DEVELOPMENT OF NUMERICAL TARGETS FOR THE DELISTING OF BENEFICIAL USE IMPAIRMENTS IN THE MUSKEGON LAKE AND WHITE LAKE AREAS OF CONCERN

BY

Dr. Richard Rediske
Principle Investigator
and
Dr. Alan Steinman
Kate Rieger

Annis Water Resources Institute
740 West Shoreline Drive
Muskegon, MI 49441

AWRI Publication # TM-2007-4
Great Lakes National Program Office # FL96534-01-0
U. S. Environmental Protection Agency

PROJECT OFFICER:

Mark Elster
U. S. Environmental Protection Agency
Great Lakes National Program Office
77 West Jackson Blvd.
Chicago IL 60604-3590

January 2007

Acknowledgements

This work was supported by grant # FL96534-01-0 from the Environmental Protection Agency Great Lakes National Program Office (GLNPO) to the Annis Water Resources Institute (AWRI) at Grand Valley State University.

Project Team

EPA Project Officer

Mark Elster USEPA GLNPO

Project Staff

Dr. Richard Rediske	AWRI/GVSU	Principle Investigator
Dr. Alan Steinman	AWRI/GVSU	Ecologist
Kate Rieger	AWRI/GVSU	Research Assistant

Peer Review

Dr. Karl E. Havens	University of Florida
Dr. Tom Nalepa	NOAA/GLERL
Dr. David Jude	University of Michigan
Ms. Vicki Webster	Muskegon County Health Department

The authors would like to thank the members of the Muskegon Lake and White Lake Public Advisory Councils for their support and participation in the delisting target setting process. We also appreciate the review comments and support from Julie Simms, Roger Eberhard, and Shannon Drahiem of the Michigan Department of Natural Resources. Finally, we gratefully acknowledge the financial assistance provide by the Great Lakes Commission for the peer review process as part of support grants to the Muskegon Lake and White Lake Public Advisory Councils.

TABLE OF CONTENTS

LIST OF FIGURES

Executive Summary

The Annis Water Resources Institute (AWRI) at Grand Valley State University worked with the Muskegon Lake and White Lake Public Advisory Councils. To develop numerical targets for the delisting of the following Beneficial Use Impairments (BUIs) in the Muskegon Lake and White Lake Areas of Concern:

Muskegon Lake	White Lake
Eutrophication and Undesirable Algae	Eutrophication and Undesirable Algae
Degradation of Aesthetics	Degradation of Aesthetics
Restrictions on Fish and Wildlife Consumption	Restrictions on Fish and Wildlife Consumption
Degradation of Benthos	Degradation of Benthos
Beach closings	Restrictions on Drinking Water Consumption

An initial review of all BUIs was conducted in the fall of 2004 to determine if sufficient information and guidance were present to establish delisting targets. Based on this review, the BUIs listed above were selected for target development early in 2005. Site-specific considerations, historical data, peer reviewed literature, available guidance documentation from state and federal agencies, the target setting process used at other AOCs, and public comment were used to develop the targets for each BUI. Preliminary targets were developed and consensus was obtained by each PAC for the initial version. The preliminary targets then were presented in two public meetings for each AOC and any comments or concerns were discussed. The results of the public meetings were reviewed during subsequent PAC meetings and appropriate revisions were made. The preliminary targets then were sent to scientists for peer review and comment during the summer and fall of 2005. After the peer review comments were obtained, the targets were revised and presented in final form for the PACs for approval by vote. A consensus vote was obtained for all targets by both PACs by the summer of 2006. In January 2006, the MDEQ issued their guidance for the development of delisting targets and conducted a staff level review of targets proposed by the PACs in October 2006. The Muskegon Lake PAC agreed to incorporate the MDEQ comments in their targets and approved a final set of revised targets in November 2006. As of December 2006, the White Lake PAC is still reviewing the MDEQ staff comments. The final targets developed for the Muskegon Lake AOC and the White Lake AOC are summarized in this report.

1. Introduction

The Muskegon Lake and White Lake Areas of Concern (AOCs) are located in Muskegon County, Michigan. Both AOCs are drowned river mouth systems with long histories of anthropogenic disturbance. The aquatic habitat in the lakes was extensively impacted by logging in the 1800s when the riparian vegetation was removed and the littoral zone was filled for the construction of saw mills. In the 1900s, industrial development of the shoreline occurred with the establishment of leather tanning and specialty chemical facilities in the White Lake AOC and heavy manufacturing in the Muskegon Lake AOC. Anoxic conditions, fish kills, poor fisheries, degraded benthic invertebrate and wildlife populations, contaminated sediments, and hypereutrophic conditions were reported by the EPA and Michigan Department of Environmental Quality (MDEQ). The following Beneficial Use Impairments were identified in these AOCs in the 1987 Remedial Action Plans (RAPs):

Eutrophication or Undesirable Algae (White and Muskegon)	Degradation of Fish and Wildlife Populations (White and Muskegon)
Beach closings (Muskegon)	Restrictions on Dredging (White and Muskegon)
Loss of Fish and Wildlife Habitat (White and Muskegon)	Restrictions on Fish and Wildlife Consumption (White and Muskegon)
Degradation of Aesthetics (White and Muskegon)	Degradation of Benthos (White and Muskegon)
Restrictions on Drinking Water (White and Muskegon)	

Since their listing as AOCs, considerable environmental restoration efforts have occurred to improve the environmental quality of the lakes. In the mid 1970s, municipal and industrial wastewater discharges were removed from the lakes by the construction of advanced extended aeration/land treatment systems. The new wastewater systems, coupled with aggressive industrial pretreatment programs, reduced excessive nutrient and contaminant loading in the two lakes. Fish and benthic populations responded positively to the extent that the lakes now support economically important fisheries. In White Lake, the two major areas of contaminated sediments were removed in 2003 and the locations are being monitored for recovery. For Muskegon Lake, contaminated sediment areas were identified and remediation of one location, Ruddiman Creek, was completed in 2006. In addition, the Muskegon Lake Public Advisory Council (MLPAC) and the White Lake Public Advisory Council (WLPAC) have been involved in numerous aquatic and terrestrial habitat enhancement programs.

