are used to indicate the trophic state of lakes. These measurements include Secchi disk transparency, total phosphorus, and chlorophyll *a*. Secchi disk readings are measured as the depth to which an 8-inch diameter, white and black weighted disk is just visible in the water column. This crude measurement has been used since the 1800s to document long-term relative changes in water clarity. Since decreased transparency is most often caused by algae growth, this is a good measure of lake trophic status. In eutrophic lakes, a Secchi disk may only be visible down to five feet, whereas in an oligotrophic lake the disk is visible beyond 10 feet. Total phosphorus is most often the nutrient that limits plant growth in lakes. Any inputs of phosphorus stimulate increased weed and algae production. Measurement of concentrations of total phosphorus can range from less than 10 micrograms per liter (µg/l) in oligotrophic lakes to greater than 30 µg/l in eutrophic lakes. Chlorophyll *a* concentration in lake water is a measurement of the density of algae. During the growing season (late July and early August), oligotrophic lakes will have low chlorophyll *a* concentrations of less than 5 µg/l. Eutrophic lakes will have chlorophyll *a* concentrations that exceed 10 µg/l. The combination of these three measurements can be used as a single indicator called the Trophic State Index and is the recommended indicator to be used to assess aquatic productivity by the NRC (2000).

Currently these data are being collected across much of the United States by volunteer monitoring programs. In Michigan, the Michigan Lakes and Streams Association is cooperating with Michigan State University and the MDEQ to provide tools and education to volunteer lake monitors. Important trend information would be gained if these data were presented as overall number of lakes in various trophic states, and as numbers of lakes that have changed and the direction of that change. The Panel concurs with the MDEQ on the usefulness of this assessment and recommends that lake trophic status measurement be included as an environmental indicator for Michigan.

Potential Gaps Among the Ecological Indicators. The Panel recognizes that some potentially useful indicators may not have been proposed by the state due to legitimate concerns with either the quality or extent of the baseline data currently available. The Panel recommends, however, that the state take a closer look at some of these ecological indicators to see what would be needed to improve or enlarge the databases. For example, data on mammalian species such as the beaver, which can have profound influence on ecosystems and landscapes, and the gray wolf, which is a recovering species but holds a position at the top of the food chain, would be useful to enhance baseline biodiversity information and plan future monitoring protocols.

Review of Proposed Physical/Chemical Indicators

Air Quality. In determining the adequacy of an indicator to be used to determine environmental trends, there are several factors that need to be considered. One is spatial distribution of the monitoring system. The system should be designed to provide representative trends over specific geographic areas where the pollutant is of concern. For example, the concentrations of some pollutants are fairly homogeneous over large geographic areas, so an evenly distributed, low density monitoring system would be optimum. Conversely, other pollutants exhibit sharp concentration gradients that require more densely located monitors near specific sources or source areas.

Another consideration is the actual statistic that is used to determine the trends. Some of the statistics in use are: the annual average concentrations or deposition rate, the annual maximum 1-hour concentration (some use second highest), annual maximum 8-hour concentration, or the number of times the concentration exceeded a certain concentration (usually the National Ambient Air Quality Standard). The most appropriate measure depends on whether the concern is over acute or chronic effects. However, even if the effect of concern is acute, a trend in the maximum 1-hour concentration or the number of times the standard is exceeded may not be appropriate statistics to use to evaluate the effectiveness of a control strategy. A good example of this is ozone. An ozone concentration over the standard is an extreme value associated with a rare meteorological event in Michigan. The highest concentrations occur on the hottest days of the year. Consequently tracking the extreme ozone concentrations may be a better indicator of the number of 90-degree days in a summer than of the effectiveness of air quality strategies. One way to improve upon this is to adjust the data for meteorological variability (Wolff *et al.,* 2001). Another way is to use a more robust statistic like a 95th percentile, which is more insulated from rare extreme events (Chock, 1995; Korsog and Wolff, 1991).

The state proposed six air quality measurements as environmental indicators: A*mbient Levels of Criteria Pollutants and Air Toxics, Rates of Deposition of Persistent and/or Bioaccumulative Air Toxics, Emission Rates for Criteria Air Pollutants and Air Toxics,* and *Pollutant Standards Index* (Appendix 4). Adverse effects of air pollutants are due to inhalation or deposition of the pollutants. The effects are proportional to the concentration inhaled or the amount deposited. Consequently, the most productive way to document the progress of the state's air quality management programs is to document the trends of the ambient concentrations and deposition rates of the pollutants of concern (e.g., MDEQ's recommended measurements of *Ambient Levels of Criteria Pollutants and Air Toxics*, and *Rates of Deposition of Persistent and/or Bioaccumulative Air Toxics,* Appendix 4). A second but less useful type of measurement is pollutant emission rate estimates (e.g., MDEQ proposed measurement of *Emission Rates for* C*riteria Air Pollutants and Air Toxics,* Appendix 4). These latter measurements are useful management tools, but because they are estimates, and because they may relate to ambient concentrations in a non-linear way, they are better used as programmatic measurements rather than environmental indicators.

The third type of measurement proposed by the state is a *Pollutant Standards Index*. The index was developed by the USEPA to provide a simple, uniform way to report daily air pollution concentrations. It also allows governmental agencies to advise the public about the health effects that are associated with various levels of pollution and to advise precautionary steps if conditions warrant. Episode criteria and significant harm levels have been established for the various air pollutants used in the index. While useful as a public health media tool, the index is based more on judgment than rigorous scientific measurements and is, therefore, open to considerable interpretation.

<u>Concentration Measurements: Criteria Pollutants</u>

Air pollutants of concern are categorized into two groups: criteria air pollutants and hazardous air pollutants. The criteria pollutants are relatively ubiquitous because they are either emitted directly of result from the emission of combustion processes, and have been the target of air quality management programs for over 30 years. Consequently, there is a substantial infrastructure that exists to monitor the concentrations of these pollutants throughout the state. The criteria pollutants consist of sulfur dioxide, nitrogen dioxide, ozone, carbon monoxide, particulate matter, and lead. The basis for each measurement and its use as indicators is presented below. Information on the monitoring networks, pollutant levels, and trends was obtained from the MDEQ (1999a).

Sulfur Dioxide - Sulfur dioxide has a 3-hour, a 24-hour and an annual standard reflecting concerns over both acute and chronic effects. Control strategies that have been implemented over the last 30 years have reduced concentrations in Michigan to about 20 percent of the allowed standards. Monitoring stations remain in a number of locations in southern lower Michigan and one in the Upper Peninsula. They are sited at locations that used to be areas of concern. The Panel believes that they are sufficient to detect any potentially important inhalation impact in the state. The most appropriate indicator in terms of judging the overall effectiveness of emission controls is the trend of the annual mean. For the acute exposure indices, the 95th percentile should be used instead of the annual maxima.

Nitrogen Dioxide - The only part of Michigan where nitrogen dioxide was ever a concern from an inhalation perspective was in the Detroit Metropolitan area. Consequently, there are only three monitors in the state, all in the Detroit area. The only standard is an annual mean reflecting a concern from chronic exposure. Recent data show that the Detroit concentrations are about a third of the standard. The Panel believes that the limited monitoring is sufficient and that the trend of the annual average is the appropriate indicator.

Carbon Monoxide – Two carbon monoxide standards, a 1-hour and an 8-hour indicate the health concerns are from acute exposure. The main source of carbon monoxide is traffic so the concern is limited to urban areas in Michigan. Because of the large emission reductions that have occurred, Michigan is only required to monitor carbon monoxide in the Detroit Metropolitan area where the MDEQ has eight sites. In addition, it operates one site in Grand Rapids. In Detroit, the maximum 8-hour concentrations were less than 50 percent of the standard, and the maximum 1-hour concentrations were less than 33 percent of the standard. Given these low concentrations, the monitoring appears adequate. However, neither of the indicators reported by the MDEQ are robust because they are at the mercy of unusual weather events. The 95th percentile of both would reflect better the impacts of the emission control programs.

Lead – With the removal of lead from gasoline, the concern over the inhalation route of lead has disappeared except in a few areas of the country where there are large stationary sources of lead (Bulkley *et al.,* 1995). None of these sources are in Michigan. Because there are small stationary sources of lead in the state, the Panel recommends that lead be included in the suite of hazardous air pollutants (HAPs) that are measured. Measurements of HAPs are discussed in a later section.

Ozone – Presently a 1-hour standard exists, but in the near future an 8-hour standard is expected. In any event, the concern is for acute exposure. The MDEQ maintains an extensive monitoring network with 24 monitors operating in the southern two-thirds of the Lower Peninsula. The coverage appears to be sufficient to determine trends. As mentioned above, ozone concentrations are significantly affected by meteorology. In Michigan, 40 to 60 percent of the variance in the 1-hour daily maximum ozone concentrations can be explained by meteorology (Wolff *et al.,* 2001). With such a dependency on meteorology, even the trend of the 95th percentile is dominated by the meteorology (Korsog and Wolff, 1991). To overcome this dilemma, a number of statistical techniques have been developed to factor out the meteorological influence. The most promising appear to be time series techniques (Porter *et al.,* 2001; Rizzo and Scheff, 2000). The North American Research Strategy for Tropospheric Ozone is in the process of reviewing the various techniques (Porter *et al.,* 2001; Wolff *et al.,* 2001). The Panel recommends that the MDEQ study these reviews and select an appropriate method.

Particulate Matter – Presently, there exists a 24-hour and annual standard for particulate matter (PM) less than or equal to 10 μm in diameter (PM_{10}) and it is expected that a 24-hour and annual standard for particulate matter less than or equal to 2.5 μm in diameter ($PM_{2.5}$) will be forthcoming in the near future. Consequently, both the chronic and acute exposures are of concern. PM_{10} monitors are located in southern Michigan in areas that historically had PM problems. Presently, 24-hour and annual concentrations average about 50 percent of the standards so the spatial coverage appears to be sufficient. The annual average is a robust indicator, but the maximum 24-hour concentration is not. It is recommended that a 95th percentile be used instead as the indicator for the 24-hour measure.

Within the last two years, the MDEQ deployed an extensive network of $PM_{2.5}$ monitors throughout the entire state. The annual average and the 95th percentile are appropriate indicators for $PM_{2.5}$ as well.

Concentration Measurements: Hazardous Air Pollutants (Air Toxics)

The HAPs differ from the criteria pollutants in that they are generally less ubiquitous, more localized, and are managed differently. For criteria pollutant, an ambient air quality standard is set and then an emission reduction strategy is developed to achieve the standard. For HAPs, there are no ambient air quality standards. These are managed by applying state-of-the-art emission control technology (see Wolff *et al.,* 1999).

The HAPs, as referred to in this report, include 188 substances identified by the USEPA and some 750 substances for which the MDEQ has developed screening levels. Most of the substances on these lists likely exist in harmless concentrations in the atmosphere and are only an issue of concern within the fence line of the source. The USEPA is in the process of identifying substances from the list of 188 that potentially exist in the atmosphere at concentrations that may pose an inhalation risk. Thus far, it has identified some 33 compounds and these are included in the MDEQ's HAPs monitoring program discussed below.

Before the measurements are discussed, however, there is another subset of HAPs that warrant identification. This subset has been called the persistent hazardous air pollutants (PHAPs) (Wolff *et al.,* 1999) and the 15 Great Waters Pollutants of Concern (USEPA, 1997). None of these substances pose a risk from the inhalation route at present ambient concentrations, but their persistence allows them to be transported long distances before they deposit and accumulate in the environment over time. Some of these substances have the ability to bioaccumulate and biomagnify resulting in concentrations in top predatory species that are several orders of magnitude higher than in the natural waters or in the lower levels of the food chain. These substances will be discussed further in the Deposition Measurements Section of this report.

In 1990, the MDEQ began a program to monitor HAPs with a goal of characterizing ambient concentrations in the major urban areas in Michigan. Since the program began, there has been funding to only operate approximately three sites per year. Consequently, in order to characterize all the urban areas, sites were moved around after a year or two. As a result, the monitoring has been of limited term at any given site. Recently, the Michigan Relative Risk Air Quality Issues Task Force (Wolff *et al.,* 1999) attempted to construct trends with the help of MDEQ but concluded the data were not amenable to such an analysis. The Task Force recommended the creation of a HAPs database be a high priority. As a result, the MDEQ is in the process of developing a comprehensive monitoring strategy that in the future will include ambient levels and deposition sites for HAPs (Appendix 4; MDEQ, 2000b).

In its present form, the plan calls for the establishment over a five-year period of 35 HAPs sites located throughout the state. Sampling will be conducted every 12th day. The network is being designed to: (1) determine spatial distribution of the HAPs on both statewide- and urban-scales, (2) assess trends, (3) determine background and transport concentrations, and (4) identify hot spots. The HAPs species that will be monitored have not been determined yet but consideration is being given to a long list that includes the USEPA's 33 priority substances (USEPA, 2000b). Such a monitoring network will be more than sufficient to provide indicators of HAPs throughout the state. With a 12-day sampling schedule, consideration should be given to using the mean or the median values as the appropriate indicators.

<u>Deposition Measurements: Hazardous Air Pollutants (Air Toxics)</u>

At present, the MDEQ conducts no routine deposition measurements. However, the comprehensive HAPs measurement plan, which is under development, includes five to 16 deposition sites, depending on the parameters being measure. For example, pesticide data will be collected at five sites while mercury will be sampled at 16 sites. Species that will be analyzed for are the 15 Great Waters Pollutants of Concern. The appropriate indicators are the annual wet and dry deposition rates.

While the Great Waters Pollutants of Concern include nitrogen species, they do not include sulfur species or acidity. Because of concerns about acid deposition in certain sensitive areas in the Upper Peninsula, the Panel recommends that sulfur and acidity deposition measurements be added at two or more sites.

Contaminants in Water. Numerous measurements can be made in flowing and still surface waters to indicate, directly and indirectly, the habitability of those waters by plants, animals, and insects. The measurements range from dissolved oxygen, which must be above a certain level in order to support life, to the amount of suspended sediment, which can limit sunlight penetration and, therefore, the photic zone or the depth to which plants can live.

The Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, authorizes the MDEQ to develop water quality standards (WQS) to protect the quality of state waters. The purposes of the WQS are to: (1) establish water quality requirements for the Great Lakes, their connecting waterways, and all other surface waters of the state; (2) protect public health and welfare; (3) enhance and maintain the quality of water; (4) protect the state's natural resources; and (5) carry out the aims of the federal CWA and the Great Lakes Water Quality Agreement between the U.S. and Canada. Michigan's WQS for surface waters are based on uses designated by the state and are protected accordingly. These designated uses are agricultural, industrial, and municipal water supply; navigation; body contact recreation; and use by aquatic life and wildlife. The goals of the WQS are to protect Michigan's surface waters for fishable and swimmable uses. Fishable waters are those where the protection and propagation of fish, shellfish, and wildlife are guaranteed. Swimmable waters are those that are safe for recreation on and in the water (Gracki *et al*., 2000).

According to the MDEQ (Appendix 4), several rivers around Michigan were monitored for a variety of water quality parameters by the state on a monthly basis during the 1970s and 1980s. By 1997, the state's water chemistry trend program consisted of monitoring only the Saginaw Bay and Detroit River. In 1998, the state's water chemistry trend program was expanded to include sample collections from major Great Lakes tributaries, all three Great Lakes connecting channels, and the Grand Traverse and Saginaw Bays.

Currently, water samples are collected from 31 Michigan tributaries to the Great Lakes. Six of these rivers (Au Sable, Clinton, Grand, Kalamazoo, Muskegon, and Saginaw) are sampled intensively (12 times) every year using a flow-stratified design in which most samples are collected during high flows. The remaining 25 sites are sampled intensively on a flow-stratified basis once every five years, consistent with the MDEQ's National Pollution Discharge Elimination System 5-year rotating basin schedule, and at a lower level (4 times) during the other four years. Loading rates are calculated on tributaries from which 12 samples are collected. Samples are collected using clean techniques and are analyzed using low-level, USEPA-approved methods.

All samples are analyzed for nutrients (total and ortho-phosphorus, nitrate, nitrite, ammonia, Kjeldahl nitrogen), ions (sulfate, calcium, chloride, magnesium), and conventional parameters (temperature, conductivity, hardness, suspended and dissolved solids, pH, dissolved oxygen, and total and dissolved organic carbon). In addition, total mercury and trace metals (cadmium, chromium, copper, lead, nickel, and zinc) also are measured at all sites.

The MDEQ recently completed a project establishing ratios of total and dissolved metals in several Michigan rivers. According to the MDEQ (see Appendix 4), this information can be used to convert total metal concentrations to dissolved concentrations, if necessary. In addition, if data for total metals concentrations indicate possible exceedance of water quality standards, then follow-up sampling using dissolved techniques will be conducted. The Panel suggests that care should be taken with this protocol, however, since the ratio of dissolved to total metals is not simply a function of suspended matter concentration. The amount of particulate organic carbon, the surface area per unit, mass of the particles, etc. all play a role. In addition, the potential for sample contamination is high when concentrations are in the part per billion to part per trillion range. Finally, often the species of a specific dissolved metal is what is most important from a toxicity standpoint (e.g., chromium (VI) versus (III) or the free ion activity of cadmium versus the cadmium-chlorine ion pair). The Panel would caution against doing dissolved metals unless there was a compelling argument otherwise and one that would give unique information relative to what is obtained by analyzing biota or sediments.

The MDEQ is currently working with the U.S. Geological Survey to collect samples from additional sites around the state to ensure broad statewide coverage. The purpose of the state program is to evaluate the extent of attainment of Michigan WQS, measure temporal and spatial trends in contaminant levels, identify high-quality waters; provide data for water quality protection programs, determine exposure of aquatic life, and identify emerging problems. Data are reviewed each year to determine whether additional parameters should be added, removed, or analyzed at a greater or lesser frequency (Appendix 4).

The Panel recognizes that most of the MDEQ administered water quality monitoring programs have been designed to evaluate how well state and federal regulatory mandates are being met rather than to serve as tool to detect changes in the overall quality of the state's environment. Despite this, the water quality data collected may be used to identify and assess directly and indirectly changes in environmental quality. Consequently, the Panel recommends that the current water quality monitoring programs be reported on in the state's environmental indicators report. In addition, the Panel suggests that an evaluation be conducted by the MDNR and MDEQ to determine how these data can be best used to complement other environmental indicator protocols.

Contaminant Levels in Inland Lakes Sediments. The purpose of the state's proposed *Inland Lakes Sediments* indicator is to record the level of contaminant loadings to the aquatic environment and to measure the level of possible exposure of aquatic life to toxic contaminants in near surface sediments. Chemicals that are routinely monitored under this program include mercury, trace metals, PCBs, and other selected organic parameters (Appendix 4). The Panel agrees with the MDEQ that chemical loadings in the sediments of inland lakes are good indicators of exposure and potential impacts to aquatic life. In addition, this information is useful to better understanding the nature and extent of both past and current trends of contaminant loadings as well as helping to assess the impact of future changes. This is a well tested approach and provides a solid framework for this indicator.

The Panel suggests, however, that the word, *trends* be added to the title of the indicator since the current title does not reflect the temporal aspects of this indicator. Considering the temporal aspects of this indicator, it also is suggested that the MDEQ description for the *Measure* be modified to read, "*Recent and historical concentrations of chemicals in the sediments from inland lakes*."