The two AOCs have reached a critical point where it is imperative to assess the effectiveness of restoration activities and establish numerical targets for completion. The target-setting process must integrate public values and goals for the ecosystem with sound science and applicable federal and state regulations. The restoration must be achieved within an appropriate timeframe and to a degree indicative of the urban setting of both AOCs. Finally, the targets must have measurable indicators that can be monitored in a cost-effective program and be summarized clearly to the public. In summary, the targets should establish a clear mandate with measurable goals that the AOC can achieve.

The Annis Water Resources Institute (AWRI) at Grand Valley State University developed numerical targets for delisting selected Beneficial Use Impairments in the White Lake and Muskegon Lake AOCs. With staff support and expert scientific assistance, AWRI established a group of measurable parameters for the selected BUIs. In addition, numerical values for each parameter were developed based on site-specific considerations and historical data, peer reviewed literature, and the target setting process used at other AOCs. The target development process involved an initial review of historical data from the RAPs for each AOC, available guidance documentation from state and federal agencies, and the targets established for other AOCs.

The establishment of scientifically defendable numerical targets is important for Muskegon Lake and White Lake in the AOC program because they:

- Define the endpoint for AOC restoration
- Provide scientific credibility for the process
- Determine progress made
- Direct the planning and prioritization of future actions
- Assist in the development of funding strategies

With a set of numerical targets established, the Muskegon Lake and White Lake PACs can begin to assess the current status of restoration efforts and move forward with the necessary planning, restoration, and monitoring programs to achieve delisting. The process will be documented and available to other Great Lakes communities as a successful model for numerical target setting at other AOCs.

2. Project Objectives

The objective of this project was to develop indicators and numerical targets for delisting Muskegon Lake and White Lake as AOCs. Specific objectives and task elements are summarized below:

- Review historical and current data related to the Muskegon and White Lake AOCs

    - Data from the historical and current Remedial Action Plans (RAPs) for each lake was reviewed to develop a summary of conditions that resulted in the listing of each AOC and supported the designation of BUIs. In addition, recent data from MDEQ and EPA lead/sponsored monitoring programs was reviewed to determine current status.

- Review EPA/MDEQ guidance for target setting and the numerical targets established by other AOCs.

    - Published guidance from the EPA and MDEQ, in addition to applicable water quality criteria/standards, were reviewed and incorporated in the target setting process. In addition, numerical targets and indicators established for other

AOCs were reviewed. Wherever possible, supporting documentation from each AOC with established targets was included in the review.

- Develop the list of indicators and numerical targets for each AOC.

  - Based on the above information, a suite of indicators and numerical targets was developed for 5 BUIs in each AOC. The indicators and targets were presented to the PACs for review and then in a public forum to solicit community input. PAC and public comments were incorporated into the targets where appropriate.

- Conduct a scientific peer review of the proposed targets.

  - The proposed targets were sent to a group of scientific experts for review and comment. Peer reviewers were selected for their expertise in issues related to individual BUIs (i.e., fisheries, benthic invertebrates, water quality, etc.). The reviewers were provided a summary of historical conditions that resulted in the listing of a BUI, current monitoring data, applicable federal/state criteria, information from other AOCs, and the rationale used for target development in each lake.

- Develop the final list of targets and indicators.

  - Comments from the peer review were incorporated into the final list of indicators and numerical targets. The results of the peer review and final targets were presented to the PAC in a public meeting.

3. The Delisting Process

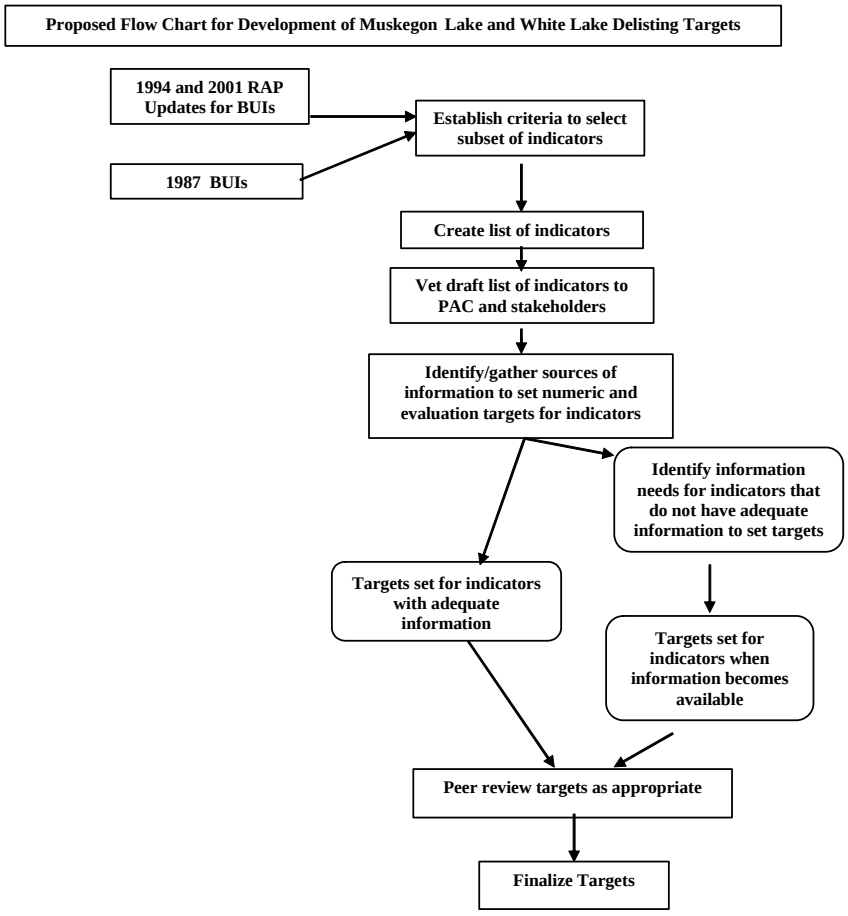
The IJC, EPA, and MDEQ have collectively established a process for removing an AOC from the list of severely impaired sites. The process is called delisting and involves the following steps:

- Establish a list of indicators and numerical criteria for the restoration of each BIU.
- Monitor the indicators to demonstrate restoration progress
- Submit a petition for delisting with supporting data when restoration has been achieved.