The design of this indicator allows interpretations to be made on the effect of land use, land use change, other anthropogenic activities, and natural events on chemical loadings. It should be made clear that for these interpretations to be possible, not only do the organic and inorganic contaminants of interest need to be measured, but other non-contaminant elements need to be measured as well. Elements such as aluminum, iron, and calcium have biogeochemical behaviors that are fairly well known and can be used to make interpretations on the effects of events (natural and anthropogenic) on the trends in contaminant loadings observed in the sediment cores. In most cases, inductively coupled plasma mass spectrometry (ICP-MS) is used to measure the metal contaminants. Because of the capabilities of the ICP-MS that allow for the simultaneous measurement of many elements, the non-contaminant elements are measured as well. In addition, the organic carbon content and percent sand, silt, and clay should be determined on each sample to help interpret the data. Finally, vertical cores of undisturbed sediments should be collected and subsections taken to be analyzed for contaminants. These same subsections should be dated by lead-210 and cesium-137 radioactive isotope protocols to provide historical trend data.

The Panel agrees with the MDEQ that this indicator will be reported infrequently. It is quite possible, however, that the reporting frequency might vary for each lake depending on the sedimentation rates that will determine the minimum time period between sampling event and current levels and trends that will determine urgency for measurement.

The proposed Inland Lake Sediment Trends indicator will provide a large spatial and temporal database on the environmental geochemistry of lakes in Michigan. It will serve as a reference condition from which decisions can be made as to health of the lakes and future monitoring efforts. In addition, because of its spatial extent, this database will be important for the Great Lakes Region. The implementation of this indicator is also important as it addresses another weakness in many environmental monitoring approaches; that of being contaminant or target specific as opposed to being multi-element. The multi-element approach attempts to incorporate the surrounding biogeochemical environment so that more informed decisions can be made on contaminant loading history, fate, and mobility. The Panel recommends that this indicator be included in the state's environmental indicator program.

Contaminant Levels in Fish. The state has been collecting data on *Contaminant Levels in Native Fish* continuously since 1990 (Appendix 4). Currently, fish are collected every three to five years from 26 fixed trend locations representing inland lakes, rivers, Great Lakes, and connecting channels. Tissues are analyzed for selected bioaccumulative chemicals (PCBs, chlorinated pesticides, and mercury). These data are used to evaluate temporal and spatial trends in fish contaminant levels throughout the state. In addition, the state collects additional fish contaminant data through caged fish studies and the fish consumption advisory process. These data also are used, where possible, to detect trends in fish contaminants. Finally, the state works with several federal agencies and other states to implement a fish contaminant trend program for the Great Lakes.

Tracking the levels of contaminants in fish populations can provide an excellent indication of aquatic ecosystem health since:

1. Fish live in the water all of their life and, therefore, the levels of contaminants in their bodies can reflect levels in water. Further, as fish prey on the species below them in the food chain, concentrations of chemical contaminants can bioaccumulate in the flesh of fish reaching levels many times higher than those found in the water (DeVault, Willford and Hesselberg, 1985). Therefore, contaminant level trends in fish flesh can provide a sensitive indicator of contaminant levels in the water in which they live (USEPA, 1996; Hellawell, 1986);

2. Different species of fish differ in their tolerance to amount and types of pollution. Further, different life stages of fish also respond differently to pollutants (Hellawell, 1986);

3. Fish communities are persistent and recover rapidly from natural disturbances. Fish communities respond to disturbances with predictable developmental stages. Deviations from community succession can indicate the presence and persistence of environmental stressors such as chemical contaminants (Whittier and Paulson, 1992; Schindler, 1990; Karr, 1981);

4. Fish represent a broad spectrum of community tolerances ranging from very sensitive to highly tolerant and respond to chemical, physical, and biological degradation in characteristic response patterns; and

5. Fish are highly visible and valuable components of aquatic communities and also are important food and recreational targets for humans. Because contaminants in fish can be transferred to humans and pose a human health risk, contaminant levels in fish are of concern to the public. This makes them a valuable indicator for communicating ecosystem health and contaminant trend information to the public.

Based on successful experience with studies investigating human diseases, one promising avenue for demonstrating causality between toxic substances and reproductive dysfunction in Great Lakes organisms is offered by epidemiological methods (Zint *et al*., 1995; Fox, 1989) (see Table 2). In applying these methods to lake trout, Mac and Edsall (1991) concluded that there was strong evidence for maternally derived PCBs causing reduced hatchability in eggs from southeastern Lake Michigan under the rules of time order, strength of association, and coherence. They also believed there was equally strong evidence for toxic substances causing the swim-up of fry mortality syndrome under the rules of strength of association, specificity, replication, and coherence.

The Panel recommends that this measurement be incorporated in the state's environmental indicators program and be coordinated with the MDNR's and MDEQ's fish and benthic macroinvertebrates monitoring programs described earlier in this report.

Contaminant Levels in Bald Eagles. The state proposed that a *Bald Eagle* sampling program designed to evaluate and track the levels of mercury, PCBs, and other bioaccumulative chemicals of concern be considered as one of the environmental indicators (Appendix 4). The state program, which was begun in 1999, involves the collection of blood and feather samples from nestling bald eagles at 12 fixed inland locations as well as accessible Great Lakes and connecting channel nests. The inland nests are located primarily in the Upper Peninsula and the northern Lower Peninsula. Initially, these fixed locations will be sampled annually (as long as they are occupied by eagles) to establish a trend baseline and to measure annual variability in contaminant levels. Each year during this initial period, the data will be analyzed to determine whether continued annual sampling is justified or whether a less intense sampling frequency is sufficient. In addition, bald eagle sampling in watersheds on the 5-year permit basin cycle will create a statewide trend database, but the trend analysis will be less rigorous than possible with the annual sampling.

Table 2. Description of the Rules used in Epidemiology.

Rule	Description
Time Order	Cause must precede effect in time.
Strength of Association	Greater exposure must result in a more severe effect.
Specificity	A precise association between the proposed cause and the observed effect must exist.
Consistency on Replication	Repeated observations under different circumstances must have the same outcome.
Coherence	The proposed cause-effect relation must not conflict with existing knowledge (e.g., biology of the organism).

The Panel recognizes that the eagle represents a top predator and that it has been a good sentinel in the past to help track the impacts of such contaminants as 1,1,1-trichloro-2, 2-bis (p-chlorophenyl) ethane (DDT); however, eagles eat carrion, as well as animals other than fish and it will be difficult to determine the locations of the feeding sites, and thus the contamination source, and it is questionable whether what was true for DDT will be necessarily the same for other contaminants of concern. Given these limitations, the Panel suggests that this proposed indicator might have only limited utility.

Climate and Weather Change. In July 1992, the Michigan Relative Risk project identified 24 environmental issues of concern in Michigan in a report entitled, *Michigan's Environment and Relative Risk* (Rustem *et al.,* 1992). The issues were classified into one of four relative risk categories: high-high, high, medium-high, and medium. Global climate change was ranked in the high-high category. Because Michigan is both the northern and southern extent of numerous ecosystems, any small change in climate could have a significant impact on these ecosystems. In additional, agricultural operations are located where they are because of the local climate. Consequently, a changing climate could have an impact these operations as well.

Although no state agency has the responsibility to collect and analyze weather and climatic indicators, the Panel recommends that such data and analyses be included in the indicator report. Throughout the state, there are about 140 weather stations where observers collect daily maximum and minimum temperatures, precipitation and snowfall amounts, and measure snow depths. Many of the sites have been in existence since the early 1900s. These data are transmitted monthly to the National Climatic Data Center and a statewide summary published monthly in *Climatological Data – Michigan.*

The data collected in Michigan are divided into ten climatic divisions: west upper, east upper, northwest lower, northeast lower, west central lower, central lower, east central lower, southwest lower, south central lower, and southeast lower. Each division has an average of 14 sites – some rural, some urban. The Panel suggests that some agency be designated within the state to take the lead to analyze trends in these data. The first task would be to identify the record length for each site and select those sites for trend analysis that have a sufficient continuous record length. The beginning record should be the same for all the sites selected and should be as early in the 1900s as feasible. The sites should then be divided into rural and urban sites. Annual time series would then be created for each climatic division for urban and rural sites separately. The reason for the rural/urban separation is to remove the urban *heat island* effect from the rural database.

The parameters that should be examined are: annual average temperatures, annual average daily maximum temperature, annual average daily minimum temperature, average diurnal temperature range, length of growing season (defined as the number of days between the last freeze in the spring and the first freeze in the fall), heating degree days, cooling degree days, annual precipitation, and annual snowfall amount. If resources are sufficient, the Panel recommends that the trends also be analyzed by season. Time series graphs should be created for each of the above indicators. Also a linear regression analysis should be performed on the data to determine the magnitude and slope (if any) of the regression line that should also be shown on the graphs.

Master Stations

Michigan's natural environment is dynamic and both temporally and spatially variable. To accurately track changes and trends taking place in Michigan's environment would require enormous financial and human resources. Since such resources are not likely to be forthcoming, it is important to optimize existing state environmental monitoring programs to obtain the most accurate and precise estimation possible with the available resources. Consequently, the Panel recommends that the state consider the establishment of a system of Master Stations where environmental indicator data would be consistently and uniformly collected.

Goal. The goal of a Master Stations program would be to systematically and consistently collect spatially distributed, temporal information of biotic, chemical, and physical elements of the environment of the state. Master Stations would need to be intensively monitored for a wide range of biological, physical, and chemical parameters. These environmental data collection sites would be permanent to provide long-term trend analyses. Such a system also would incorporate a more distributed sampling grid and would optimize and integrate existing state monitoring programs.

Approach. Between 10 to 25 Master Stations (ranging from tens to hundreds of hectares in size) should be selected in order to reasonably represent the major landscape/waterbody types and geographic regions across Michigan. In order to determine status and trends in the biotic and abiotic components of the sites, the state would need to conduct intensive monitoring and assessment activities at the designated sites at the desired scales and necessary frequencies to obtain the data needed. The Panel recognizes that extrapolations of status and trends of some components, such as mercury, from these sites to the total universe of Michigan's ecosystems would be difficult. For other components, such as ultraviolate radiation, the site specificity may not be as great. The important thing is that the Master Stations would provide a detailed picture of the biotic and abiotic conditions and trends at a number of sites around Michigan.

A portion of Michigan's monitoring activities should be focused on larger geographic areas, such as the western Upper Peninsula or Southwestern Michigan, relative to the Master Stations. Monitoring in these areas would be less intensive and more dispersed. It is highly likely that there would be a Master Station undergoing more detailed assessments located in each of the larger geographic areas. Apparent findings or trends in the dispersed monitoring could be compared with observations made at the Master Stations.

Michigan occupies a large portion of the Great Lakes' watershed. Therefore, the data collected from the monitoring stations will not only be important for the state, but for the region. In addition, this concept would provide an approach to environmental monitoring that might be implemented in other Great Lake States and become the framework by which national and international Master Station systems might be established. The United States already has the elements of such a system in place currently with its Long-term Ecological Research Station Program.

Collaboration. Results from measurements taken at the Master Stations would allow hypotheses to be formulated about other areas within the state, and experiments to be designed and conducted by the state and/or others (e.g., academic researchers) to test those hypotheses.

Implementation. A suggested strategy for the development of Master Stations in Michigan could be as the follows:

1. Identification, recognition, and incorporation, where appropriate, of the:

    (a) Accumulated database of indicator measurements collected by the MDNR, MDEQ, and federal government (e.g., U.S. Geological Service stream gauging program, USEPA (e.g., STORET data), and

    (b) Current database of indicator measurements collected by newer programs (e.g., the MDEQ's Michigan Sediment Trends Program) for additional insights into the spatial and temporal dynamics of Michigan's environment;

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2. Establishment of a *temporary* task force involving state, academic, and perhaps federal scientific personnel to collect, organize, and synthesize the environmental data outlined in item 1 above;

3. Assignment of a subtask force to develop a general design framework for the Master Stations;

4. Holding of scientific workshop(s) to finalize the design and distribution of the Master Stations;

5. Selection of three to five pilot Master Stations to be established even before the final designs and locations for the permanent stations are agreed on. These pilot Master Stations might mask use of current monitoring stations associated with federal and state projects, as well as university initiatives (e.g., the Long Term Ecological Research site at Michigan State University's Kellogg Biological Station, University of Michigan's Douglas Lake facility); and

6. Development of an interactive state website where a portion of the ongoing information collection could be made available to the general public. This would allow real time data to be available to citizens in Michigan and the Great Lakes region. Suggested information might include, physical measurements (e.g., temperature, rain, and stream gage/discharge), biological measurements, and chemical measurements (e.g., river dissolved oxygen and rain chemistry).

Basic Environmental Monitoring Design Considerations

Ideally, data from any monitoring program should be used only to answer the questions the program was designed to address. This is often not the case. More frequently than not, data generated by monitoring programs are used for scientific input into questions that were not considered when the program was designed and for which the dataset is seldom adequate. As a result, the questions go unanswered, or worse, the data are used improperly and a wrong or inconclusive answer is derived. For instance, monitoring Michigan's standing crop of Jack Pines, by itself, does little to help ascertain the ecological health of Michigan's forests. Hence, it is not scientifically possible to extrapolate Jack Pine abundance to general forest health. By the same token, compliance monitoring of criteria air pollutants, while important to discern trends in human exposure to hazardous substances, does little to answer questions about the health of ecosystems. Yet these types of data sets are often used by state and federal agencies and environmental organizations as indicators of overall environmental health. If they are indicators, they are only marginally so.

Selecting environmental indicators to monitor requires a careful definition of what it is that needs to be detected. Unfortunately, *ecosystem health* and *environmental health* are somewhat nebulous terms that defy measurement by any manageable set of indicators. It follows, therefore, that subsets or aspects of the environment and a determination of their health or status should be more precisely defined by picking indicators appropriate for those subsets.

The task of determining appropriate indicators is somewhat simplified by application of the first three steps of the *Scientific Method* (observations, hypothesis formulation based on the observations, and experiments to test the hypotheses) to the problem. For instance, there is little doubt that global temperatures are rising. This statement is based on extensive research of the Quaternary period and historical observations ranging from rising sea levels or shrinking ice caps to integrated daily temperature measurements from various locations. It can be logically hypothesized, therefore, that some plant species will move north and some cold tolerant species will disappear from their present habitats as has occurred several times before in the geological past. To test this hypothesis, indicators should be chosen (e.g., temperature-limited plant species), sampling designs created (i.e., when, where, how and for how long to observe or monitor the plants) and a program implemented that will test or try to disprove the hypothesis. This is radically different from assuming that, for instance, existing plant monitoring programs designed to ascertain abundances of commercially important and actively managed timber species will be able to detect such changes.

The Panel recommends that a thorough and systematic examination of existing and proposed monitoring programs should be undertaken by both the MDNR and the MDEQ to explicitly delineate what can and cannot be derived from the collected data.

Adaptive Approach

Given the countless variables that comprise environmental quality and the uncertainty involved with effectively evaluating environmental phenomena, it is important for the state to strongly consider an *adaptive management* approach (Walters, 1986) to its indicators monitoring program. This means that there should be a periodic, systematic review of how well the chosen environmental indicators are working (or not working) to achieve the underlying objectives of tracking environmental quality. In general, this type of review should include: (1) the relevance of the data collected to the questions being posed, (2) accuracy and precision of the data, (3) limitations of the data, (4) efficiency of data collection, and (5) refinements, where needed, to the monitoring approach. This type of periodic review might best be accomplished by an independent panel of scientists.

Conclusions and Recommendations

The specific charge given to the MESB by Governor John Engler was to review a set of environmental indicators proposed by the MDEQ and MDNR for use in Michigan to determine whether the indicators have a sound scientific basis, and also to determine if change in the quality of the environment can be ascribed to observed changes in indicator values from one reporting period to the next (Engler, 2000).

Two general themes were considered in the Panel's review of the state's proposed indicators. First, in addition to evaluating the proposed environmental measurements individually, the Panel evaluated the indicators collectively from the standpoint of their being able to be developed into an integrated, adaptive, and informative program capable of identifying and monitoring statewide environmental trends. Second, the Panel advanced the concepts of biodiversity as an important guiding principal in the selection of ecological indicators and the need to establish a sound biodiversity information baseline for these measurements.

The 21 environmental indicators recommended by the Panel for use in Michigan are presented in Table 3. This list is based on a review of the environmental measurements that are currently being monitored or, in the case of three indicators (Ambient Levels of Air Toxic Contaminants, Persistent and Bioaccumulative Air Toxics, and Mammalian Populations), proposed to be monitored in the future. In addition, the list includes one indicator (Climate and Weather Change) that neither the MDNR nor MDEQ is currently tracking, but would be needed to be taken into consideration in the state's evaluation of all the other indicators.

Table 3. Recommended Michigan Environmental Indicators.

Ecological Indicators:	Land Cover
	Breeding Bird Abundance
	Trends in Habitat of Interior and Edge Bird Species
	Trends in Game Fish Populations
	Trends in Fish and Benthic Macroinvertebrate Populations
	Trends in Frog and Toad Populations
	Invasive Species
	Forest Acreage, Mortality, Growth and Removals
	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 Mammalian Populations
Optional Indicator:	Contaminant Levels in Bald Eagles

The Panel found that several of the state's environmental measurements were often times not systematically and consistently collected in terms of location and methodology. Consequently, the Panel recommends that the state employ the use of a protocol for sample collection, referred to as *Master Station*s and described in the report, from which it can systematically and consistently collect biotic, chemical, and physical information on the state's environment. The Master Stations would need to be: permanent to provide long-term trend analyses, incorporate a distributed sampling grid, intensively monitored, and integrated and optimized with the existing state monitoring programs.

The reporting frequency outlined in the state's Environmental Indicators Act (1999) is every two years. Given the number and variety of different environmental indicators recommended, the different degrees of development of baseline information for each of the indicators, and the individual natural biological and physical dynamics of each indicator, the Panel concluded that a two year reporting period may not be sufficient to accurately determine a change in the quality of the environment for many of the recommended indicators. Many of the recommended environmental indicators will require a much longer time frame before trends and changes to trends can be discerned. The Panel offered suggestions for several of the state's proposed environmental indicators to improve the quality and interpretation of the data collected. It is recommended that the state address the various issues raised by the Panel to explicitly delineate, where needed, what can and cannot be derived from the data collected from the recommended indicators. In addition, the Panel suggests that after the state's environmental indicators program has been instituted, periodic, systematic reviews be conducted by the state to determine whether the recommended environmental indicators are achieving the underlying objectives of tracking environmental quality.

Finally, in making the various recommendations throughout this report, the Panel was cognizant of the fact that most state environmental monitoring programs described by the MDEQ and MNDR were designed initially to fulfill a specific state or federal regulatory mandate for information rather than to generate specific ecological information. Consequently, the Panel recognizes that several of its recommendations may need to be evaluated further by the state before they can be fully implemented. Given this recognition, the Panel recommends that the state not try to institute all of the suggestions made by the Panel before its first legislatively required report in October 2001. Rather, it would be more productive for the state to incorporate the suggested changes and report on what it can currently and to take the additional time needed to carefully develop the more involved Panel recommendations (e.g., development of Master Stations).

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Appendix 1
Public Act 195 of 1999 (Environmental Indicators Act)

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Act No. 195
Public Acts of 1999
Approved by the Governor
December 15, 1999
Filed with the Secretary of State
December 16, 1999
EFFECTIVE DATE: December 16, 1999

STATE OF MICHIGAN
90TH LEGISLATURE
REGULAR SESSION OF 1999

Introduced by Senators Sikkema and Young

ENROLLED SENATE BILL No. 462

AN ACT to amend 1994 PA 451, entitled "An act to protect the environment and natural resources of the state; to codify, revise, consolidate, and classify laws relating to the environment and natural resources of the state; to regulate the discharge of certain substances into the environment; to regulate the use of certain lands, waters, and other natural resources of the state; to prescribe the powers and duties of certain state and local agencies and officials; to provide for certain charges, fees, and assessments; to provide certain appropriations; to prescribe penalties and provide remedies; to repeal certain parts of this act on a specific date; and to repeal certain acts and parts of acts," (MCL 324.101 to 324.90106) by adding section 2521; and to repeal acts and parts of acts.