The restoration criteria are often referred to as targets and process of criteria establishment is called target setting. In September 2003, a group of MLPAC and WLPAC members, federal, state and local governmental officials, scientists, and citizens met to discuss the status of each AOC and the process of target setting. The consensus of the group was that considerable progress towards restoration of the BUIs had occurred and process of target setting should move forward. Scientists at the Annis Water Resources Institute (AWRI) worked with the PACs and developed a process for establishing the delisting targets that involved the integration of scientific information,

site specific data, stakeholder values, and scientific peer review. The process is described in Figure 1. In the fall of 2004, AWRI obtained grant funding from the EPA's Great

Figure 1. Target Setting Process



Lakes National Program Office to develop delisting targets for 5 BUIs. The MLPAC and WLPAC obtained additional funding from the MDEQ to facilitate the target setting process and support the scientific peer review. AWRI focused on the BUIs that had sufficient information available for target setting. Based on consultation with PAC members, the following BUIs were initially evaluated:

- Eutrophication and Undesirable Algae;
- Beach Closings;
- Degradation of Aesthetics;
- Restrictions on Drinking Water Consumption
- Restrictions on Fish and Wildlife Consumption; and
- Degradation of Benthos.

BUIs related to eutrophication, fish consumption, beach closings, and benthos have considerable guidance documentation available related to indicator parameters and acceptable concentrations. In addition, the BUIs related to drinking water consumption and aesthetics are related to specific issues in the AOC that must be resolved. In contrast, guidance documentation for restoration targets for benthos, fish and wildlife populations, and habitat were general in nature and required a more detailed evaluation. A group of preliminary targets were developed by AWRI and approved by the PACs in March 2005. The targets were presented to the public during a series of two meetings for each AOC in April and May 2005 and approved with minor revisions. Scientific peer review of the targets was conducted during the summer and fall of 2005 and final versions were prepared by AWRI. In January, 2006, the MDEQ issued their guidelines for the development of delisting criteria and the Muskegon targets were modified to reflect the latest requirements. The targets for the 5 BUIs were formally adopted in final form at the September and October PAC meetings and submitted to the MDEQ for review. The targets summarized in this report for the Muskegon Lake AOC reflect MDEQ staff review and comments. As of December 2006, the WLPAC is still considering the MDEQ staff comments and has not acted to revise their targets. Final MDEQ administrative review of the Muskegon Lake AOC targets is in process and should be complete by March 2007. Targets for the remaining BUIs need to be established by the individual PACs.

The final targets developed for the Muskegon Lake AOC and the White Lake AOC are summarized on Sections 4 and 5, respectively. While AWRI presented preliminary versions of the targets for consideration by the PAC, the final language for each target presented in this report represents the consensus of the PAC after peer review and public comment. The targets are presented in the same format that was submitted to the MDEQ for approval. The MDEQ requested that each target contain the justification and supporting information used for development, a demonstration of functional equivalence to the State guidance, and an identification of the responsible entities and funding sources. A discussion of the dynamics of the delisting process and conclusions and recommendations are provided in sections 6 and 7, respectively. The peer review comments are included in the Appendices.

4. Muskegon Lake Area of Concern Delisting Targets

4.1 Target of Delisting the Beach Closings Beneficial Use Impairment

4.1.1 Introduction

In 1999, 2000, and 2001, excessive quantities of raw sewage were discharged into Muskegon Lake due to the failure of sewers and lift stations. Human contact advisories were posted during these events and millions of gallons of untreated sewage were discharged. In addition to sewage overflows, a tributary of Muskegon Lake, Ruddiman Creek, is on the MDEQ 303(d) list for pathogens. High levels of *E. coli* have been historically reported in this tributary and the source is unknown.

4.1.2 Available Guidance

The Michigan Department of Environmental Quality has established the following restoration criteria for the Beach Closings Beneficial Use Impairment:

> "This BUI will be considered restored when no waterbodies within the AOC are included on the list of impaired waters in the most recent Water Quality and Pollution Control in Michigan: Section 303(d) and 305(b) Integrated Report."

4.3.3 Delisting Target

Ruddiman Creek is currently on the Section 303(d) list for pathogens. Identification of the sources of *E coli* and their remediation will be required for delisting. Because of the importance of Muskegon Lake as a recreational resource and the history of sewage infrastructure failures in its immediate watershed, the Muskegon Lake Public Advisory Council (PAC) voted to adopt a target for delisting the Beach Closings BUI that is more restrictive than the State of Michigan guidance. In addition to the identification of the source(s) and remediation of the pathogen problem on Ruddiman Creek, the PAC will require that contact advisories are not placed on Muskegon Lake due to sewage infrastructure failure.

> The **Beach Closings BUI** will be considered restored when: (1) no waterbodies within the AOC are included on the list of impaired waters in the most recent Water Quality and Pollution Control in Michigan: Section 303(d) and 305(b) Integrated Report and (2) contact advisories have not placed on Muskegon Lake due to sewage infrastructure failure for three consecutive years beginning in 2006. Ruddiman Creek is the only waterbody in the Muskegon Lake AOC listed in the 2006 Integrated Report for pathogens. Compliance with the first part of the target will be achieved when Ruddiman Creek is no longer included in the 303(d) list of impaired waters.

The PAC will work with the MDEQ to develop the monitoring and assessment program for Ruddiman Creek as part of the TMDL process.