The People of the State of Michigan enact:

Sec. 2521. (1) The department of environmental quality, in conjunction with the department of natural resources, shall biennially prepare a report that assesses the status of and trends related to the overall state of the natural environment in Michigan. The report shall be based upon environmental indicators identified by the departments of environmental quality and natural resources and upon data obtained through sound scientific methodologies and processes. The report shall be submitted to the governor, to the standing committees of the legislature with jurisdiction over issues primarily related to natural resources and the environment, and to the senate and house appropriations subcommittees on environmental quality and natural resources. The first report shall be submitted not later than October 1, 2001, and subsequent reports shall be submitted not later than October 1 every other year. The reports shall also be made available to the public electronically and, upon request, in paper format.

(2) The departments of environmental quality and natural resources shall monitor efforts undergoing in other states and nationally to establish uniformity among environmental indicators that might be included within the report.

(3) All state agencies shall cooperate with the departments of environmental quality and natural resources in carrying out their responsibilities under this section.

(4) As used in this section, "environmental indicator" means a measure of the state of the natural environment that can be derived from empirical data. The department shall use the most recent data available. If relevant data is not available, the department shall include in the report recommendations for gathering data in the future.

(5) This section is repealed effective December 31, 2005.

This act is ordered to take immediate effect.

Secretary of the Senate.

Clerk of the House of Representatives.

Approved
Governor

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Appendix 2

January 28, 2000 Correspondence to the Michigan Environmental Science Board from Governor John Engler

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STATE OF MICHIGAN
OFFICE OF THE GOVERNOR
LANSING

JOHN ENGLER
GOVERNOR

January 28, 2000

Dr. Lawrence Fischer, Chair
Michigan Environmental Science Board
P.O. Box 30680
Lansing, Michigan 48909-8180

Dear Dr. Fischer:

On December 16, 1999, I signed into law Public Act 195. The Act requires the Department of Environmental Quality (DEQ), in conjunction with the Department of Natural Resources (DNR), to biennially prepare a report that assesses the status of, and trends related to, the overall state of the natural environment in Michigan. The report is to be based on environmental indicators identified by the DEQ and DNR, and upon data obtained through sound scientific methodologies and processes.

Given the above, I am requesting the Michigan Environmental Science Board (MESB) to review the list of proposed environmental indicators by the DEQ and DNR. As part of this review, I would ask the MESB to evaluate each of the proposed indicators based on the following criteria:

1. Scientific basis for the use of the indicator as a measure of the quality of the environment (i.e., does the proposed indicator describe a measure of the natural environment); and

2. Utility of the indicator (i.e.; what would it mean in terms of the quality of the environment if there is a change in the value of the indicator from one reporting period to the next).

Mr. Lawrence Fisher
Page 2
January 28, 2000

I am directing the DEQ and the DNR to provide to the MESB a list of their proposed indicators along with a scientific justification for their inclusion, and to otherwise cooperate fully with the Board's review of this important issue. I encourage the Board to seek input from other outside interests and experts, as it deems necessary. I would appreciate the Board providing me with its evaluation as soon as possible.

Thank you for your continuing service to the citizens of Michigan.

Sincerely,

John Engler
Governor

cc: Mr. Russell J. Harding, Director, DEQ
Mr. K. Cool, Director, Director, DNR
Mr. Keith G. Harrison, Executive Director, MESB

Appendix 3

Proposed Environmental Indicators from the Michigan Department of Natural Resources

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1. MICHIGAN LAND USE

MEASURE
This indicator will measure the percent change in major land use and land cover types (referred to as land cover throughout this document). Land cover change will be shown through a series of charts and maps displaying trends in major land cover types. Major land cover categories include urban, agricultural, range, forest and wetlands.

Data points to illustrate changes in land cover may be drawn from statistical analysis derived from a variety of federal and state programs. Forest cover change could be assessed from analysis of data from the United States Forest Service's Forest Inventory and Analysis (FIA) Program (Schmidt, 1993). Agricultural, wetland, range, forest and urban land cover change could be assessed though analysis of data from the United States Department of Agriculture, National Resource Inventory (NRI) program (Natural Resources Conservation Service, 2000) and the Michigan Department of Agriculture (Michigan Agricultural Statistics Service, 2000). The NRI program has land cover statistics for 1982, 1987, 1992 and 1997. The FIA program collects much more detailed forest data than NRI. Detailed forest cover information is available from the FIA program for 1993 1980 1966, 1955, 1935 (R. Bertsch, per. comm.).

PURPOSE
A direct measure of changes in the percent of different land cover types provides a very useful indirect measure of ecosystem health.

High rates of land conversion place stress on natural ecosystems and may be associated with inefficient land use. Human population growth and/or dispersal usually cause a conversion of land cover types from natural vegetation or agricultural types to urban uses. These changes can have negative impacts on ecosystem health through loss of wildlife habitat and increased water and air pollution.

LIMITATIONS
This indicator provides a measurement of the conversion of the land cover type, but not a direct measure of the potential impact of the change on the environment. For example, conversion of a highly intensive, chemical-intensive agricultural area to an urban area, particularly one that is well planned, may result in less environmental stress.

Programs such as FIA and NRI that attempt to quantify changes in the landscape over long periods often undergo changes in their sampling protocols with each new survey. Efforts are made to maintain comparability among survey years but these protocol changes must be considered in any analysis of land cover change.

Using multiple landscape inventory programs that measure different components of land cover will cause some confusion with classification of major land cover categories. For example, a land cover type defined as forest in one classification system may be classified as urban in another classification system. Understanding change vectors (forest changed to agriculture or agriculture to urban) is very difficult when analyzing data from multiple programs.

The United States Geological Survey (USGS) has two programs that the Michigan DNR has cooperated with that map land cover (as opposed to sampling land cover like FIA and NRI). The DNR is the primary agency implementing the USGS GAP Analysis Program (Scott et al., 1993) in the state. The land cover mapping activity associated with this program has already been incorporated into the DNR's vegetation inventory program. The USGS's National Land Cover Characterization Project (USGS, 2000) has recently completed a land cover map for Michigan (circa 1993) and are planning for another map to be completed around 2002. DNR coordination with these USGS programs should produce land cover maps that are better designed for land cover change analysis. Maps of land cover change would allow analysis of change over relatively small environmentally sensitive areas.

Overall, this would be a very valuable indicator that would require strict land cover classification methodologies to be maintained over long periods of time. This can be difficult when improvements in land cover inventory technologies offer significant cost savings but may be so different from past technologies that inventory numbers are not comparable.

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2. MICHIGAN BREEDING BIRD ABUNDANCE

MEASURE

Relative abundance of breeding bird populations in selected habitat types.

PURPOSE

To measure the status of breeding bird populations and to indirectly measure the health of breeding bird habitat in Michigan.

DESCRIPTION

This is a measure of breeding bird relative abundance through the use of the annual Breeding Bird Survey (BBS) organized by the U.S. Fish and Wildlife Service (USFWS). Results for certain species guilds (e.g., grassland, forest edge, wetland, etc.) could be summarized by habitat types that lend themselves to this roadside count. This would show population trends for species guilds as well as an index of the health and abundance of the habitat on which they depend.

BASIS

The BBS was formally launched in 1966 when approximately 600 surveys were conducted in the U.S. and Canada east of the Mississippi River. The survey spread to the Great Plains states and Prairie Provinces in 1967. By 1968, approximately 2000 routes were established across southern Canada and the contiguous 48 states, with more than 1000 routes surveyed annually. During the 1980s, the BBS expanded into the Yukon and Northwest Territories of Canada, and Alaska. Additional routes have been added in a number of states. Today there are approximately 3700 active BBS routes across the continental U.S. and Canada, of which nearly 2900 are surveyed annually.

Protocols for data collection as well as the management of the database are well established, making this a reliable source of data for trend analysis. Each route is 24.5 miles (39.4 km) long, with 3-minute point counts conducted at 0.5 mile (0.8 km) intervals for a total of 50 point count stops. All birds heard or seen within a 0.25-mile (0.4-km) radius of each stop are recorded. These surveys begin 30 minutes before sunrise and normally require 4 - 5 hours for completion. Sky condition, wind speed, and temperature are also recorded at the beginning and end of each survey. Over 2500 skilled amateur birders and professional biologists participate in the program each year.

ILLUSTRATION
Trend data could be shown on a simple line graph with each species guild represented as a separate line. National trends for the same species assemblages could also be shown on this graph or separate graphs to put Michigan's data in context. National and/or regional maps could also be used to show continental distribution of the species in question.

LIMITATIONS
Roadside surveys like the BBS do not sample all avian species equally well. Nocturnal species like owls are difficult to sample in this daytime survey scheme. Less vocal species (e.g., woodpeckers, waterfowl, and raptors) are also poorly represented using this survey. Additionally, relative abundance estimates do not consider productivity of populations. Although these estimates are frequently used

To make generalizations about the quality of habitat for a given species, this can be misleading when large numbers of non-breeding individuals are forced into poor quality habitat by territorial breeding pairs. Abundance estimates can also be misleading when an area attracts breeding pairs, but is also an area of high adult or nestling mortality via predation, nest destruction, etc.

Wildlife populations fluctuate annually based on a number of factors including climate, seasonal food resources, predator numbers, disease outbreak, habitat change, etc. Although the BBS is conducted on an annual basis, the real value of this database is for long term monitoring. Fluctuations over the 2-year reporting window are only valuable when compared to the long-term trend. It's also important to note that migratory species are impacted both by changes on their breeding grounds here in Michigan as well as on their wintering grounds. With that said, the avian diversity of Michigan is an integral part of the State's natural resources, and we should be aware of population trends regardless of what factors are driving these trends.

COMMENTS
For more information on BBS data, visit the results and analysis website: http://www.mbr.nbs.gov/bbs/bbs.html

For more general information on the BBS and its sampling protocol, visit: http://www.mp2-pwrc.usgs.gov/bbs

3. TRENDS IN HABITAT, INTERIOR VERSUS EDGE BIRD SPECIES

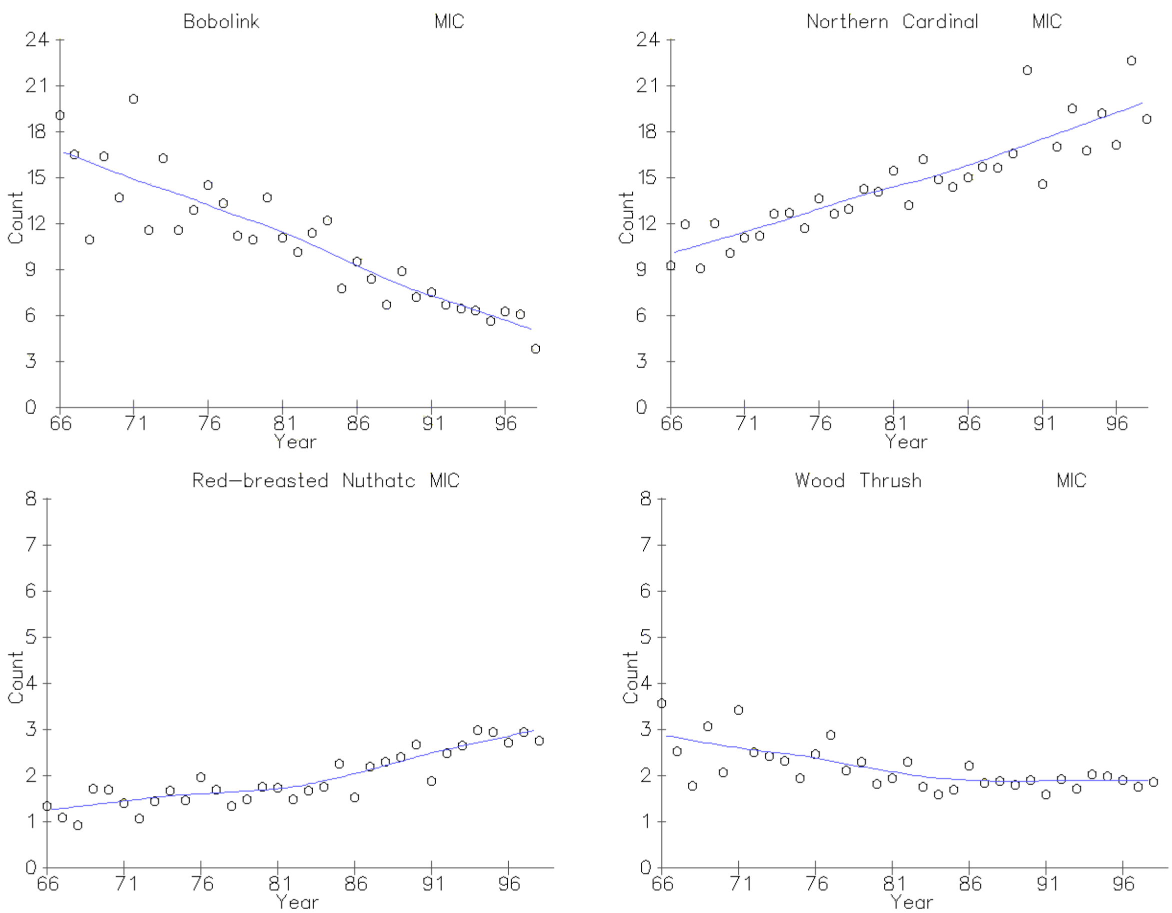
MEASURE
This measure would be an indirect indicator of habitat fragmentation by comparing trends in the abundance of breeding birds that are habitat interior species with those that are habitat edge species. Data from the Breeding Bird Survey, an annual census of breeding birds conducted nationwide, would be used to determine trends. For analysis, species would be combined into habitat guilds of habitat interior species and habitat edge species. Habitat types would separate the interior species groups. Because of differences in the relative abundance of each species, the counts will have to be weighted or otherwise standardized within each guild. By using guilds instead of individual species, the annual fluctuations of an individual species that may be unrelated to habitat fragmentation will be minimized.

Example species groupings: Grassland Interior Species could include Bobolink, Grasshopper Sparrow, Eastern Meadowlark and Upland Sandpiper. Mature Deciduous Interior Species could include Cerulean Warbler, Cooper's Hawk, Scarlet Tanager and Wood Thrush. Coniferous Forest Interior Species could include Red-breasted Nuthatch, Pine Warbler and Golden-crowned Kinglet. The trends for these guilds would then be compared to the trends for edge species guilds that could include species such as Brown-headed Cowbird, Rufous-sided Towhee, Grey Catbird, Northern Cardinal and Wild Turkey. The following are trends for some of the individual species for Michigan from the Breeding Bird Survey (groupings have not yet been done):

The Breeding Bird Survey data for Michigan is kept by the Kalamazoo Nature Center in conjunction with MNFI and USFWS. Contact Ray Adams with the Kalamazoo Nature Center for data and advice on the logical grouping of guilds.

PURPOSE

Fragmentation is emerging as one of the most pressing threats to environmental health in Michigan and nationally. As habitat are divided into smaller parcels and set in a landscape matrix which isolates the parcels, the species that depend on those habitats are becoming increasingly challenged. The smaller area to perimeter ratio of habitat fragments allows greater intrusion into habitats by predators, parasites and competitors that exploit the edges between habitats. Habitat interior species have not evolved with the presence of these edge organisms and generally are not well adapted to deal with them. This measure is important because not only does it provide a measure as to the degree of habitat fragmentation, it also demonstrates the consequences of fragmentation on species abundance.



This measure will indicate an increase in habitat fragmentation if the interior guilds for a habitat show a declining trend while edge species guilds show an increasing trend. Conversely, a decrease in fragmentation will be indicated by an increasing trend of interior guilds compared to a decreasing trend of edge guilds. This analysis, however, may need to be done by region for Michigan. The southern portion of the state is undergoing rapid development, urban sprawl and loss of farmland. In northern portions, however, large tracts of public land are recovering from intensive over-logging that occurred in the early 1900s. Therefore, trends in fragmentation may be opposite for different regions of the state.

An added value of this measure is the stability of the data. The Breeding Bird Survey has been nationwide and throughout Michigan since the 1960s. The survey is conducted annually and is organized and supported by the USFWS. This survey should continue indefinitely in the future.

LIMITATIONS
The Breeding Bird Survey is a roadside survey conducted by volunteers each spring. The routes used tend to be along habitat edges, therefore, interior species may be under-represented in the survey. In addition, trends in some species may be affected by changing habitat conditions on the wintering grounds, especially for neo-tropical migrants. A further limiting factor is that yearly fluctuations in a species may not be indicative of long term trends for the species. This type of trend data is usually useful over spans of 5-10 years.

4. STREAM FLOW

MEASURE
Stream (and river) flow patterns, especially summer 10% excedence (flashiness) and summer 90% excedence (baseflow) as a measure of human-induced hydrologic alteration.

PURPOSE
To directly measure stream flow patterns as indirect indicators of stream habitat, water quality, stability, flashiness, and overall stream health. Natural hydrologic 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 amount and type of habitat available for fish and other aquatic organisms. It is also an indirect indicator of water quality in streams, and in lakes and reservoirs occurring in stream systems. Flow patterns are expected to primarily reflect changes in runoff from land, groundwater level, water extraction, discharge from upstream reservoirs (if present), and climatic change.

Increases in flashiness, characterized by higher peak flows or unusual expected low flow, will most likely be due to increased runoff caused by land use in the watershed, such as increases in impervious surfaces accompanying urbanization. Other causes can be factored out by comparing flow data in altered watersheds to flow data in pristine watersheds, and by reference to other environmental indices. This index should confirm any trends indicated by indices of land use. Schueler (cited by SEMCOG) provides these classifications: “stressed streams” are 1-10% impervious; “impacted streams” are 11-25% impervious; and “degraded streams” are 26-100% impervious. Thus a negative effect is likely when as little as 1% of a watershed becomes impervious. Higher runoff correlates to decrease ground water recharge, decreased baseflow, increased and flashier stream flow, increases in temperature, turbidity, pollutants, erosion and changes in aquatic biota.

Our ecosystem objective for streams should be to minimize deviations in flow patterns from normal for each type of stream. This should result in the least disruption to the ecosystem and fulfillment of “the natural flow paradigm”. A desirable endpoint is to minimize and mitigate change, and a deviation of no more than one standard error in stream flow variation from pre-settlement norm has been suggested as a management targets (Richter et al.).

INFORMATION
The primary source of flow data will be USGS and other gauging stations. The excedance values recommended for this index will probably have to be calculated from daily gauge readings. Long-term data are readily available on a USGS web site and elsewhere. Streams should be grouped (typed) by inherent flashiness and stability on the basis of soil types. Models already exist for predicting flow patterns.

An appropriate illustration might be a table or graph illustrating trends in 10% and 90% excedence values by watershed, type of stream, and state average. An alternative procedure is “the range of variability approach” (Richter et al.). This reference also provides theoretical support for the concept.

Stream flow is already being used as an indicator by SEMCOG and The Rouge Remedial Action Plan Advisory Council. SOLEC is proposing a flow index for Great Lakes' tributaries but from the perspective of input of water into the Great Lakes rather than understanding changes in streams themselves. A postdoctoral student at the University of Michigan and the Institute for Fisheries Research, Leon Hinz, will be studying topics closely related to this index for the Great Lakes region.

LIMITATIONS
At present, USGS gauging stations and 30+ year data sets exist for 62 Michigan sites. For a more random sample of stream types, additional gauging stations need to be established on more pristine and northern waters. This will require special funding at the cost of several thousand dollars per station per year. Only trends established by many years of data will be meaningful because high, random variation caused by storm events will obscure gradual changes caused by shifts in land use. Shifts in flow may also occur due to shifts in ground water withdrawal, precipitation, or evaporation (global warming effects).