4.1.4 Functional Equivalence

The proposed targets for the Muskegon Lake AOC are functionally equivalent to the MDEQ guidance as they require that no waterbodies within the AOC are included on the list of impaired waters in the most recent Water Quality and Pollution Control in Michigan: Section 303(d) and 305(b) Integrated Report as a condition for delisting. Ruddiman Creek is the only waterbody within the AOC that is listed in the 2006 Integrated Report and delisting of the BIU requires restoration to the extent that it is removed from the 303(d) list. The targets exceed the MDEQ guidance as they require that contact advisories are not placed on Muskegon Lake due to sewage infrastructure failure for three consecutive years beginning in 2006. Muskegon Lake is not included in the 2006 Integrated Report for pathogens.

4.1.5 Programs for Monitoring and Assessing Restoration Success

Funding for the monitoring and assessment of Ruddiman Creek will be provided by the MDEQ as part of the TMDL process. If necessary, additional funds will be solicited by the PAC and/or Annis Water Resources Institute from the MDEQ CMI Program and GLNPO for supplemental monitoring and outreach programs. Quality Assurance Project Plans will be prepared for all supplemental assessment activities and agency approval will be obtained for all monitoring programs. All releases of sewage are reported to the Muskegon County Health Department and consequently, a specialized monitoring program is not necessary for Muskegon Lake.

After three successive years of no contact advisories being placed on Muskegon Lake from to sewage infrastructure failure, the MLPAC will submit a status report to the MDEQ along with the acknowledgement that the BUI no longer applies to Muskegon Lake. The MLPAC will submit a request for formal delisting of the Beach Closings BUI to the MDEQ when the TMDL process results in the removal of Ruddiman Creek from the 303(d) list and no contact advisories were placed on Muskegon Lake from sewage infrastructure failure for three consecutive years.

4.2 Target for Delisting the Degradation of Aesthetics Beneficial Use Impairment

4.2.1 Introduction

Improvements in the water quality of Muskegon Lake have resulted in increased public usage of the resource and community interest in the enhancement of both access and habitat quality of the shoreline. At the time of AOC listing, the Michigan Department of Environmental Quality (MDEQ) did not include the Degradation of Aesthetics Beneficial Use Impairment (BUI) however mentioned the environmental impact of excessive shoreline filling. The BUI was listed by the PAC in 2002 because excessive amounts of metal scrap and concrete rubble were discarded along the shoreline and in the lake by historical industrial activity. These deposits impede the safe access and enjoyment of

Muskegon Lake by the public and the ability to conduct shoreline habitat improvement efforts.

4.2.2 Available Guidance

The IJC criteria for listing the Degradation of Aesthetics are provided below:

> "When any substance in water produces a persistent objectionable deposit, unnatural color or turbidity, or unnatural odor (e.g. oil slick, surface scum)."

The MDEQ provides the following guidance for delisting:

> "This BUI will be considered restored when monitoring data for two successive monitoring cycles indicates that water bodies in the AOC do not exhibit persistent, high levels of the following "unnatural physical properties" (as defined by Rule 323.1050 of the Michigan WQS) in quantities which interfere with the State's designated uses for surface waters:
>
> - turbidity
> - color
> - oil films
> - floating solids
> - foams
> - settleable solids
> - suspended solids
> - deposits
>
> For the purposes of this criteria, these 8 unnatural properties impair aesthetic values if they are unnatural – meaning those that are manmade (e.g., garbage, sewage), or natural properties which are exacerbated by human-induced activities (e.g., excessive algae growth from high nutrient loading). Persistent, high levels are those defined as long enough in duration, or elevated to the point of being injurious, to any designated use listed under Rule 323.1100 of the Michigan WQS."

4.2.3 Delisting Target

Because of the importance of Muskegon Lake as a recreational resource and the presence of excessive deposits of metal and concrete scrap in shoreline areas, the Muskegon Lake Public Advisory Council (MLPAC) voted to adopt a target for delisting the Degradation of Aesthetics BUI that is functionally equivalent the State of Michigan criteria. The PAC has identified priority restoration sites for the BUI that enhance public access and enjoyment of Muskegon Lake and are consistent with future habitat improvement projects and municipal planning. The target is presented below:

> The **Degradation of Aesthetics BUI** will be considered restored when monitoring data for two successive monitoring cycles indicates that important public areas in the Muskegon Lake AOC do not exhibit persistent, high levels of the following "unnatural physical properties" (as defined by Rule 323.1050 of the Michigan WQS) in quantities which interfere with the State's designated uses for surface waters:

• turbidity	• foams
• color	• settleable solids
• oil films	• suspended solids
• floating solids	• deposits

Important public locations in Muskegon Lake include: Ruddiman Creek (including the Amoco property), Ryerson Creek, Grand Trunk, Heritage Landing, and the Michigan Steel Bay. Special emphasis will be placed on the removal and restoration of areas at the above locations where deposits of submerged rubble, and metallic debris impede the safe access and enjoyment of Muskegon Lake.

4.2.4 Programs for Monitoring and Assessing Restoration Success

The MLPAC will solicit funding for assessment and restoration activities by the submission of grants and requests for assistance from the following sources:

- Michigan Department of Environmental Quality Clean Michigan Initiative (CMI) Fund
- Environmental Protection Agency Great Lakes National Program Office (GLNPO)
- Local foundations, conservation groups, municipalities, business, and industry.

The MLPAC will obtain approval from the MDEQ for all restoration activities involving the removal of submerged rubble and debris. The MLPAC will request that MDEQ conduct the final monitoring of these locations as part of their 5 Year Basin Program. If this request is not possible, additional funds will be solicited by the MLPAC from the MDEQ CMI Program and GLNPO for supplemental monitoring and outreach programs. Quality Assurance Project Plans will be prepared for all supplemental assessment activities and agency approval will be obtained for all monitoring programs.

The MLPAC will submit a report of the monitoring data and documentation that the restoration activities at each site were completed. The report will include quality assurance data demonstrating that the data quality objectives of the QAPP and delisting targets were achieved. The MLPAC will submit a request for formal delisting of the Degradation of Aesthetics BUI to the MDEQ along with the above report.

4.3 Target for Delisting the Degradation of Benthos Beneficial Use Impairment

4.3.1 Introduction

Muskegon Lake is a 16.8 km^2 drowned river mouth lake located in western Michigan. The lake was listed as an Area of Concern (AOC) by the International Joint Commission (IJC) in 1987 because of severe environmental impairments related to the historic discharge of municipal and industrial wastes. The Beneficial Use Impairment (BUI), Degradation of Benthos, was listed because of sediment toxicity related to heavy metals

and organic chemicals and impacts to species diversity from the discharge of municipal sewage. Data from 1972 (Evans 1976) showed that pollution tolerant oligochaete worms comprised 89% of the total benthic population, chironomid numbers were low (< 200/m^2), and species diversity was only 0.68 (Shannon Weaver). In 1974, the direct discharge of municipal and industrial wastewater to Muskegon Lake was eliminated by the construction of an advanced tertiary treatment facility. In addition, industrial pretreatment programs, hazardous waste site remediation projects, and numerous conservation and non point source reduction efforts have resulted in large improvement in water quality. In 1999, Shannon Weaver diversity improved to 1.66, oligochaetes were reduced to 68% of the total population, and chironomid numbers increased to over 600/m^2 (Carter 2002; Rediske et al. 2002).

4.3.2 Available Guidance

The IJC criteria for listing the Degradation of Benthos are provided below:

> "When the benthic macroinvertebrate community structure significantly diverges from unimpacted control sites of comparable physical and chemical characteristics. In addition, this use will be considered impaired when toxicity (as defined by relevant, field-validated, bioassays with appropriate quality assurance/quality controls) of sediment associated contaminants at a site is significantly higher than controls"

The Michigan Department of Environmental Quality (MDEQ) provides the following guidance for delisting:

> "This BUI will be considered restored when:
>
> > An assessment of benthic community, using either MDEQ's SWAS Procedure #51 for wadeable streams or MDEQ's pending rapid assessment procedure for non-wadeable rivers yields a score for the benthic metrics which meets the standards for aquatic life in any 2 successive monitoring cycles (as defined in the two procedures).
> >
> > OR, in cases where MDEQ procedures are not applicable and benthic degradation is caused by contaminated sediments, this BUI will considered restored when:
> >
> > All remedial actions for known contaminated sediment sites with degraded benthos are completed (except for minor repairs required during operation and maintenance) and monitored according to the approved plan for the site. Remedial actions and monitoring are conducted under authority of state and federal programs, such as Superfund, Resource Conservation and Recovery Act, Great Lakes Legacy Act, or Part 201 of Michigan's National Resource and Environmental Protection Act (NREPA) of 1994."

4.3.3 Delisting Target

The MDEQ provides two options for target development: using SWAS Procedure #51 and completing all necessary remedial actions. SWAS Procedure #51 is not applicable to

lakes and while completing sediment remediation projects at individual sites is important, Muskegon Lake has been impacted on a system-wide basis by chemical and nutrient pollution. Because of the importance Muskegon Lake as a recreational resource and public concern related to sustaining the current trend of improving water quality, the Muskegon Lake Public Advisory Council (MLPAC) voted to adopt a target for delisting the Degradation of Benthos BUI that exceeds the State of Michigan criteria. The target is presented below:

> The **Degradation of Benthos BUI** will be considered restored when all remedial actions for known contaminated sediment sites with degraded benthos are completed (except for minor repairs required during operation and maintenance) and monitored according to the approved plan for the sites. The known contaminated sediment sites in the Muskegon Lake AOC are the Division Street Outfall, Ruddiman Creek, and Ryerson Creek. In addition, average benthic macroinvertebrate populations in Muskegon Lake should reflect the following conditions:

Indicator	Target
Sediment Toxicity	**Amphipod Survival >60%**
Hexagenia	**Present in river mouth littoral zone**
% Oligochaeta	**< 75%**
Chironomidae (#/m^2)	**> 500**
Diversity (SW)	**> 1.5**

For Muskegon Lake, compliance with the sediment toxicity indicator will be determined by review of pre and post remediation toxicity and benthic invertebrate data for Ruddiman Creek, Ryerson Creek, and the Division Street Outfall. Compliance with the remaining indicators will be based on a benthic survey conducted at a group of the same stations sampled in 1999 (Figure 2). If any station shows an indication of significant degradation (> ±3 standard deviations), the area will require resampling and analysis to determine the source of the problem.

4.3.4 Functional Equivalence

The proposed targets for the Muskegon Lake AOC are functionally equivalent to the MDEQ guidance in that it requires that all remedial actions at Ruddiman Creek, Ryerson Creek, and the Division Street Outfall are completed (except for minor repairs required during operation and maintenance) and monitored according to the approved plan. No other locations in the AOC are currently being considered for the removal/remediation of contaminated sediments. The targets exceed the MDEQ guidance as they require specific conditions in the benthic macroinvertebrate community of Muskegon Lake be achieved prior to delisting.