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5. TRENDS IN FROG AND TOAD POPULATIONS

MEASURE
This measure would use the trends in breeding frog and toad populations as an indirect indicator of habitat degradation. Breeding frogs and toads have been counted annually for the past four years throughout Michigan as part of MNFI's Frog and Toad Survey. In addition, the survey will continue to be collected every year as part of a nationwide effort to monitor amphibian populations.

PURPOSE
Amphibians are sensitive indicators of environmental quality because of the intimate relationship they have with their immediate environment. Many amphibians exchange oxygen and other substances directly through their skin for at least some portion of the year. In addition, the eggs of most species are aquatic; they must be deposited in water where they can exchange gases and nutrients directly through their permeable membrane. Even the eggs of species that are not aquatic have permeable membranes and must remain moist. These associations mean that even small changes in environmental chemistry, nutrients, toxicants and even ultraviolet light can affect populations.

At this time, the mechanisms of widespread declines in amphibian populations are not entirely understood. It seams logical, however, that given the intimate association of these organisms and their environment, that these declines are associated with deteriorating environmental conditions. Trends in populations can be interpreted as trends in habitat degradation.

LIMITATIONS
Volunteers with varying abilities to identify species and estimate numbers in an area by listening to calls conduct this survey. In addition, the survey may not have adequate coverage statewide in all survey years. There is also little historic data to compare with the four years of survey data to determine long-term trends.

6. INVASIVE SPECIES

The number and types of invasive plant and animal species present in the State. The number and kinds of alien plant and animal can be tallied and used to infer the condition of plant and animal communities and thus to some degree the quality and condition of associated ecosystems. In addition, potential threats to certain ecosystems can be assessed using knowledge of alien species characteristics. For example, the wetland affinity of a species would allow an evaluation of the potential for certain habitat types to be invaded. Statewide animal and flora list are available and being updated regularly. These lists can be sorted to identify non-native species.

PURPOSE
To indirectly assess the quality of a habitat or natural community and measure the degree of human disturbance and impact, and also assess the vulnerability of sites to invasive species that will result in habitat degradation as well as the displacement of native plant and animal species.

LIMITATIONS
Statewide databases currently exist for vertebrates and for plants documented in Michigan. The listing for invertebrates is much less complete. Non-natives can be sorted for these lists; however, invasiveness has not been rated, although the qualities of many species are well known through observation and experience in the Great Lakes region and elsewhere by land managers and others. In addition, the raw lists would include non-native species such as ring necked pheasant, king salmon, smelt (to name but a few) that most people would consider to be positive or at worst benign introductions. Therefore the listings would require some qualitative interpretation.

7. FOREST ACREAGE AND TIMBER VOLUME, MORTALITY, GROWTH AND REMOVALS

PURPOSE
To monitor changes in forest types (and related habitats), and the sustainability of forest resources. This provides a measure of trends with respect to Michigan's forests and a primary use (wood fiber extraction) that is of public concern. The U.S. Forest Service, through its Forest Inventory and Analysis (FIA) program, has carried out five "modern" extensive inventories of Michigan's forests in 1935, 1955, 1966, 1980, and in 1993. The inventories provide acreage, volume, growth, and mortality data that may be broken down by ownership and forest type.

Since 1984, surveys of Michigan's wood-using mills have taken place every two years, providing estimates of timber removals from within the state as well as flows across state lines.

Combined, the inventory and wood-utilization data can be used to determine current status and trends affecting Michigan's forests and timber industry, including the ability to assess forest sustainability and health.

LIMITATIONS
A large amount of data is generated as part of these data collection efforts and reducing the information down to one or a few indices may be difficult or misleading. As forests and wood product markets are dynamic, a single index may invite overly simplistic interpretation. For example, with an over-mature, underutilized forest cover type, such as Jack Pine in Michigan, removals may need to exceed growth to avoid loss of forest or forest type and to re-invigorate it. Likewise, the use of a timber growth-to-removals

ratio has been criticized because it does not take into account restrictions on portions of what is counted as growth.

COMMENTS
Within the next couple of years, the forest inventory information will begin to be collected and published every 5 years, with modeled updates available in between publications. This will permit closer monitoring of changes than has been available in the past.

8. VEGETATION STRUCTURE & DIVERSITY

PURPOSE
The Forest Health and Monitoring (FHM) program's vegetation indicator is intended to help evaluate biological diversity, vitality, soil conservation, and carbon cycling in forested ecosystems. The data sets will ultimately be used to document native plant diversity, detect areas of invasion by exotic species, measure the effects of land use practices on plant diversity, and provide an index of forest health nationwide. The indicator measures three components of forest ecosystems: 1) understory diversity/general vegetation structure, 2) dead and down woody debris, and 3) fuel loading. Information collected includes:

Vegetation diversity:
Number and abundance of forest-dependent species
Number of native species
Number of exotic species
Vertical structure

The degree of disturbance and percent cover by various microhabitat variables (litter/duff, rocks, dead wood, live roots/bole, etc.) is also estimated within a 1 square meter quadrant.

Down woody debris measurements are subdivided into two categories:

Coarse: >3 inches, Fine: 3 inches or less
Information collected includes:
Number and volume of coarse down woody debris
Number of fine woody debris
Measurements are made along 3 transects that begin at subplot center and radiate out at 30, 150, and 270 degrees. Transects are 59 feet. There are 12 transects per FHM plot.

The fuel-loading component of the indicator provides information for several fuel-loading models and flammability assessments, including the Missoula fire lab index and the biomass accumulation index. Fuel load measurements are made on the 5.9 foot radius microplot. Variables measured include: (1) Cover and depth of grass, shrub layer, slash, litter, and duff; Vegetation diversity/cover; and Diversity of overstory, midstory, and understory microplot cover.

Cover estimates are made for grasses, shrubs, slash, and litter independently and expressed as the percentage of ground surface under live aerial plant parts. Cover is estimated in 5% classes, and may exceed 100% because of overlap. Average depth for grasses, shrubs, slash, and litter is also estimated.

COMMENTS
(*FHM* web site: http://willow.ncfes.umn.edu/fhm_fact/list.htm) A primary advantage of this indicator is that it is an established index measured by the FHM program across many states. Another advantage is that its interpretation tends to be less ambiguous relative to other indicators that could have multiple or unclear implications for Michigan's natural environment (e.g., more motorized use of trails and timber removals).

9. LICHEN COMMUNITIES

PURPOSE
The Forest Health and Monitoring (FHM) program's lichen communities indicator is intended to measure changes in nitrogen- and sulfur-based pollutants and the extent of areas where air pollution may affect forest productivity and biodiversity.

OBJECTIVE RELATIVE TO ASSESSMENT OF HEALTH OF MICHIGAN'S NATURAL ENVIRONMENT
This indicator is one of a battery of measures to gauge the health of Michigan's forests and landscapes.

FEATURES
Due to their total reliance on atmospheric sources of nutrition, epiphytic lichens are very responsive to environmental stresses and are well suited to serving as early indicators of changes in air quality. In turn, air quality may then be identified as a causal agent of change in biodiversity, forest productivity, etc.

Field data on lichens is collected between June and September. The data are used in conjunction with other air quality and climatic data sets.

INTERPRETATION
Use of the lichen community indicator enables validation of other air quality measures. In conjunction with other data sets, early, direct consequences of changes in air quality on flora are established and probable spatial patterns can be discerned. See *FHM* web site: http://willow.ncfes.umn.edu/fhm_fact/list.htm.

A primary advantage of the FHM indicators is that they are established indices measured by the FHM program across many states. Another advantage to most of them is that their interpretation tends to be less ambiguous relative to other indicators that could have multiple or unclear implications for Michigan's natural environment (e.g., more motorized use of trails, timber removals, etc.).

A specific advantage to the lichen community indicator over other air quality measures is that it shows a direct, cumulative organic impact from changes in air quality, rather than just a change itself at a given point in time.

10: TRENDS IN DEER POPULATIONS (Possible Indicator, Proposed 5/15/2001)

MEASURE
This measure would indirectly measure habitat quality by measuring the trends in the estimated population of white-tailed deer in Michigan.

PURPOSE
This measure would provide an indirect measure of habitat quality by tracking population trends of white-tailed deer. Deer populations are estimated annually in Michigan by MDNR. Primarily, two methods based on statistics are used to estimate populations: sex/age/kill ratio estimates and pellet count surveys. A variety of data is collected by the MDNR for use in these estimators. Considerable time and effort is used to collect this data. This data is collected annually as an integral part of the Wildlife Division's deer management program. The MDNR will continue to collect this data indefinitely. Presumably, deer populations are influenced by their reproductive success and survival, which is a function of habitat quality.

LIMITATIONS
There are a number of limitations associated with deer population estimates. Most are the result of deer biology and active population management, however, the population estimates themselves have limitations. Deer are a prey species and have evolved high reproductive capabilities to offset losses to predation. As with most prey species, deer have not evolved mechanisms to limit their population growth based directly on habitat quality. Historically, predators would have kept deer numbers below levels where habitat quality could have a meaningful impact on reproductive potential. With the removal of

predators, deer populations may exceed what the habitat can support. Without supplemental feeding in the northern lower and upper peninsulas, deer populations often exceed what the vegetation can support. The result is a crash in deer numbers when vegetation is severely impacted followed by years of increasing populations as the vegetation recovers. This cyclic population response will lag behind the quality of vegetation available to the deer. In the southern lower peninsula, deer numbers can remain above what can be supported by natural habitat because of the availability of agricultural crops and the lack of severe winters.

White-tailed deer are Michigan's most important game species. Annually, over 700,000 hunters harvest more than 500,000 deer. Because of the intense harvest pressure on this species, populations in any given year may be more a factor of hunter kill than a reflection of habitat quality. In addition, hunting pressure is not constant from year to year. Weather during the firearm season can greatly influence hunter success, which in turn can influence deer populations in ways unrelated to changes in habitat quality.

Another severe limitation of using deer population estimates as an indicator of habitat quality is the limitations of the estimators themselves. The only statewide estimator of populations is the sex/age/kill ratio estimator; pellet surveys are not conducted in southern Michigan. The sex/age/kill ratio is largely derived from the annual buck kill. The annual buck kill can vary yearly for many reasons unrelated to the change in deer populations. As already mentioned, weather during the firearm season can greatly affect hunter success regardless of deer population levels. In addition, the timing of the harvest of corn in southern Michigan has a direct impact on hunter success. Therefore, although sex/age/kill ratio estimators are valuable in examining deer population trends over many years, the fluctuation in the estimates in any given year may be unrelated to the actual population.

Pellet survey estimates are less susceptible to annual fluctuations for reasons other than population changes. These surveys, however, are not conducted statewide. In addition, these surveys are very time consuming and costly. Often the data analyses can not be completed until after the regulations for that year have to be set. Therefore, the long-term use of this population estimator by the Wildlife Division may be uncertain. Even if this estimator could be conducted on an annual basis for all of Michigan, as previously mentioned deer populations in any given year can be influenced by factors other than habitat quality.

In addition, the Wildlife Division has been actively managing to reduce deer populations in much of the state. This reduction is necessary to restore ecological balance between deer and their habitat. As a result, in the near future deer numbers may be reduced through hunting while vegetation is allowed to recover. Consequently, deer numbers may be falling while habitat quality is increasing.

11. TRENDS IN GAME FISH POPULATIONS (Proposed 5/15/2001)

MEASURE
Assess trends in population (size and age structure) of representative game fish and/or fish communities in streams and inland lakes.

PURPOSE
The intent is to evaluate specific fish populations and fish community structure as a relative measure of the ecological integrity of the water body. Information about flow and temperature are also recommended for monitoring to improve our understanding of the relationship between these dynamic natural conditions and biological responses. Changes in fish communities and fish conditions may also indicate changes in environmental quality.

LIMITATIONS
Changes observed in fish populations and/or fish community structure are site specific and may be difficult to extend for statewide trend analysis.

Existing information may be of limited value due to sporadic collection schedule and varying methods. Plans for future resource assessment will improve conformity and new assessment efforts are anticipated in preparation for assertion of tribal fishing rights on inland waters.

Fisheries management practices (stocking, harvest regulations, removal treatments) have established and/or sustain fisheries not necessarily indicative of local environmental quality. Site and species selection should be designed to avoid compounded influences.

Potential relationship between environmental conditions and fish communities is not well understood. For example, changes in the fishery due to climactic or other natural causes will be difficult to discern from land use or water quality changes. Several factors may be involved.

Fish populations have wide natural variability and trends will not be evident (or reliable) on an annual basis.

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Appendix 4

Proposed Environmental Indicators from the Michigan Department of Environmental Quality

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PROPOSED INLAND LAKES PRODUCTIVITY AND QUALITY ENVIRONMENTAL INDICATORS

Michigan's inland lakes are classified based on their level of productivity, or trophic state. The water quality parameters Secchi disk transparency, total phosphorus, and chlorophyll *a* are measured as indicators of lake productivity. The Carlson Trophic State Index (TSI) is used to quantify the relationship between these parameters and the trophic state of a lake. The Carlson TSI is useful for comparing lakes statewide or across a region and for assessing changes in trophic status over time. Long-term monitoring of these indicator parameters is useful for identifying nutrient enrichment and eutrophication in Michigan's inland lake resources. The Land and Water Management Division (LWMD) proposes that the indicators transparency, total phosphorus, chlorophyll *a*, and the Carlson TSI be reported in the Environmental Indicators report.

Historically, over 700 public lakes in Michigan have been classified using the Carlson TSI approach. Currently, a volunteer lakes monitoring program provides for long-term measurement of these indicator parameters and continues the lake classification process. Lake quality status and trends assessment will be expanded and enhanced under the Department of Environmental Quality's water quality monitoring strategy, as supported by the Clean Michigan Initiative (CMI). Additional indicators may be proposed by LWMD following identification of new monitoring parameters under the CMI.

<u>Inland Lake Water Quality (Trophic Status)</u>

Lake quality is influenced by many factors, such as the amount of recreational use it receives, shoreline development, biological integrity, and water quality. Lake water quality is a general term covering many aspects of lake chemistry and biology. The health of a lake is determined by its water quality. Problems most commonly cited by lake residents, such as excessive weed growth, algal blooms, and mucky bottom sediments are caused by water quality factors that lead to increased lake fertility or productivity. Productivity refers to the amount of plant and animal life that can be produced within the lake. Plant nutrients are a major factor that cause increased productivity, or eutrophication in lakes. In Michigan, phosphorus is the nutrient most responsible for plant and algae growth (primary productivity) in inland lakes.

A lake's ability to support plant and animal life defines its level of productivity, or trophic state. Lakes are commonly classified based on their productivity. Low productive oligotrophic lakes are generally deep and clear with little aquatic plant growth. These lakes maintain sufficient dissolved oxygen in the cool, deep-bottom waters during late summer to support cold-water fish, such as trout and whitefish. By contrast, highly productive eutrophic lakes are generally shallow, turbid, and support abundant aquatic plant growth. In deep eutrophic lakes, the cool bottom waters usually contain little or no dissolved oxygen. Therefore, these lakes can only support warm-water fish, such as bass and pike. Lakes that fall between these two classifications are mesotrophic lakes. Lakes that exhibit extremely high productivity, such as nuisance algae and weed growth are hypereutrophic lakes.

Three commonly measured water quality parameters: Secchi disk transparency, total phosphorus, and chlorophyll *a* are often used as indicators of the degree of eutrophication, or trophic status of a lake. The concept of trophic status is based on the fact that changes in nutrient levels (as measured by total phosphorus) causes changes in algal biomass (as measured by chlorophyll *a*) which in turn causes changes in lake clarity (as measured by Secchi disk transparency). A trophic state index based on these parameters is a convenient way to quantify this relationship.

Although there are several methods to classify lakes, the Carlson Trophic State Index (TSI) is used for Michigan's lakes (Carlson 1977). The Carlson TSI expresses lake productivity on a continuous numerical scale from 0 to 100 with increasing numbers indicating greater productivity. The Carlson TSI uses a log transformation of Secchi disk transparency values as a measure of algal biomass. Each increase of ten units on the scale represents a doubling of algal biomass. Because chlorophyll *a* and total phosphorus are usually closely correlated to Secchi disk measurements, these parameters can also be assigned trophic state index values. The Carlson TSI equations are provided in Exhibit 1. The relationship between the TSI values, water quality indicators, and lake productivity classifications are illustrated in Exhibit 2.

$TSI_{SD} = 60 - 14.41 \ln(SD)$

$TSI_{TP} = 14.42 \ln(TP) = 4.15$

$TSI_{CHL} = 9.81 \ln(CHL) + 30.6$

where, SD = Secchi disk transparency (m)
TP = total phosphorus concentration (ug/l)
CHL = chlorophyll *a* concentration (ug/l)

Exhibit 1. Carlson TSI Equations.

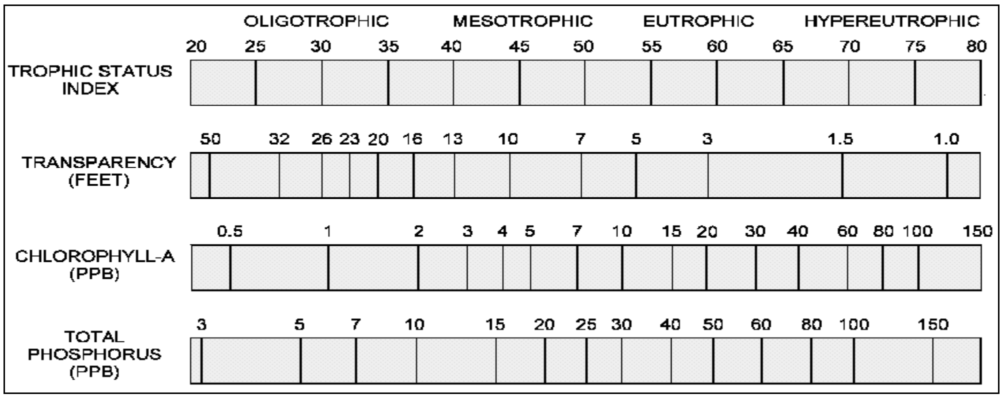

Exhibit 2. Carlson TSI Scale.

Although the Carlson TSI is well suited for Michigan lakes, it may underestimate the trophic state of lakes dominated by aquatic macrophytes. Therefore, the relative abundance of the submergent macrophyte community is used as a secondary trophic status indicator for shallow macrophyte dominant lakes. Dissolved oxygen and temperature profiles also aid in the lake classification process. The federal Clean Water Act (CWA) requires states to assess lake quality and to classify lakes according to productivity. Since the early 1970's, over 700 public lakes in Michigan have been assessed and classified using the Carlson TSI approach. Lake water quality assessments and classifications of these lakes have been reported in the 1982 Lake Classification Report (Michigan Department of Natural Resources [MDNR] 1982) and Michigan's CWA Section 305(b) reports (MDNR 1988-1994, Michigan Department of Environmental Quality [MDEQ] 1996-1998). The majority (67 percent) of these lakes are classified as mesotrophic (moderate productivity) or oligotrophic (low productivity). Only five percent of the assessed lakes are considered hypereutrophic (excessive productivity), as illustrated in Exhibit 3.