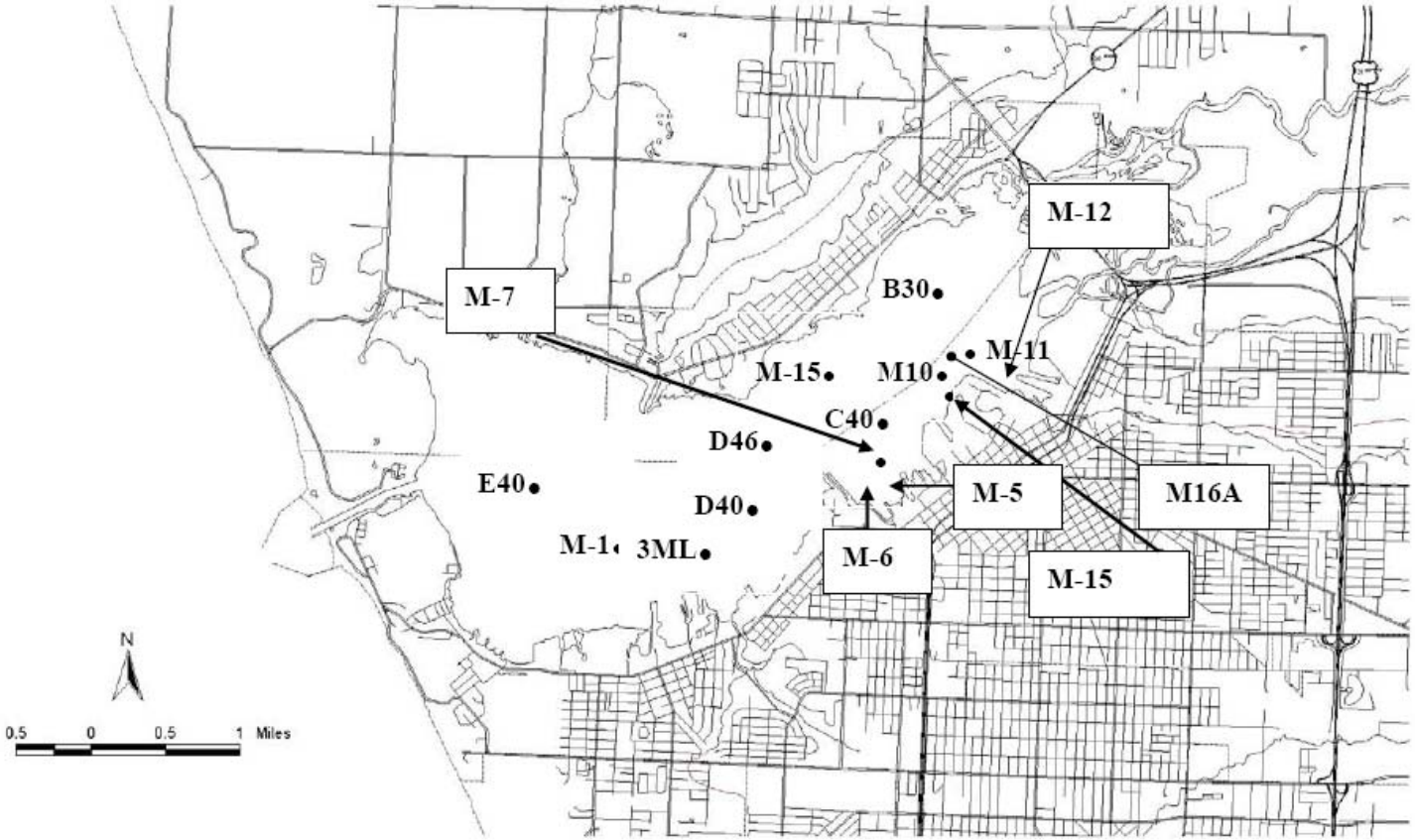


Figure 2. Muskegon Lake Benthos Sampling Locations.

4.3.5 Programs for Monitoring and Assessing Restoration Success

The MLPAC and/or the Annis Water Resources Institute (AWRI) will obtain funding for the monitoring programs for the delisting targets by the submission of grants and request for assistance from the following sources:

- Michigan Department of Environmental Quality Clean Michigan Initiative (CMI) Fund Local Monitoring Grants
- Environmental Protection Agency Great Lakes National Program Office (GLNPO) and the Great Lakes Legacy Act.

The Annis Water Resources Institute (AWRI) will conduct the monitoring and assessment of Muskegon Lake in 2006 as part of the program developed for a CMI grant. AWRI will prepare a Quality Assurance Project Plan for Muskegon Lake monitoring activities and obtain MDEQ approval for the methods and data quality objectives associated with the program. If the data show that additional monitoring is required to achieve the Muskegon Lake targets, the MLPAC and/or AWRI will submit a supplementary grant request to the above agencies. Monetary support for the monitoring and assessment of Ruddiman Creek, Ryerson Creek, and the Division Street Outfall will be provided by the EPA and the MDEQ as part of the Great Lakes Legacy Act and other agency funds allocated to the individual projects. If necessary, additional funds will be solicited by the PAC and/or AWRI from the MDEQ CMI Program and GLNPO for supplemental monitoring and outreach programs. Quality Assurance Project Plans will be prepared for all supplemental assessment activities and agency approval will be obtained for all monitoring programs.

The MLPAC will submit a status report and request for formal delisting of the Degradation of Benthos BUI to the MDEQ when post remediation monitoring at Ruddiman Creek, Ryerson Creek, and the Division Street Outfall show that sediment toxicity is not present at these locations and the results of benthic macroinvertebrate monitoring in Muskegon Lake meets the proposed targets. The report will include the monitoring data, numerical analyses, and quality assurance information demonstrating that the data quality objectives of the project QAPPs and delisting targets were achieved.

4.3.6 References

Carter G. 2002. *Environmental Assessment of the Benthic Macroinvertebrate Community of Muskegon Lake and Evaluation of Changes Since 1972*. M. S. thesis, University of Michigan. Ann Arbor, MI.

Evans, E. 1976. Final report of the Michigan Bureau of Water Management's investigation of the sediments and benthic communities of Mona, White, and Muskegon Lakes, Muskegon County, Michigan, 1972.

Rediske R., Thompson C., Schelske C., Gabrosek J., Nalepa T. F., and Peaslee G. 2002. *Preliminary investigation of the extent of sediment contamination in Muskegon Lake, MI*. U. S. Environmental Protection Agency, Great Lakes National Program Office, Chicago IL. GL-97520701-01. http://www.epa.gov/glnpo/sediment/muskegon/index.html

4.4 Target for Delisting the Eutrophication and Undesirable Algae Beneficial Use Impairment

4.4.1 Introduction

Improvements in the water quality of Muskegon Lake have resulted in increased public usage of the resource and community interest in sustaining the progress of restoration and preventing future adverse environmental impacts. At the time of AOC listing, the Michigan Department of Environmental Quality (MDEQ) did not include the Eutrophication or Undesirable Algae Beneficial Use Impairment (BUI) however mentioned historical water quality degradation. Surface water total phosphorus (TP) concentrations averaged nearly 70 µg/L in 1972, chlorophyll *a* averaged 25 µg/L, and Secchi disk transparencies were below 1.5 m (Freedman et al 1979). The lake also experienced frequent, late summer, blooms of cyanobacteria. The BUI for the AOC was listed by the PAC in 2002 because of concerns related to historical non point source pollution in the Muskegon Lake watershed and the water quality of Bear Lake. **C**urrent water quality data for Muskegon Lake and Bear Lake was not available at the time of the BUI listing. Due to the establishment of an endowment by the community for the monitoring of Muskegon Lake in 2003, recent water quality data are available (AWRI 2006). Muskegon Lake was in the middle of the eutrophic range as listed by the Carlson Index (Carlson 1977). The lake also experienced frequent, late summer blooms of cyanobacteria. The BUI was listed by the Muskegon Lake Public Advisory Council (MLPAC) in 2002 because of concerns related to non point source pollution in Muskegon Lake and the water quality of Bear Lake. In 2002, current water quality data for Muskegon Lake and Bear Lake were not available. Due to the establishment of an endowment by the community for the monitoring of Muskegon Lake in 2003, recent data are available (AWRI 2006). Surface water TP concentrations in 2003-05 averaged < 30 µg/L, chlorophyll *a* averaged 5 µg/L, and Secchi disk transparency was greater than 2 m, indicating that water quality had improved in the lake. Transparency in Muskegon Lake during 2003-05 exceeded that of nearby Pentwater Lake while total phosphorus and chlorophyll *a* concentrations were similar. Pentwater is a drowned river mouth lake with a rural watershed that can be considered as a reference site. Based on the above data, Muskegon Lake is currently at the mesotrophic/eutrophic border line based on the Carlson index (Carlson 1977). The preliminary results of water quality sampling by the MDEQ in 2006 indicated that surface water total phosphorus concentrations averaged 48 µg/l (range 33 µg/l –76 µg/l).

4.4.2 Available Guidance

The IJC criteria for listing the Eutrophication or Undesirable Algae is provided below:

> "When there are persistent water quality problems (e.g. dissolved oxygen depletion of bottom waters, nuisance algal blooms or accumulation, decreased water clarity, etc.) attributed to cultural eutrophication."

The MDEQ provides the following guidance for delisting:

> "This BUI will be considered restored when:
>
> • no waterbodies within the AOC are included on the list of impaired waters due to nutrients or excessive algal growths in the most recent Clean Water Act *Water Quality and Pollution Control in Michigan: Section 303(d) and 305(b) Integrated Report* (Integrated Report), which is submitted to U.S. EPA every two years."

4.4.3 Delisting Target

Muskegon Lake is currently not included on the 303(d) listing as requiring a TMDL or on the 305(b) lists for nutrient pollution or algal growths. Bear Lake, however, is included on the 303(d) listing as not meeting standards due to elevated phosphorus concentrations and nuisance algal growths. Because of the importance of Muskegon Lake as a recreational resource and public concern related to sustaining the current trend of improving water quality, the Muskegon Lake Public Advisory Council (MLPAC) voted to adopt targets for delisting the Eutrophication and Undesirable Algae BUI that exceed the State of Michigan Delisting Guidance. The target is presented below:

> The **Eutrophication and Undesirable Algae BUI** will be considered restored when will be considered restored when: (1) no waterbodies within the AOC are included on the list of impaired waters due to nutrients or excessive algal growths in the current Clean Water Act Water Quality and Pollution Control in Michigan: Section 303(d) and 305(b) Integrated Report and (2) the following average annual concentrations/values are achieved in Muskegon Lake for two consecutive annual monitoring events:

Indicator	Target	Reasoning
Surface Total Phosphorus Concentration	**30 µg/l**	**MDNR Recommendation for the 1987 RAP[1]**
Chlorophyll *a*	**10 µg/l**	**U.S. EPA[2]**
Secchi Disk depth	**~ 2.0 m**	**Pentwater Lake as reference**
Trophic Status Index	**50-55**	**Pentwater Lake as reference**

[1] A total phosphorus concentration of 30 µg/l (during spring and fall turnover) was recommended to maintain water quality at levels that will not produce nuisance algal blooms.

[2] A Chlorophyll a target of 10 µg/l (during the summer) was recommended to maintain water quality at levels that will not produce nuisance algal blooms.

Bear Lake is the only waterbody listed in the AOC on the 2006 303(d) and 305(b) Integrated Report for nutrients or excessive algal growths. The MLPAC will use the 2006 Integrated Report as the reference document to determine which waterbodies require restoration to meet the MDEQ delisting guidance.

The proposed locations of water quality monitoring sites are shown in Figure 3. The sites in Muskegon Lake currently are monitored by the Annis Water Resources Institute (AWRI) in May, July, and late September (since 2003) as part of program supported by the Muskegon Lake Monitoring Endowment Fund. The MLPAC will work with the MDEQ to develop the monitoring and assessment program for Bear Lake as part of the TMDL process. Targets for Bear Lake will be established to be consistent with the TMDL. Suggested monitoring locations for Bear Lake are shown in Figure 3.

Public concerns were expressed regarding the recent occurrence of late summer cyanobacteria blooms and the presence of the toxin, microcystin. Cyanobacteria blooms are becoming more frequent in the Great Lakes basin due to nonpoint source pollution, cultural eutrophication, and the selective feeding of zebra mussels. A detailed investigation of cyanobacteria and their toxins will be conducted by AWRI in 2006 as part of a MDEQ Grant. The MLPAC will review these data and determine if numerical targets for cyanobacteria and their toxins are necessary.