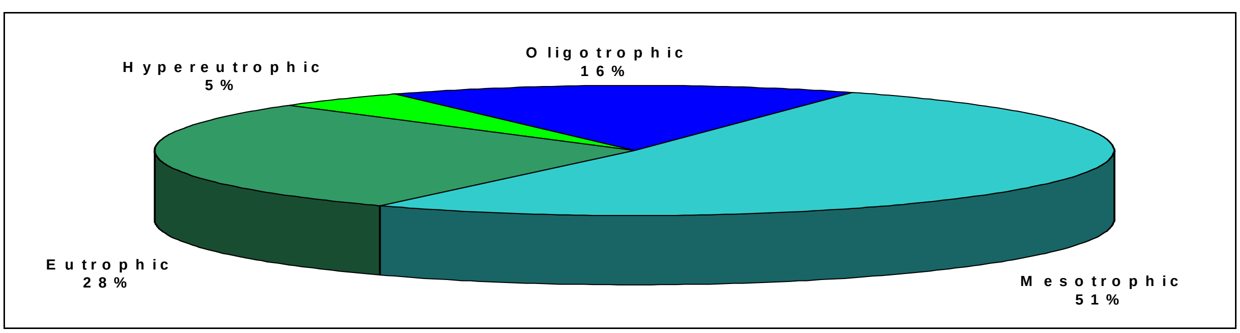

Exhibit 3. Michigan's Public Lakes Classification (730 Lakes).

The median Carlson TSI for the 730 Michigan public lakes evaluated is 43, which is indicative of good quality lakes (Exhibit 4).

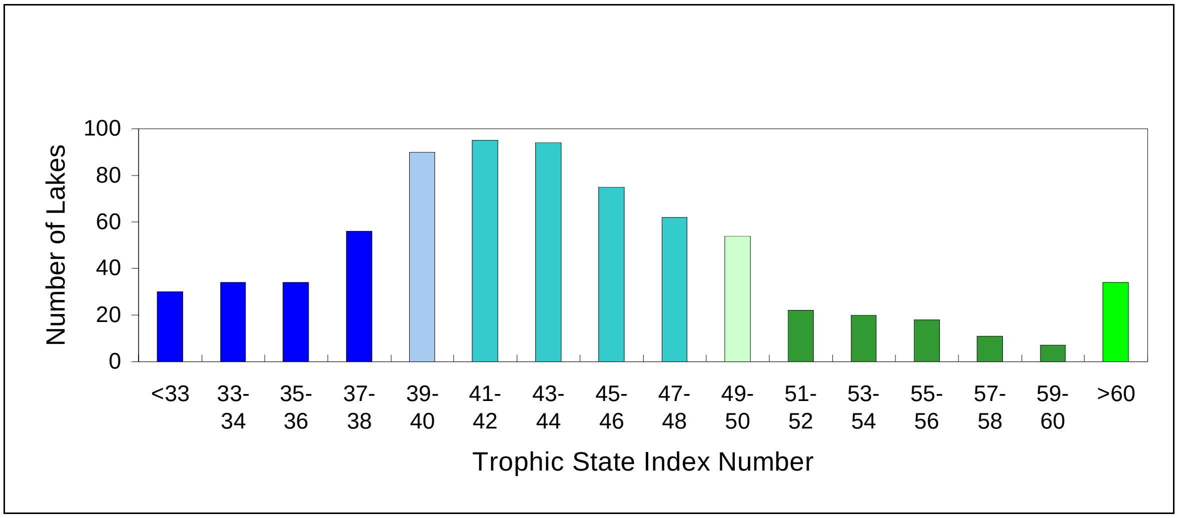

Exhibit 4. Michigan's Public Lakes Carlson TSI Distribution (730 Lakes).

Reduced funding over the past several years has restricted Michigan's inland lakes monitoring activities. Most of the monitored public lakes have been sampled only once or twice over the past 25 years and many of these lakes have not been sampled during the last 15 years. Very few lakes without public access have been monitored. Currently, baseline data collection and lake classification efforts are limited to the Cooperative Lakes Monitoring Program (CLMP), which is Michigan's volunteer lake monitoring program (MDEQ 1999).

The CLMP enlists citizen volunteers to monitor water quality in their lake and to document changes in water quality over time. The volunteers measure indicators of lake productivity, including Secchi disk transparency, total phosphorus, and chlorophyll *a*. The CLMP, formerly Self-Help program, was established in 1974 with Secchi disk transparency measurements. Spring overturn total phosphorus monitoring was added in 1993, and summer total phosphorus and chlorophyll *a* monitoring were added in 1998. Currently, the CLMP is administered as a partnership with the Michigan Lake and Stream Associations, Inc., a non-profit statewide riparian organization.

A quality assurance/quality control (QA/QC) component that includes replicate and side-by-side sampling is an important element of the CLMP. The volunteers collect all samples in duplicate and 10 to 15 percent of the duplicate samples are analyzed as QA/QC samples. Additionally, program staff work side-by-side with the volunteers on approximately 10 percent of the participating lakes to ensure the integrity of the volunteer monitoring methods as compared to standard monitoring methods. Exhibits 5 and 6 illustrate the cumulative results for the replicate and side-by-side spring overturn total phosphorus samples, respectively, since the QA/QC program was implemented in 1993.

During the 1998-1999 inland lakes monitoring cycle, over 250 volunteers on 154 lakes participated in the CLMP. Trophic status classifications were completed on 63 lakes during the 1998-1999 cycle. Sixteen of these lakes were classified as oligotrophic, 38 mesotrophic, and 9 eutrophic. Seventeen lakes were classified for the first time.

Secchi disk transparency monitoring has been part of the volunteer monitoring program for over 25 years. Seventy lakes enrolled in the CLMP during the 1998-1999 monitoring cycle have been in the program long-term (i.e., eight or more years). Long-term monitoring on these lakes indicate increasing transparency for 29 lakes, decreasing transparency for 6 lakes, and stable or insignificant change in transparency for 35 lakes. A few lakes have been enrolled in the volunteer monitoring program since it began in 1974. Exhibit 7 illustrates the long-term transparency measurements, as annual mean values, on Corey Lake (St. Joseph County), indicating relatively stable conditions.

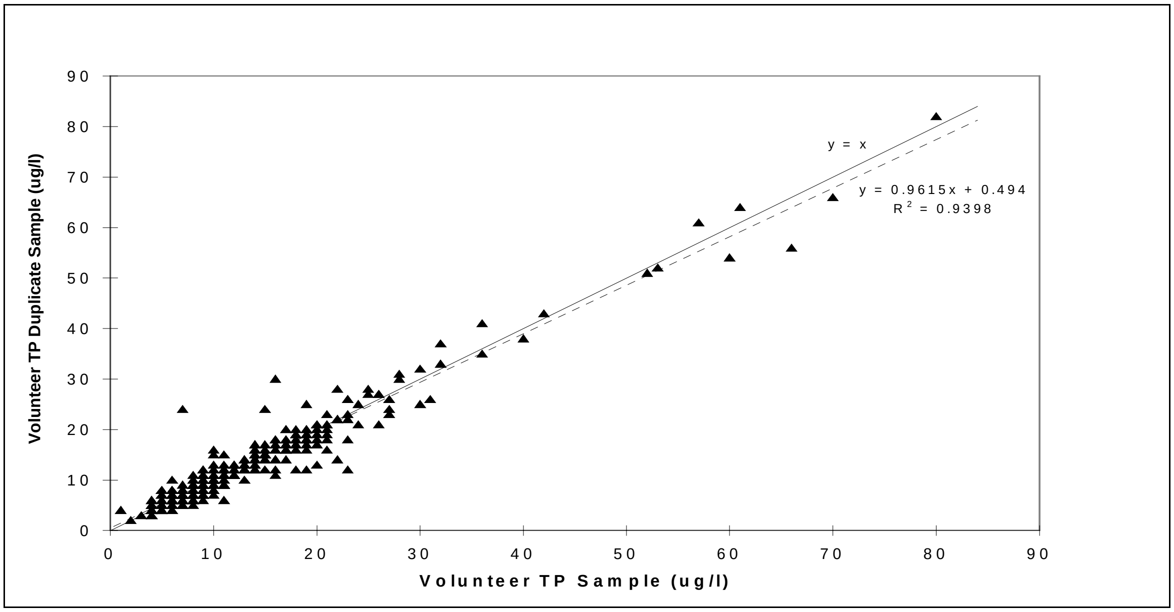

Exhibit 5. CLMP Spring Total Phosphorus QA/QC Replicate Samples.

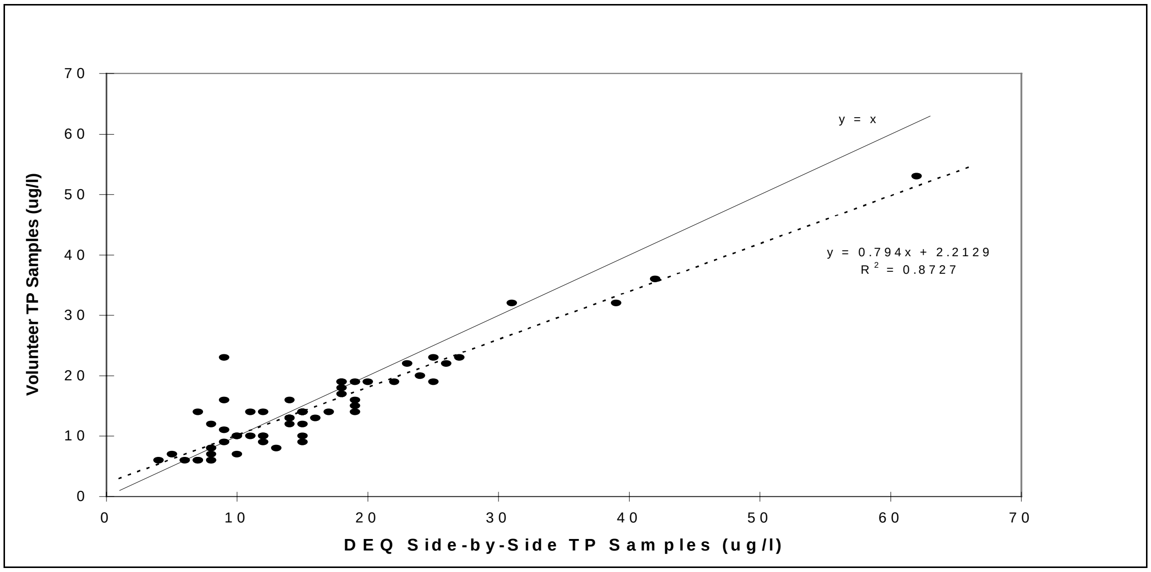

Exhibit 6. CLMP Spring Total Phosphorus QA/QC Side-by-Side Samples.

The 2000 CLMP marks the eighth year for spring overturn total phosphorus monitoring. This program has 130 lakes enrolled and 20 of these lakes have been participating since the program began in 1993. Long-term spring overturn total phosphorus data may provide an important indicator of nutrient enrichment in lakes. Exhibit 8 illustrates seven years of spring overturn data for Diamond Lake (Cass County), indicating moderate variability, but no apparent trend in total phosphorus levels over time.

Given the high variability in lake ecosystems, many years of reliable data collected on a consistent and regular basis are needed to separate true long-term changes in lake productivity from seasonal and annual fluctuations. A continual increase or decrease in the Carlson TSI or the trophic state indicators from year-to-year may indicate a change in the trophic status of the lake. However, eight to ten years of data may be required to recognize the difference between short-term, normal fluctuations and long-term changes in lake productivity.

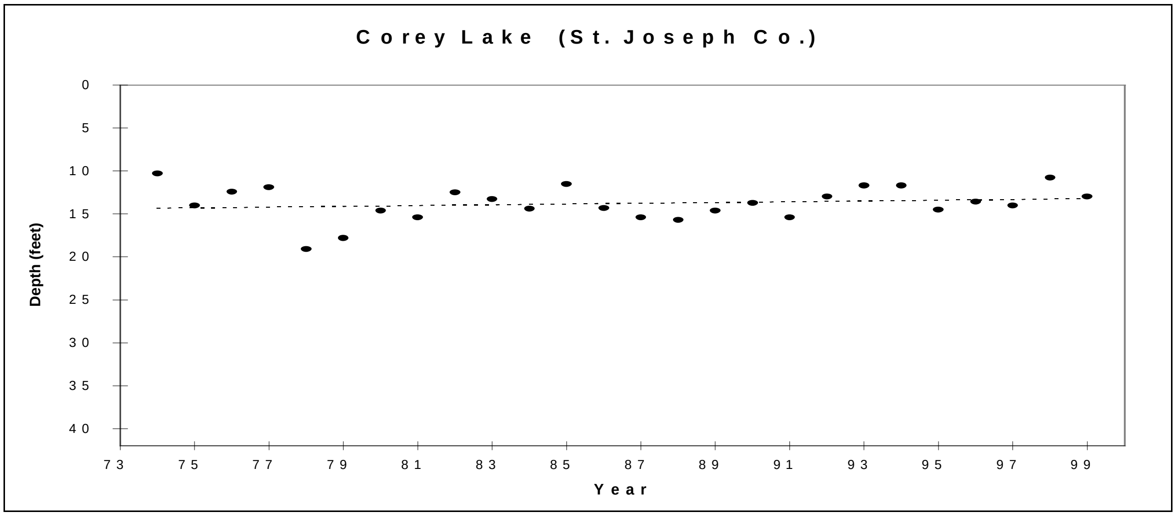

Exhibit 7. Corey Lake (St. Joseph County) Summer Mean Transparency Trend.

The CLMP is a cost-effective program for increasing baseline water quality data and trophic status determinations for Michigan's inland lakes. Long-term monitoring by the volunteers also provide data to determine water quality variability and trends in these lakes. However, results from the CLMP represent the lakes that are enrolled in the program on an annual basis and may not be representative of lakes statewide.

In November 1998, the citizens of Michigan passed a $675 million general obligation bond, the Clean Michigan Initiative (CMI), to protect and enhance Michigan's environmental quality, natural resources, and infrastructure. A portion of the CMI fund is to be used to implement the Michigan Department of Environmental Quality's water quality monitoring strategy (MDEQ 1997). A key element of this strategy is to establish a comprehensive monitoring program for Michigan's inland lake resources.

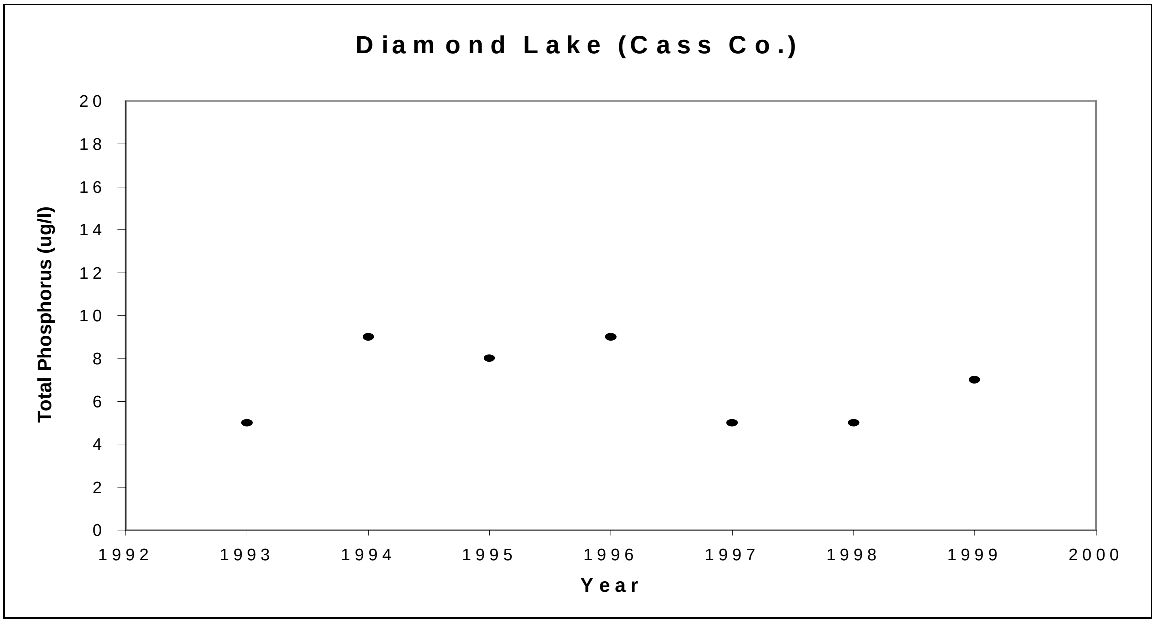

Exhibit 8. Diamond Lake (Cass County.) Spring Total Phosphorus Trend.

The inland lake quality and eutrophication monitoring framework, as described in the strategy integrates citizens' volunteer monitoring activities with statewide water quality assessment efforts to measure overall water quality and trends in Michigan's inland lake resources. The proposed plan for implementing the strategy consists of three water quality monitoring components. A trophic status monitoring component supports the expansion of the CLMP. A lake water quality assessment component re-establishes a targeted baseline monitoring program for Michigan's public lakes. A probability-based sampling component will establish a new long-term monitoring program for evaluating lake quality status and trends statewide. A fourth component of the plan creates an inland lakes information system to manage the data collected under this program and to link these data with historical water quality data for Michigan's inland lakes.

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PROPOSED SURFACE WATER ENVIRONMENTAL INDICATORS

The DEQ recommends the following environmental indicators for surface waters include:

Contaminant levels in bald eagles (Proposed Indicator);
Contaminant levels in native whole fish (Possible Indicator);
Contaminant levels in the sediments of inland lakes (Possible Indicator); and
Contaminant levels in the connecting channels, Saginaw Bay, Grand Traverse Bay, and major tributaries (Possible Indicator).

Contaminants monitored include organic compounds, metals, nutrients, and some other conventional parameters.

Extent of Monitoring for Proposed Environmental Indicators

Contaminant levels in bald eagles
This project began in 1999 using a legislative appropriation of state general funds for water quality monitoring, and will continue this year. Blood and feather samples are collected from nestling bald eagles at 12 fixed inland locations as well as accessible Great Lakes and connecting channel nests. The inland nests are located primarily in the Upper Peninsula and the northern Lower Peninsula. Samples are analyzed for mercury, PCBs, and other bioaccumulative chemicals of concern. Initially, these fixed locations will be sampled annually (as long as they are occupied by eagles) to establish a trend baseline and to measure annual variability in contaminant levels. Each year during this initial period, the data will be analyzed to determine whether continued annual sampling is justified or whether a less intense sampling frequency is sufficient. In addition, bald eagle sampling in watersheds on the 5-year permit basin cycle will create a statewide trend database, but the trend analysis will be less rigorous than possible with the annual sampling. In effect, we will be able to validate the 5-year trends seen statewide with the more site-specific annual trends. The future of this project depends on the continued $500,000 legislative appropriation and the appropriation of the requested amount from the CWF.

Contaminant levels in native whole fish (Possible Indicator)
Fish contaminant data have been collected continuously since the program's inception in 1990. Currently, fish are collected every 3-5 years from 26 fixed trend locations representing inland lakes, rivers, Great Lakes, and connecting channels. Tissues are analyzed for selected bioaccumulative chemicals (PCBs, chlorinated pesticides, mercury). These data are used to evaluate temporal and spatial trends in fish contaminant levels throughout the state. If the state legislature appropriates the requested amount ($3 million/year for 15 years) from the Clean Water Fund (CWF) of the Clean Michigan Initiative, then the number of fish and frequency of collection will be increased to improve our ability to statistically document trends. This program currently is funded entirely through state general funds and likely will continue well into the future. In addition, the DEQ collects additional fish contaminant data through caged fish studies and the fish consumption advisory process. These data also will be used where possible to detect trends in fish contaminants. Finally, the DEQ works cooperatively with several federal agencies and other states to implement a fish contaminant trend program on the Great Lakes.

Contaminants Levels in the Sediments of Inland Lakes (Possible Indicator)
This project began in 1999 with a grant to Michigan State University, and sediment core samples were collected from six inland lakes. Additional lakes will be assessed in 2000, with the exact number to be determined by whether the State Legislature appropriates CWF monies for water quality monitoring. Assuming that the $500,000 appropriation is continued and the requested CWF funding is appropriated, we intend to collect and analyze sediments from 25 inland lakes by 2003, with each lake being reassessed every 10 years. Samples are analyzed for metals and PCBs. By collecting the sediment cores using specialized equipment and keeping the cores intact, researchers can date each layer of the core and construct contaminant profiles over many years, often to the early 1900s.

Contaminant levels in the connecting channels, Saginaw Bay, Grand Traverse Bay, and major tributaries (Possible Indicator).
The SWQD has collected water quality data from the Saginaw Bay and the Detroit River for many years. In 1998 and 1999, using a legislative appropriation of state general funds for water quality monitoring, this water monitoring program was greatly enhanced. Samples were collected from Saginaw and Grand Traverse Bays, the three Great Lakes connecting channels, and near the mouths of 18 major tributaries throughout the state. Samples have been analyzed for PCBs, chlorinated pesticides, mercury, trace metals, base neutrals, nutrients, and conventional parameters. The future of this program depends on the continued $500,000 appropriation and the appropriation of the requested amount from the CWF.

Contaminant Levels in Bald Eagles

Measure: Concentration of toxic, bioaccumulative chemicals in the blood and feathers of Great Lakes and inland nestling bald eagles. Specific chemicals to be measured include mercury, PCBs, and a suite of chlorinated pesticides.

Purpose: Measure exposure of fish-eating wildlife to toxic contaminants; provide an indirect measure of potential human health impacts due to consumption of fish; evaluate trends in the bioaccumulation of contaminants in the upper levels of the food chain; identify contaminant "hotspots".

Objective: Contaminants in nestling eagles should be at levels that do not impact reproductive success or population characteristics.

Endpoint: There are two desired endpoints/outcomes: 1) contaminant levels in Great Lakes nestling bald eagles that are not statistically different than in eagles nesting in "background", relatively unimpacted locations outside the Great Lakes basin, and 2) contaminant concentrations decline to levels that have no adverse impact on bald eagles.

Features: Chemical levels in the blood and feathers of nestling bald eagles are good indicators of local exposure to contaminants and potential risk to fish-eating wildlife. The DEQ provided a grant to Lake Superior State University in 1999 to collect and analyze blood and feather samples from eagle nests at 12 fixed inland locations as well as accessible Great Lakes and connecting channel nests. Clean Water Fund money will be used to continue this project in the future. These fixed locations will be sampled annually to establish a trend baseline and determine annual variability. Targeted watersheds, consistent with the DEQ's 5-year permit basin cycle, will be sampled less intensively. Data for this indicator will be generated using consistent, widely accepted collection, analytical, and quality assurance protocols. Trends will be evaluated using rigorous statistical methods.

Limitations: The primary limitation to this indicator is the limited geographic distribution of eagle nests. Most are located in the Upper Peninsula and the northern Lower Peninsula, with very few to be found in the southern half of the state. In addition, trends in contaminant levels in bald eagles, like fish, can be affected by many factors, including food chain changes, sampling and analytical variability, as well as actual changes in contaminant levels/inputs. Therefore, the resulting trend data is best examined over a long time period.

Contaminant Levels in Native Whole Fish *(Possible Indicator)*

Measure: Concentration of toxic, bioaccumulative chemicals in the tissues of selected forage and piscivorous fish. Specific chemicals to be measured include mercury, PCBs, and a suite of chlorinated pesticides.

Purpose: Provide information on exposure of aquatic life to toxic contaminants, potential human health and wildlife impacts due to consumption of fish, and trends in the bioaccumulation of contaminants in the aquatic food chain. Assist regulatory agencies in planning pollution prevention, reduction, and remedial activities.

Objective: Fish should be safe for consumption by humans and wildlife; contaminants in fish should be at levels that do not impact reproductive success or population characteristics.

Endpoint: Concentration of mercury, PCBs, and chlorinated pesticides in native whole fish. The desired outcome of the indicator is that contaminant levels continue to decline, as they have since the early 1970s, to levels that do not impact fish, wildlife, or human health.

Features: Contaminant levels in native whole fish are good indicators of local chemical concentrations and potential risk to fish-eating wildlife. Currently, native whole fish are collected every three to five years from 27 fixed sites around the state. Clean Water Fund money will be used to increase the frequency of site visits. Data for this indicator will be generated using consistent, widely accepted collection, analytical, and quality assurance protocols. Trends will be evaluated using rigorous statistical methods. Contaminant concentrations in fish have been measured for several years, and provide one of the most extensive databases on trends in environmental contaminants in the environment.

Limitations: Trends in contaminant levels in fish can be affected by many factors, including food chain changes, weather, sampling and analytical variability, as well as actual changes in contaminant levels/inputs. Therefore, the resulting trend data is best examined over a long time period. Some fish, especially those in rivers, migrate over long distances, making it difficult to determine exactly where they were exposed to the contaminants. Finally, high-resolution trend monitoring is somewhat expensive.

Contaminant Levels in the Sediments of Inland Lakes *(Possible Indicator)*

Measure: Concentration of chemicals in the sediments from inland lakes. Specific chemicals to be measured include mercury, trace metals, PCBs, and other selected organic parameters.

Purpose: Measure exposure of aquatic life to toxic contaminants; determine “background” contaminant levels in sediments; assess contaminant trends in the sediments of a variety of Michigan inland lakes; provide an estimate of chemical inputs from anthropogenic sources; identify contaminant “hotspots”.

Objective: Contaminants in sediments should be at levels that do not adversely impact aquatic life.

Endpoint: The desired endpoints are contaminant levels below EPA and Ontario sediment quality guidelines and that fully support healthy and diverse aquatic communities and have no adverse impact on human health.

Features: Chemical levels in the sediments of inland lakes are good indicators of the exposure of, and potential impacts to, aquatic life. The DEQ provided a grant to Michigan State University in 1999 to collect and analyze sediment core samples from 6 inland lakes throughout Michigan. Clean Water Fund money will be used to continue this project in the future, with the expectation that approximately 25 lakes will be sampled over a 5-year period. Core samples allow for a year-by-year analysis of contaminant levels in sediments. The results can be compared with known changes in surrounding land use, natural events, and anthropogenic activities to identify the cause/source of chemical inputs and explain observed patterns. We anticipate that lake sediments will be sampled on a 10-year cycle. Data for this indicator are being generated using a peer-reviewed collection and analytical protocol developed for a Great Lakes sediment project. Trends will be evaluated using rigorous statistical methods.

Limitations: This indicator will be reported infrequently. Because of the time required for sediment accumulation, the DEQ anticipates collecting new data on each lake only once every ten years.

Contaminant Levels in the Connecting Channels, Saginaw Bay, Grand Traverse Bay, and Major Tributaries *(Possible Indicator)*

Measure: Concentrations of selected chemicals in the waters of Great Lakes tributaries and inland streams, the Great Lakes connecting channels (including Lake St. Clair), Saginaw Bay, and Grand Traverse Bay. Chemicals that will be measured include nutrients, total suspended solids, mercury, trace metals, and PCBs.

Purpose: Evaluate the extent of attainment of Michigan Water Quality Standards; measure temporal and spatial trends in contaminant levels; identify high-quality waters; provide data for water quality protection programs; determine exposure of aquatic life; and identify emerging problems.

Objective: All waters should be attaining Michigan Water Quality Standards for nutrients, metals, and PCBs. The result should be waters that support healthy and diverse aquatic life communities, provide safe drinking water and recreation opportunities, and are not affected by nuisance aquatic plants or algae.

Endpoint: Concentration of contaminants in water should be at or below water quality standards. Examples include mercury (0.0013 ug/l) and PCBs (0.000026 ug/l). In addition, it is hoped that contaminants will decline to levels sufficient to support healthy and diverse aquatic communities and that have no adverse impacts on human health.

Features: During the 1970s and 1980's, the DEQ monitored several rivers around Michigan on a monthly basis. By 1997, the DEQ's water chemistry trend program consisted of monitoring only the Saginaw Bay and Detroit River. In 1998, the water chemistry trend program was expanded to include sample collection from major Great Lakes tributaries, all three Great Lakes connecting channels, and the Grand Traverse Bay. With Clean Water Fund money becoming available in Fiscal Year 2000, the DEQ and the U.S. Geological Survey will collect samples from even more sites around the state to ensure broad statewide coverage. Loading calculations from major tributaries to the Great Lakes will be made based on a flow-stratified sampling design, such that the majority of samples are collected during high-flow events. Samples will be collected using clean techniques and samples analyzed using low-level methods. Data for this indicator are being generated using consistent, widely accepted collection, analytical, and quality assurance protocols. Spatial and temporal trends will be evaluated using rigorous statistical methods. Extensive historical data exist for Saginaw Bay and the Detroit River, while much less information is available for other waters.

Limitations: Available nutrient data for the Saginaw Bay indicates that year-to-year variability in chemical concentrations can be high, making short-term trend analysis difficult. As a result, long-term data likely will be required to assess trends. A number of factors can contribute to this variability, including chemical inputs, weather, and sampling or analytical error. Changes in loadings between years can be caused by changes in flow conditions rather than actual changes in contaminant inputs to surface waters.

Fish and Benthic Macroinvertebrates (Proposed 5/30/2001)

DEQ-SWQD biologists routinely collect data on the relative abundance of fish and benthic macroinvertebrates in wadable streams and rivers throughout Michigan. These surveys are a major component of the Department's watershed assessments, conducted on a 5-year cycle to support the NPDES and nonpoint source protection programs. The sampling method, known as Procedure 51, is a rapid assessment protocol designed to quickly determine stream condition and aquatic life conditions. Biologists sample a stream reach to identify the fish and benthic macroinvertebrate species present and determine their relative abundance. Based on this information, there are nine benthic invertebrate metrics (e.g., total number of taxa, number of mayfly taxa, percent caddisflies, to name three) which are based upon reference conditions and are used to calculate an overall metric score. The overall metric score is rated as "excellent", "acceptable", or "poor". There are ten fish metrics for warmwater streams. For coldwater streams, we simply say that if >1% of the fish collected are salmonids, the site is meeting water quality standards for fish.

Limitations: It should be noted that we often don't collect fish at sites where we collect benthic invertebrates. This is primarily because of the extra time, equipment, and staff required to assess fish, and the fact that benthic invertebrates are good indicators of water quality. Generally, biologists have a specific reason to collect fish rather than doing it routinely. The result is that we have many more sites from which we have benthic invertebrate data than fish data. Because Procedure 51 is a rapid assessment technique, it is qualitative rather than quantitative. That is, we record the percentage of each taxa based on the total number of individual organisms. We do not generate quantitative, statistical measures for each species, such as population densities (e.g., numbers per square meter) or production rates, which are much more time-intensive. This limits the use of these data as long-term, consistent water quality "indicators". Another limitation is that we currently do not have "fixed sites" that are monitored for fish and benthic invertebrates on a regular basis. Rather, we sample different watersheds each year during a 5-year cycle, so that a given site likely will not be sampled more than once every 5 years.

The DEQ-SWQD recently released an Invitation to Bid on a project to develop a procedure to measure long-term trends in aquatic life at fixed stations. The focus is on benthic invertebrate communities, but may encompass fish as well. We expect to have a preliminary procedure in place for testing in 2002, with a final procedure ready for implementation in 2003.

PROPOSED AIR ENVIRONMENTAL INDICATORS

Ambient Levels of Criteria Air Pollutants and Emission Rates of Criteria Air Pollutants from Stationary Sources

National Ambient Air Quality Standards

The Federal Clean Air Act of 1963, as amended in 1970, 1977 and 1990, requires the U.S. EPA to establish National Ambient Air Quality Standards (NAAQS) which define the maximum permissible concentrations for certain pollutants. In early 1971, the U.S. EPA established standards for five "criteria" pollutants: total suspended particulate matter (TSP), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and photochemical oxidants. On October 5, 1978, the U.S. EPA established an additional ambient air quality standard for lead (Pb). A new air quality standard for ozone (O_3) replaced the photochemical oxidant standard on February 8, 1979. In July 1987, the particulate matter standards were revised by U.S. EPA to place greater importance on fine particles with diameters less than ten microns in size (PM_{10}). On July 18, 1997 both the ozone and particulate standards were revised by the EPA. In addition, a new standard for particulate material with a diameter of less than 2.5 microns in size ($PM_{2.5}$) was introduced. The current Air Quality Standards are summarized by pollutant in the section below and in Table 1 (1).

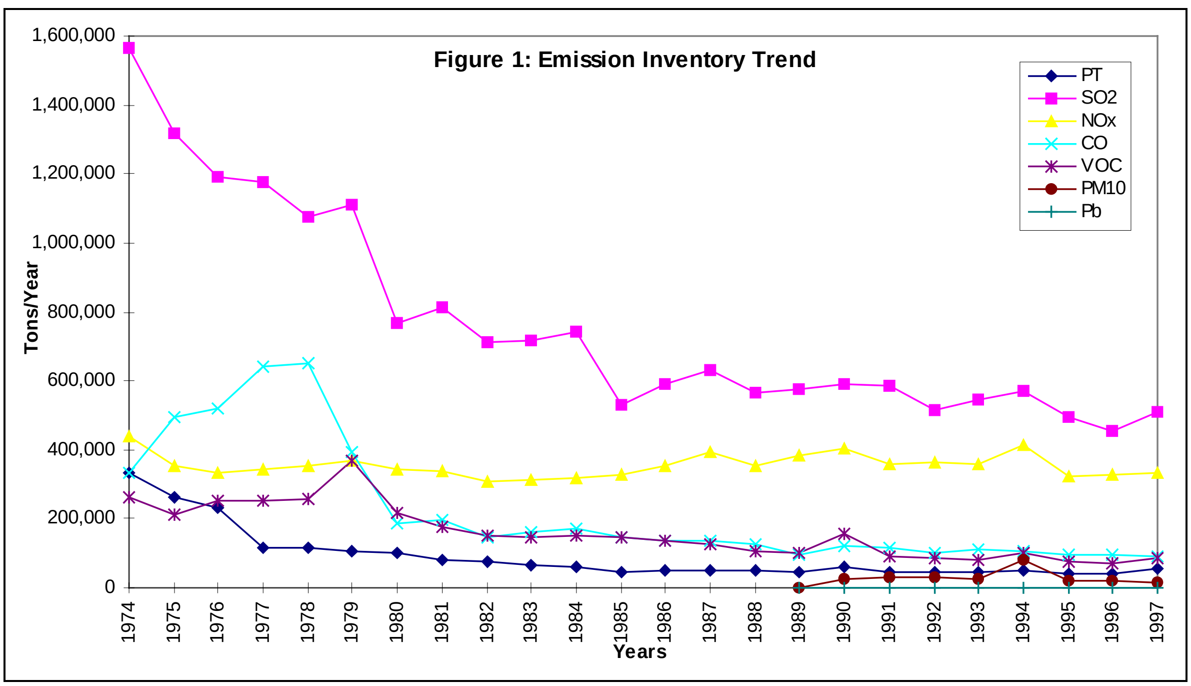
Table 1: National Ambient Air Quality Standards (NAAQS) in Effect during 1997.

	Primary (Health Related)		Secondary (Welfare Related)	
Pollutant	Type of Average	Standard Level Concentration[a]	Type of Average	Standard Level Concentration
CO	8-hour[b]	9 ppm (10 ?g/m^3)	No Secondary Standard	
	1-hour[b]	35 ppm (40 ?g/m^3)	No Secondary Standard	
Pb	Maximum Quarterly Average	1.5 µg/m^3	Same as Primary Standard	
NO_2	Annual Arithmetic Mean	0.053 ppm (100 µg/m^3)	Same as Primary Standard	
O_3	Maximum Daily 1-hour Average[c]	0.12 ppm (235 µg/m^3)	Same as Primary Standard	
	4th Highest 8-Hour Daily Maximum[d]	0.08 ppm	Same as Primary Standard	
PM_{10}	Annual Arithmetic Mean[e]	50 µg/m^3	Same as Primary Standard	
	99th percentile 24-hour[e]	150 µg/m^3	Same as Primary Standard	
$PM_{2.5}$	Annual Arithmetic Mean[f]	15 µg/m^3	Same as Primary Standard	
	98^{h} percentile 24-hour[f]	65 µg/m^3	Same as Primary Standard	
SO_2	Annual Arithmetic Mean	80 µg/m^3 (0.03 ppm)	3-hour[b]	1300 µg/m^3 (0.50 ppm)
	24-hour[b]	365 µg/m^3 (0.14 ppm)		

[a] Parenthetical value is an approximately equivalent concentration. ppm = parts per million. ug/m^3 = micrograms per cubic meter.
[b] Not to be exceeded more than once per year.
[c] The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than 1, as determined according to Appendix H of the Ozone NAAQS. The 1-hour standard applies to areas that have not been redesignated to attainment.
[d] The 8-hour ozone standard applies to areas that have been designated as reaching attainment of the 1-hour standard. The 8-hour standard is met when the 3-year average of the annual 4th highest daily maximum 8-hour ozone concentration is less than or equal to 0.08 ppm.
[e] Particulate standards use PM_{10} (Particles less than 10 microns in diameter) as the indicator pollutant. The annual standard is attained when the expected annual arithmetic mean concentration is less than or equal to 50 µg/m^3 (3-year average); the 24-hour standard is attained when the 3-year average of the 99th percentile is less than or equal to 150 µg/ m^3.
[f] The annual standard is met when annual average of the quarterly mean $PM_{2.5}$ concentrations is less than or equal to 15 µg/m^3, when averaged over 3 years. If spatial averaging is used, the annual averages from all monitors within the area may be averaged in the calculation of the 3-year mean. The 24-hour standard is met when the 98th percentile value, averaged over 3 years is less than or equal to 65 µg/m^3.
Taken from Reference 1 pp. 7, 27, 35.

As shown in Table 1, there are two types of air quality standards. The primary standard is designed to protect the public health with an adequate margin of safety. Permissible levels were chosen to protect the health of the most susceptible individuals in a population, including children, the elderly and those with chronic respiratory ailments. The secondary standard is designed to protect public health and welfare or insure quality of life. Air quality conditions described by the secondary standard may be the same as the primary standard and are chosen to limit economic damage as well as effects to buildings, plants and animals.

Each standard is comprised of several parts which must be met in order to achieve compliance. Ambient levels must not be exceeded over various averaging times. Short averaging times, like the 1-hour maximum level of 35 ppm used for carbon monoxide, reflect the need to protect against acute, or short term toxic effects. The long term averaging times, like the annual mean (average) concentrations for PM_{10}, SO_2 and NO_2 are designed to protect against chronic effects.



Emission Estimates

The Clean Air Act requires states to prepare and maintain emission inventories of major sources and for all non-attainment areas. The emission data included in this report was obtained from the Emission Inventory database collected by the Department of Environmental Quality. Large facilities in Michigan are required to submit completed Michigan Air Pollution Reporting (MAPR) forms annually (2, 3). The procedure for maintaining the Emission Inventory is described in the DEQ Air Quality Division Operational Memo No. 13, which may be obtained from the DEQ Air Quality Division Internet home page or any Air Quality Division office. Emissions data for all sources is now updated every year. For most sources, emissions are calculated using standard EPA emission factors for particulate, sulfur dioxide, oxides of nitrogen, carbon monoxide, volatile organic compounds and lead. For a few sources, emissions of other pollutants are also estimated (4).

This database compiles information from over 2000 facilities and from 18,928 emission points. The approximately 900 largest sources in Michigan are responsible for over 98% of the emissions for CO, NO_2, and SO_2. They account for over 80% of the VOC's and 73% of the particulates. Emissions from commercial and residential properties (area sources) and from mobile sources are not currently included in the database (4). Figure 1 shows continuing reductions in emission estimates from 1974 until the present. Note that in the graph, estimates for lead and PM_{10} emissions are difficult to see because the levels are shown toward the bottom of the graph and are only available after 1990. Due to the self-reporting nature, the large number of sources and complexity of the database, accuracy in emission levels has varied from year to year.

Michigan Air Monitoring Networks

Requirements were set forth in the *Federal Register* to establish a network of the National Air Monitoring Stations (NAMS) for the criteria air pollutants. The *Federal Register* specifies how many NAMS stations are required in an urban area, based on its population (Part 58, Appendix D)(5). These data from these stations are used in nationwide long term trend analysis, and to develop a consistent database in primarily urban areas.

The State and Local Air Monitoring Stations (SLAMS) are used by state and local governments for specific long-term purposes. Special Purpose Monitors (SPMs) are used in specific applications, short term monitoring, and source oriented monitoring. The data generated by these networks is archived in the EPA's Aerometric Information Retrieval System (AIRS). The NAMS and SLAMS sites are subject to approval by the U.S. EPA.

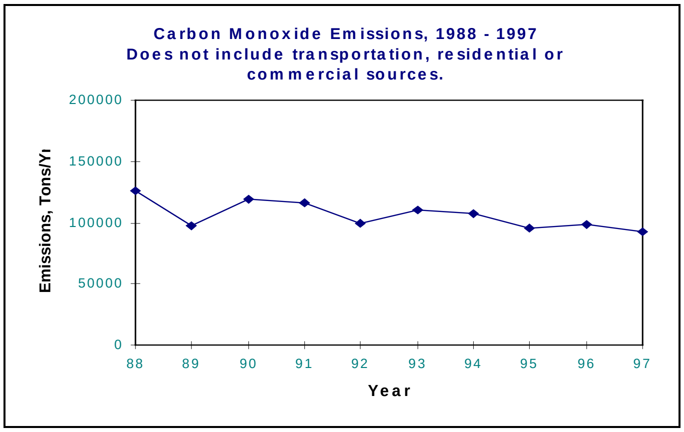
The Michigan Air Sampling Network (MASN) is designed to measure air quality throughout the state, and consists of almost 200 monitoring sensors in 25 counties. The network is operated by the Air Quality Division (AQD), Michigan Department of Environmental Quality (DEQ), city or county agencies as well as industries.

Both the monitoring data and the emissions estimates are two complementary indicators of environmental quality. The next section will examine trends in both measurements of air quality and emissions estimates for each of the criteria pollutants.

Carbon Monoxide (CO)

Primary Air Quality Standard:	8-hour average not to exceed 9 parts per million more than once/year. 1-hour average not to exceed 35 parts per million more than once/year.
Secondary Air Quality Standard :	None

Concentrations of carbon monoxide in Michigan's air have decreased steadily from 1986 to 1988, then leveled off. A slight increase occurred from 1994 to 1995 with levels declining since then. A similar pattern occurs when levels are examined by metropolitan statistical area (MSA). From 1988 until 1997, 8-hour carbon monoxide concentrations decreased by 28.5%. Stationary source carbon monoxide emissions currently fluctuate at about 100,000 short tons/year. carbon monoxide is primarily produced from transportation, fuel-burning for space heating and electrical generation. Some industrial processes, as well as wood, agricultural, and refuse burning also contribute to emissions of carbon monoxide.



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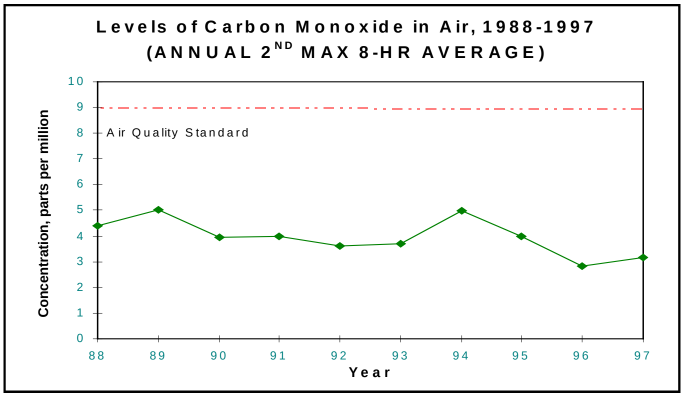


The 8-hour standard tends to be the more restrictive of the two primary standards. During 1994, two carbon monoxide exceedances were detected at the Evergreen site in Detroit. An eight- hour reading of 10.3 parts per million was recorded on January 10, 1994 and 10.7 parts per million on December 23, 1994. These are the only exceedances of the air quality standards for carbon monoxide since 1988. During seven of the previous ten years, the Evergreen site has detected the highest 8-hour carbon monoxide levels across the state. There were no exceedances of the carbon monoxide standards from 1995 to 1997.

The highest one-hour reading recorded during the previous ten years was 25.4 parts per million reached at Warren, just outside of the City of Detroit during 1986. Median values for the 1-hour average across the state are about 10 parts per million, less than a third of the air quality standard.

Beginning in the 1970's, about 23.8% of Michigan's population reside in an area that did not meet the air quality standard for carbon monoxide. This area covered portions of Wayne, Macomb, and Oakland Counties. Currently, the air monitoring data show that the air quality has improved and now meets the air quality standard. The State of Michigan is in the process of asking the EPA to redesignate the area to an attainment classification.

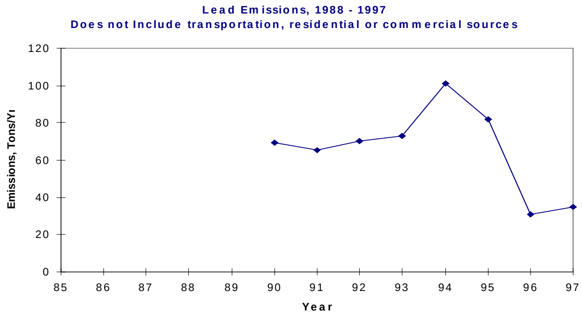
Health and Welfare Effects:

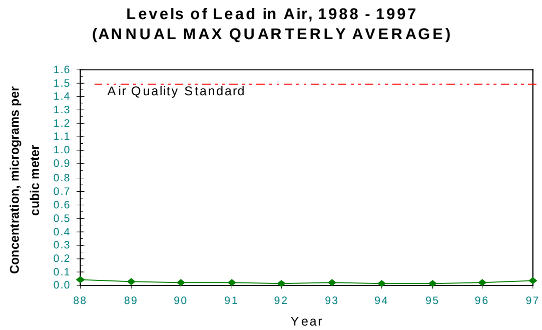
Carbon monoxide exerts toxic effects by limiting oxygen distribution to organs and tissues. People with impaired circulatory systems are vulnerable at lower levels than healthy individuals. Exposure to carbon monoxide impairs visual perception, work capacity, manual dexterity, learning ability, and the performance of complex tasks.

Lead (Pb)

Primary Air Quality Standard:	Maximum Quarterly Average not to exceed 1.5 micrograms per cubic meter more than once/year.
Secondary Air Quality Standard:	Same as primary standard.

The most common sources of lead (Pb) emissions are gasoline additives, non-ferrous smelting plants and battery manufacturing. Historically, lead was added to gasoline as tetraethyl lead to prevent engine knocking. The lead content of gasoline began to be controlled in the 1970's when legislation was introduced to gradually reduce lead levels. Currently, smelters and battery plants are the major sources of lead, nationwide





Concentrations of lead in the air have been steadily decreasing since the removal of lead from gasoline, which began in the 1970's. Average quarterly lead levels across Michigan are less than a tenth of the air quality standard of 1.5 micrograms per cubic meter. From 1988 through 1997, the average of the maximum quarterly lead levels at all sites in Michigan experienced a 18.7% decline. The maximum quarterly lead concentration (0.13 micrograms per cubic meter) detected during the previous ten years occurred at Dearborn in Wayne County in the third quarter of 1988. Similar trends in the reduction of lead levels have occurred in all metropolitan areas in Michigan.

The air quality standard for lead has been met from 1985 through the present. There are no areas in Michigan that are designated as non-attainment for lead.

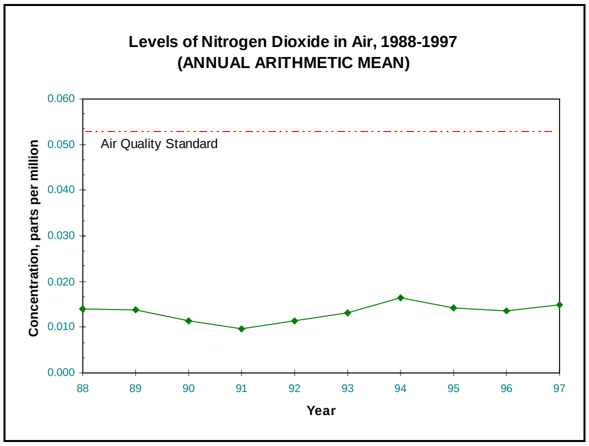
Health and Welfare Effects:

Exposure to lead can occur via ingestion or inhalation. Low levels of lead affect enzymatic functions and homeostasis. Lead may also be a factor in high blood pressure and heart disease in middle aged white males. The nervous system is most sensitive to effects from lead and changes can occur as a result of low doses. Larger exposures can result in behavioral and learning disorders.

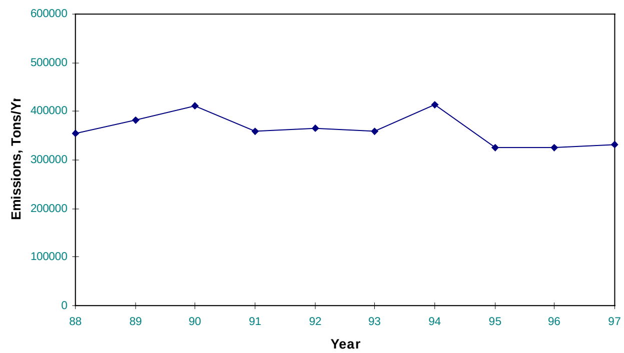
Nitrogen Dioxide (NO_2)

Primary Air Quality Standard: Annual Arithmetic Mean not to exceed 0.053 ppm more than once/year.

Secondary Air Quality Standard: Same as primary standard.



Nitrogen Dioxide Emissions, 1988 - 1997
Does not include transportation, residential or commercial sources.



Nitrogen dioxide is formed during combustion processes that create extremely high temperatures, such as those that result from burning coal, oil and gas fuel and from burning fuels in motor vehicle engines.

Annual emissions of nitrogen dioxide from stationary sources have leveled out at about 330,000 tons per year based on estimates from 1995 through 1997. The annual arithmetic mean ambient concentrations of nitrogen dioxide across Michigan are well below the levels set by air quality standard. During 1997, the greatest annual mean of 0.026 parts per million was observed at the Linwood station in Detroit. For the past ten years, all areas in Michigan have met the air quality standard for nitrogen dioxide.

There are no areas in Michigan that are designated as non-attainment for nitrogen dioxide.

Health and Welfare Effects:

The respiratory system is susceptible to effects caused by exposure to nitrogen dioxide. Asthmatics are more sensitive to the effects from exposure to nitrogen dioxide. Nitrogen oxides are precursors to ground-level ozone formation and acid rain.

Ozone (O_3)

Primary Air Quality Standard:	Fourth Highest Daily Maximum 8-hour Average, averaged over 3 years not to exceed 0.08 ppm.
Secondary Air Quality Standard:	Same as primary standard.

Ozone is a colorless gas that is formed from photochemical reactions between nitrogen oxides (NO_x) and volatile organic compounds (VOC's) such as hydrocarbons from gasoline and solvents used in cleaning materials or painting applications. Sources of nitrogen dioxide are discussed in the previous section. The primary sources of VOC's and hydrocarbons include motor vehicle exhaust, gasoline storage and transfer, paint solvents, and degreasing agents. Natural sources include lighting and terpene emission from pine trees and other vegetation. Sunlight initiates the reaction, which is why elevated ozone concentrations occur during the warmer sunnier months of the tear. In addition to the formation of ozone, these reactions form many other products which, combined with ozone, are called photochemical smog. Smog itself is a brownish, acrid mixture of many gases and particles. The color, odor, and astringency of smog are due to compounds other than ozone (5). Ozone, itself, is colorless.

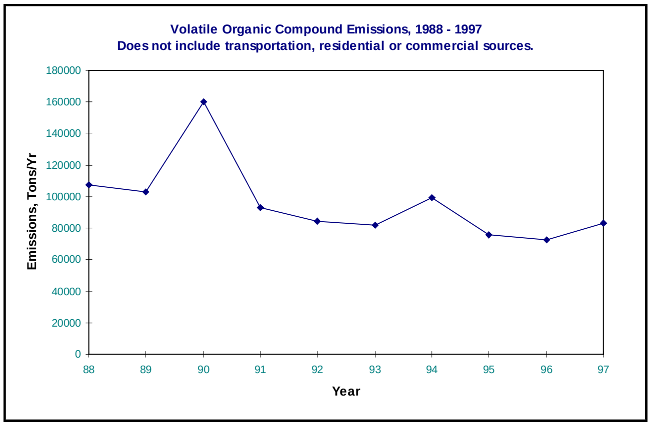
The ozone that is contained in smog is close to ground level and is also known as "tropospheric" or ground level ozone. Another layer of ozone, contained in the stratosphere (7 to 30 miles above the earth's surface), is responsible for shielding the earth's surface from the sun's harmful ultraviolet rays that cause skin cancer. The common phrase, "hole in the ozone," refers to the ozone in this layer. Aerosol propellants and various refrigerants that contain chlorofluorocarbons that have been released during their use migrate into the upper atmosphere. Once there, a complex series of chain reactions occur that involve the formation of free radicals which destroy the ozone molecules and create a thinning of the ozone layer. The two ozone layers do not generally mix, and it is the tropospheric layer that is the subject of this report.

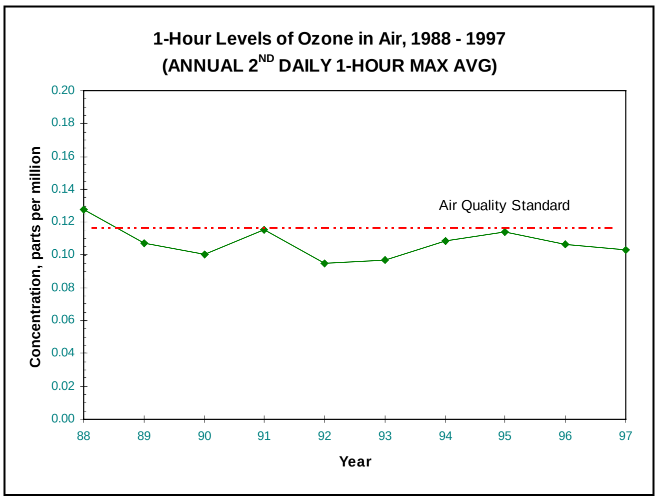
During 1997, there was a single event when the 1-hour air quality standard for ozone was not met. A level of 0.138 parts per million was detected New Haven on July 12, 1997. The new 8-hour form of the standard adopted in 1997 is more restrictive than the previous 1-hour standard. In 1997, there were 91 8-hour values over 0.084 parts per million which were measured at 25 monitoring sites. These elevated values were measured on 21 days. The highest 8-hour value (0.110 parts per million) for the year was detected at New Haven on the same day that the 1-hour value of 0.138 parts per million was measured. The greatest number of sites (15) measured elevated 8-hour values on July 12, 1997. Coloma was the individual site with the greatest number of 8-hour values over 0.084 ppm, the total reaching 12 for the 1997 ozone season. When the fourth highest annual 8-hour value was averaged for each monitor from 1995 to 1997, Muskegon had the highest average concentration at 0.0997 ppm.

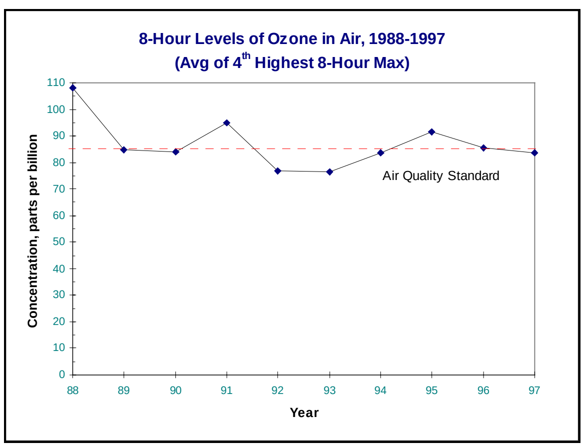
Most (10) of the 21 days during 1997 with meteorological conditions favorable to the formation of elevated 8-hour ozone levels occurred in June 1997. Twenty of the twenty-five monitoring stations measured elevated levels during the June episode days bringing the total number of 8-hour values to 39 for the month of June. There were only 7 episode days in July, but 41 values over 0.05 parts per million were measured.

In 1998, the old 1-hour air quality standard was revoked for most of the counties in Michigan. It continues to apply only in Allegan, Muskegon, Oceana, and Mason counties. As a result of the revocation of the 1-hour standard for Genesee, Midland, Saginaw, and Bay counties, the percentage of Michigan's population residing in the areas where the air does not meet the old 1-hour air quality standards has dropped from 11.6% (1,079,271 people) to 2.7% (249,492 people). Currently, only Muskegon and Allegan counties are classified as non-attainment for the 1-hour NAAQS.

Health and Welfare Effects:
Ozone irritates the respiratory system and can cause coughing and chest pains upon deep inspiration in exercising individuals. Ozone is the major component of photochemical smog. It is also responsible for crop damage and increased deterioration of rubber, dyes, paints and fabrics.



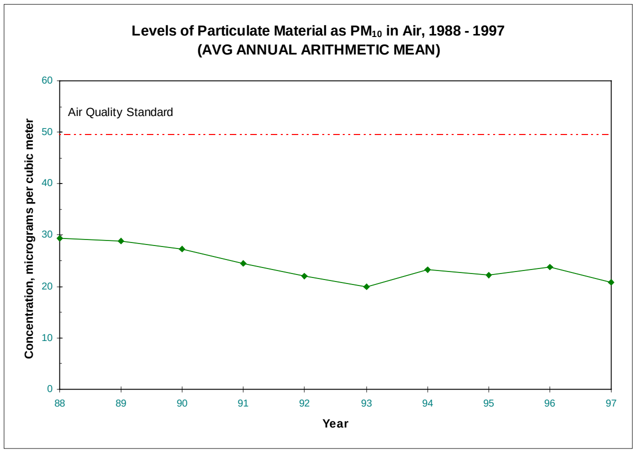


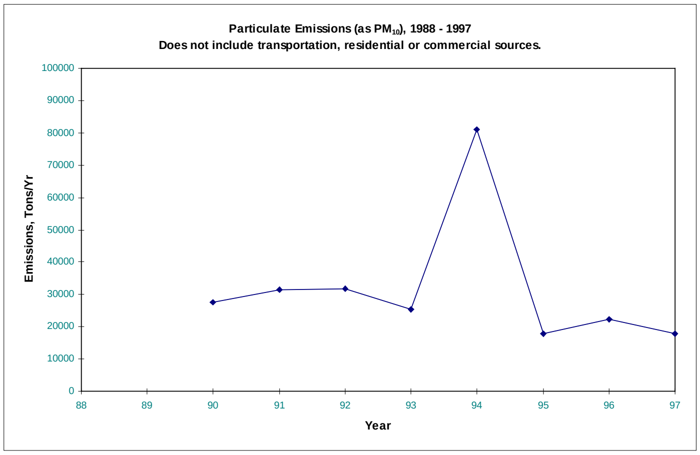


Particulate Matter (PM_{10})

Primary Air Quality Standard:	Annual Arithmetic Mean not to exceed 50 micrograms cubic meter (based on a 3 year average). 24-hour 99th percentile not to exceed 150 micrograms per cubic meter.
Secondary Air Quality Standard:	Same as primary standard.

Particulate matter is a broad classification of material that consists of either solid particles or fine liquid droplets. 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. Particulate emissions are primarily composed of 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, ocean spray, and volcanic activity.





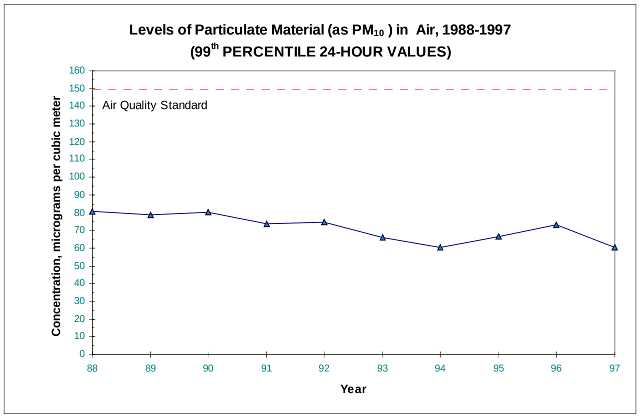
The average annual arithmetic mean levels of PM_{10} have shown a reduction over the previous ten years equaling 23.7%.

A new percentile-based form of the 24-hour PM_{10} air quality standard was adopted in July 1997. When historical data are expressed in either the old or new format, 24-hour particulate levels have decreased steadily since 1988. From 1996 to 1997, additional reductions occurred in both 24-hour and annual averages in almost every metropolitan area. The highest particulate levels have consistently been detected at the Dearborn site in Detroit.

All areas in Michigan meet the air quality standards for PM_{10}.

Health and Welfare Effects:

Exposure to particulate matter affects breathing and the defenses of the lungs and aggravates existing respiratory and cardiovascular disease. More serious effects may occur, depending on the length of exposure, the concentration, and the chemical nature of the particulate matter. Asthmatics and individuals with chronic lung and/or cardiovascular disease, people with influenza, the elderly, and children are most susceptible. Particulate matter that is less than 10 microns in diameter is especially harmful because it penetrates further into the lungs. Particulates that lodge in the alveoli remain for longer periods of time as the alveoli have a slow clearance system. Particulate matter impairs visibility, damages materials, and creates soiling.



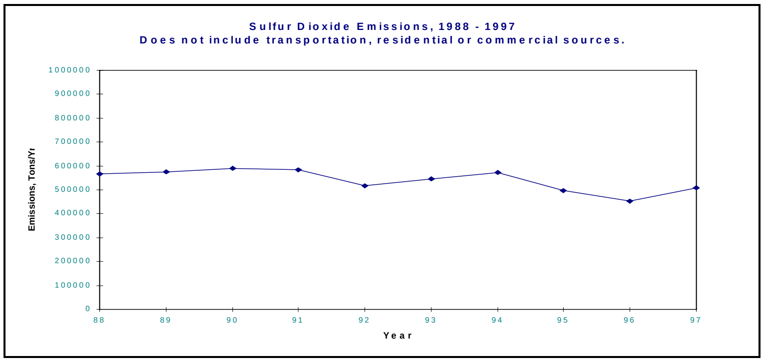
Sulfur Dioxide (SO_2)

Primary Air Quality Standard: Annual Arithmetic Mean not to exceed 0.030 parts per million. 24-hour concentrations not to exceed 0.14 parts per million more than once/year.

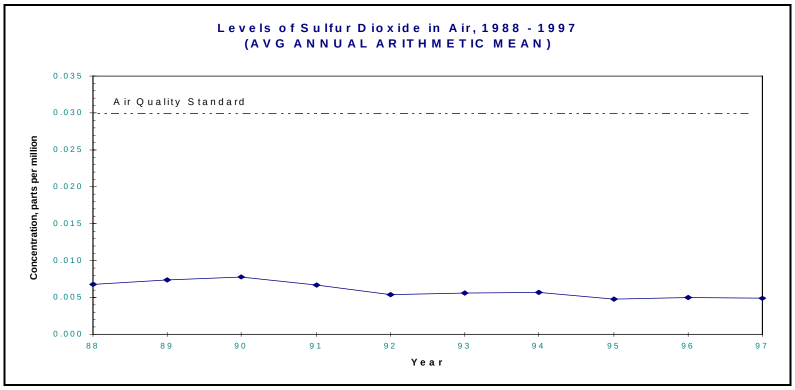
Secondary Air Quality Standard: 3-hour concentrations not to exceed 0.50 parts per million more than once/year.

Nationwide, the largest sources of sulfur dioxide that result from man's activities are coal burning power plants. State regulations require that most of the coal burned in Michigan contain low amounts of sulfur. Sulfur dioxide is also emitted from non-ferrous smelters, iron ore smelters, petroleum refineries, pulp and paper mills, transportation sources, and steel mills. Other sources include residential, commercial and industrial space heating. Volcanic eruptions are natural sources of sulfur dioxide. Emission levels of sulfur dioxide from stationary sources leveled off at just less than 600,000 tons/year until 1995 when they began to decline further and now are about 500,000 tons/year. Concentrations in the air have been less than 0.01 parts per million, an average level well below the air quality standard. The annual concentrations of sulfur dioxide have dropped by 33.0% from 1988 through 1997.

Elevated 24-hour concentrations of sulfur dioxide were measured back in 1989 and 1990 at Escanaba when values reached 0.153 parts per million and 0.154 parts per million respectively. A value of 0.124 parts per million was detected at Rosebush in Isabella county in 1991, but was less than the air quality standard.



During the previous ten years, all measurements of sulfur dioxide levels have met the secondary air quality standard. All sulfur dioxide measurements for each metropolitan area collecting data met the primary air quality standards.

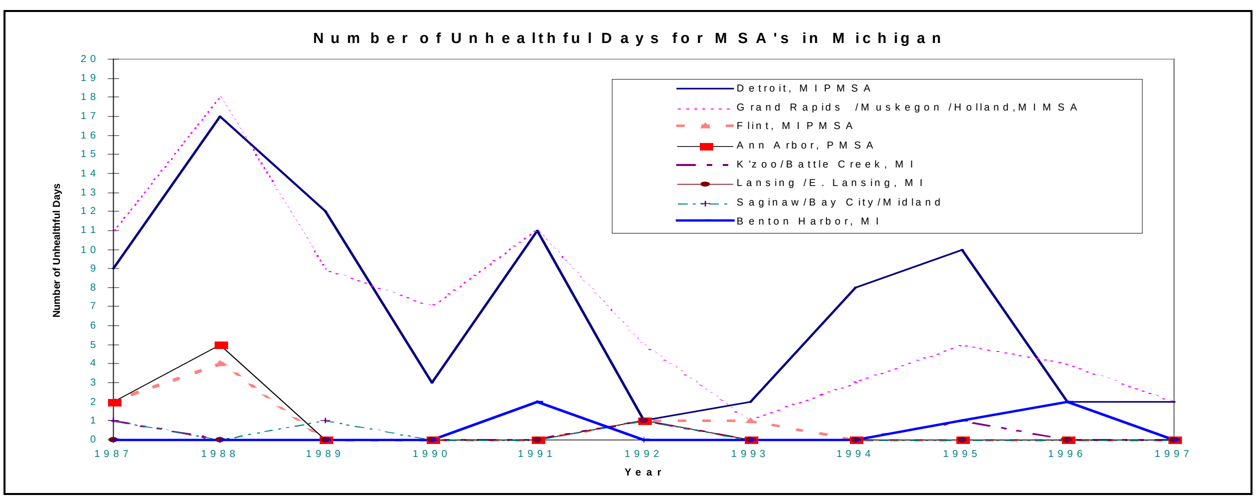


Health and Welfare Effects:

Exposure to sulfur dioxide aggravates existing respiratory and cardiovascular disease. Asthmatics and individuals with chronic lung and/or cardiovascular disease, children, and the elderly are most susceptible. Sulfuric acid is a component of acid rain, which acidifies lakes, streams and soils and corrodes building surfaces.

Pollutant Standards Index (PSI)

The Pollutant Standards Index (PSI) was developed by the EPA to provide a simple, uniform way to report daily air pollution concentrations. It also allows governmental agencies to advise the public about the health effects that are associated with various levels of pollution and to advise precautionary steps if conditions warrant. Episode criteria and significant harm levels have been established for the various air pollutants. Pollutant standards index values are available to the public and local news agencies (newspapers, television, and radio) on a daily basis (6, 7). The pollutant standards index is a tool that converts pollutant concentrations into a numerical scale that ranges from 0 to 500. The numbers on the scale are related to potential health effects of the criteria pollutants. The index allows the air quality levels in a given area to be classified as good, moderate, unhealthful, very unhealthful, or hazardous. An index value of 100 is related to the National Ambient Air Quality Standard for the criteria pollutant. Lead is not included in the PSI because the standard does not specify a short term NAAQS concentration, or federal episode criteria and significant harm levels.



The preceding figure shows the total number of unhealthful events for the 7 Michigan metropolitan areas that are required to report the index. Both the Grand Rapids and Detroit areas show improvement in air quality over the previous ten years. Prior to 1993, the frequency of unhealthful events in the two cities tracked each other rather well. After 1993, although air quality improves in both, Grand Rapids shows greater improvement than Detroit. The frequency of unhealthful events at other locations in Michigan is low, influenced by the limited number of measurements made in other areas.

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Emission Rates of Toxic Air Pollutants

Toxic air pollutants include those substances that are not among the six criteria air pollutants discussed above. These include metals, such as mercury, arsenic, cadmium, and chromium, as well as a very large number of substances that contain the element carbon and are referred to as "organic." Examples of the organic substances include dioxin, tetrachloroethylene, benzene, formaldehyde, and carbon tetrachloride. Air emissions of the toxic air pollutants are of interest because the emissions become dispersed in the air and may reach inhabited areas where people are exposed to them. Exposure includes eye and skin contact as well as the respiratory system. For some persistent and/or bioaccumulative substances, exposure may also occur through other indirect routes (which is discussed further in the section on the future air quality indicator, "Rates of Deposition of Persistent and/or Bioaccumulative Air Toxic Contaminants"). Depending on the concentration, duration of exposure, and the toxicity of the substance, the exposure to toxic air pollutants may be harmless or may cause a risk of a variety of toxic effects. These range from eye irritation to lung toxicity, and since many substances are absorbed from the lungs into the body, toxic effects may occur in other organs also.

Emission rates of the toxic air pollutants do not represent exposure levels, so they should not be used as or implied to be indicators of exposure or toxic effects. However, since there is not a very complete database on the measured levels of air toxics in outdoor air around the State (discussed below as future indicator #4, emissions data are valuable as indicators of which substances are being emitted to the air which could result in exposure to people downwind. Emissions data help to indicate the geographic areas and substances which are of relatively higher concern. The data are also useful as an indicator of whether emission trends over time are increasing or decreasing.

<u>Toxics Release Inventory (TRI) program</u>

One useful database of air toxics emissions data is the Toxics Release Inventory (TRI) program, which was initiated by the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986. The air emissions data are presented elsewhere in this report, along with the data reported for emissions to surface water, land, and underground injection. This emission reporting program requires specific types of facilities to self-report annually their emissions of a large and specific list of toxic chemicals, if their emissions exceed minimum trigger levels.

The Great Lakes Commission has provided another useful air emissions inventory, the Great Lakes Regional Air Toxic Emissions Inventory. The first report, released in August 1998, provides 1993 data on air emissions from each of the eight Great Lakes States plus Ontario. This initiative is also referred to as RAPIDS (Regional Air Pollutant Inventory Development System), which is the method used to compile the inventory. (The newly introduced Michigan Air Emission Reporting System (MAERS) is a RAPIDS based emissions reporting system.) The emissions estimates were developed by staff of the air quality agencies of the region, based on emission factors applicable to particular facility processes and activities, and the types of pollution control equipment in use. Included were large industrial or "point" sources, and smaller stationary sources called "area" sources. The 1993 inventory includes 49 of the air pollutants of highest concern in the Great Lakes region, and that number will be expanded in future reports. The next inventory should become available in 1999, based on emissions for the year 1996. The objective of this ongoing initiative is to present researchers and policy makers with detailed, region-wide data on the sources and emission levels for the air pollutants of greatest concern. This inventory differs in several important ways from the TRI inventory described above. The Great Lakes Regional inventory includes emissions estimated by agency staff at the facility process level without minimum emission quantities for reporting as in TRI, including all point and area sources of emissions rather than a limited set of facility types as in TRI. Additionally this inventory focuses on a high priority chemical list that is much smaller than the list of substances subject to reporting under the TRI program. For these reasons, significant differences may be expected in the emission estimates from these two programs, and one should be very cautious in comparing and interpreting between the two. It would be more appropriate and meaningful to look at each program separately to observe the trends of emission quantities over time.

Table 1 presents are the 1993 air emission estimates reported by the Great Lakes Commission. Included are emission estimates for 33 of the targeted 49 substances or groups of substances, for which emissions could be estimated. The Commission's report notes that the estimates for dioxins and furans (PCDD, PCDF, 2378-TCDD and 2378-TCDF) should not be considered to be accurate or reliable due to the lack of accurate emission factors.

TABLE 1: MICHIGAN 1993 AIR TOXIC EMISSIONS INVENTORY

SUBSTANCE:	TOTAL EMISSIONS (Pounds/Year)
ARSENIC	27205.
BENZ (A) ANTHRACENE	65.
BENZO (A) PYRENE	14334.
CADMIUM	3833.
CARBON TETRACHLORIDE	3699.
CHROMIUM	7282.
CHROMIUM VI	440.
CHRYSENE	21875.
COBALT	1384.
COKE OVEN EMISSIONS	233834.
COPPER	22707.
DIBUTYL PHTHALATE	3656.
DICHLORETHANE, 1,2-	30121.
DIOCTYL PHTHALATE	7.
ETHYLBENZENE	425428.
FLUORANTHENE	17673.
LEAD	144537.
MANGANESE	59219.
MERCURY	10719.
METHYLENE CHLORIDE	586970.
NAPHTHALENE	635067.
NICKEL	12245.
POLYCYCLIC AROMATIC HYDROCARBONS	1091546.
PCBs	4.

SUBSTANCE:	TOTAL EMISSIONS (Pounds/Year)
PCDD	5.
PCDF	31.
PERCHLOROETHYLENE	7546906.
PHENOL	280662.
POLYCYCLIC ORGANIC MATTER	6445.
TCDD, 2378	less than 1 pound
TCDF, 2378	73.
TRICHLOROETHANE, 111	1036431.
TRICHLORETHYLENE	2562442.

Ambient Levels of Air Toxic Contaminants (*Future Air Quality Indicator*)

Toxic air pollutants include those substances that are not among the six criteria air pollutants. Outdoor air concentrations of these substances are an important air quality indicator because at certain concentrations they may pose risks for causing cancer or other health effects. Therefore, it would be very valuable to have an extensive database of measured levels of toxic air pollutants, to observe trends and to evaluate the health risks of the levels. Unfortunately, the currently available data are quite limited in scope. The monitoring data are limited in terms of monitoring sites, monitored compounds, and years of collection (see Table 1 below). For example, the DEQ Air Quality Division currently operates only four monitoring stations statewide to measure the ambient air levels of organic substances (Detroit, River Rouge, Grand Rapids, and Houghton Lake), in addition to two industry-operated stations (Midland and Kalamazoo). Also, many substances are frequently found to be at levels too small to measure with current equipment and methods, which further complicates trend assessment. The available database is not considered to be as thorough as needed for meaningful trend analysis. However, it does provide some baseline data which will be valuable for comparison to the results of future monitoring efforts.

Although the currently available data are limited, future data collection efforts should provide some basis for limited trend analysis. This future air quality indicator will have important relevance to the state of the air quality and the degree of public health protection. Additional resources directed to toxic air pollution monitoring are needed to expand the number of monitoring locations and types of pollutants to provide a comprehensive and useful environmental indicator. It should be noted that the air toxics monitoring data have been compiled and made available in the DEQ's annual Air Quality Reports since 1988. Those reports include monitored levels on industrial properties as well as in public locations. Only the ambient air data measured in public areas are noted in Table 1.

Table 1. Monitoring Data Available for Toxic Air Pollutants in Michigan[1]

City	Years	Mercury	Arsenic	Other Metals	PCBs[2]	Dioxins	PAHs[3]	Pesticides	Aldehydes	Organics
Alpena	1995-1996 1997-1998	x	x	x	x	x				 x
Ann Arbor	1988-1991			x						
Bay Port	1990-1991			x	x		x	x		
Brimley	1991			x	x		x	x		
Dearborn	1988								x	x
Decker-ville	1993-1994			x	x		x	x		
Detroit	1988 1990-1999 1994-1999 1995-1999			 X					x X	x X
Dexter	1993-1994			x	x		x	x		
Flint	1988-1991 1994-1999			x X						
Grand Rapids	1988-1991 1994-1999 1995-1999			x X					 X	 X
Houghton Lake	1998-1999			X					X	X

City	Years	Mercury	Arsenic	Other Metals	PCBs[2]	Dioxins	PAHs[3]	Pesticides	Aldehydes	Organics
Kalama-zoo	1988-1991			x						
	1991-1996			x					x	
	1991-1999									X
Lansing	1988								x	x
	1988-1991			x						
	1992									x
Midland	1988								x	x
	1997-1998					x				
	1989-1999			X						
	1991-1999		X							X
Muskegon	1988-1991			x						
	1994-1997			x						
Pellston	1992-1994			x						
	1993-1994			x	x		x	x		
	1997-1999	x		x	x					
Portage	1990-1992			x						
Port Huron	1988								x	x
	1988-1991			x						
River Rouge	1994-1999			X						X
	1995-1999								X	
Saginaw	1988			x						
South Haven	1992-1994			x	x		x	x		
Traverse City	1990-1991			x	x		x	x		
Wyoming	1988-1991			x						
	1994-1999			X						
Eagle Harbor	1997-1999	x		x						
Isle Royale	1997-1999	x		x						
Taqua-menon Falls	1997-1999	x		x						

[1] In this table, an "x" indicates that data are available for the years specified. A bold "X" indicates that monitoring is ongoing.
[2] PCBs = Polychlorinated Biphenyls
[3] PAHs = Polyaromatic Hydrocarbons

Rates of Deposition of Persistent and/or Bioaccumulative Air Toxics (*Future Air Quality Indicator*)

Some air toxic contaminants are very persistent in the environment. Persistent airborne contaminants may be widely dispersed and may move to water bodies or soils through a process called deposition. Examples of these persistent contaminants include mercury, lead, dioxins, PCBs, and several pesticides. Many of these pollutants also have a high tendency to accumulate in fish and other organisms. For these pollutants, inhalation exposure is not the only public health concern. Therefore, if atmospheric deposition appears to be a significant contributor to overall environmental levels and human exposures, then it would be desirable to include these deposition data as air quality indicators. Atmospheric deposition rates and accumulation in sediments, soils, crops, land animals and aquatic life can be important indicators of potential public exposure for such compounds. However, at present the atmospheric deposition data are quite limited. Some data are presented in the January 1998 report, "Great Lakes Trends: A Dynamic Ecosystem", along with other data relevant to historical discharges and atmospheric deposition such as PCB concentrations in Herring Gull eggs and temporal trends of levels of lead, mercury, and toxaphene in sediments. To better understand the atmospheric deposition component of these findings, additional resources will be needed to collect deposition data and determine trends.

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