4.4.4 Functional Equivalence

The proposed targets for the Muskegon Lake AOC are functionally equivalent to the MDEQ guidance in that it requires the removal of Bear Lake from the 303(d) list as a condition for delisting. No other waterbodies in the AOC are included in the 2006 Integrated Report for phosphorus and/or excessive algal growth. The targets exceed the MDEQ guidance as they require specific concentrations/values for water quality parameters to be achieved in Muskegon Lake, which is not included on the 303(d) list.

4.4.5 Programs for Monitoring and Assessing Restoration Success

The MLPAC and/or the Annis Water Resources Institute (AWRI) will obtain funding for the monitoring program for the delisting targets by the submission of grants and requests for assistance from the following sources:

- Muskegon Lake Monitoring Endowment Fund
- Michigan Department of Environmental Quality Clean Michigan Initiative (CMI) Fund Local Monitoring Grants
- Environmental Protection Agency Great Lakes National Program Office (GLNPO)

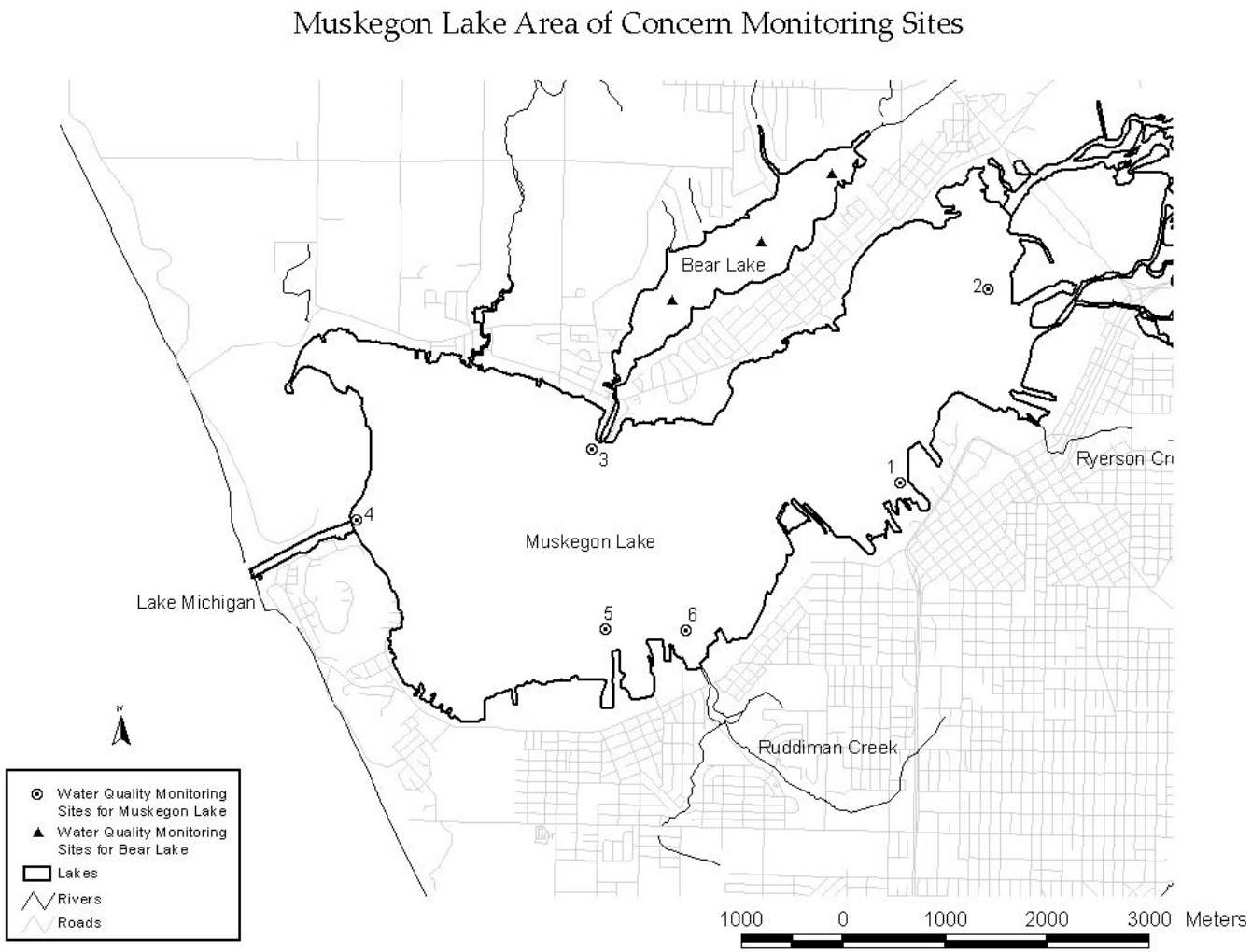


Figure 3. Proposed Water Quality Monitoring Sites in Muskegon Lake and Bear Lake.

The Annis Water Resources Institute (AWRI) will conduct the monitoring and assessment of Muskegon Lake as part of the program developed for the Muskegon Lake Monitoring Endowment Fund. AWRI will prepare a Quality Assurance Project Plan for Muskegon Lake monitoring activities and obtain MDEQ approval for the methods and data quality objectives associated with the program. Funding for the monitoring and assessment of Bear Lake will be provided by the MDEQ as part of the TMDL process. If necessary, additional funds will be solicited by the MLPAC and/or AWRI from the MDEQ CMI Program and GLNPO for supplemental monitoring and outreach programs. Quality Assurance Project Plans will be prepared for all supplemental assessment activities and agency approval will be obtained for all monitoring programs.

After two successive years of monitoring data meet the above targets for Muskegon Lake, the MLPAC will submit a summary report to the MDEQ along with the acknowledgement that the BUI no longer applies to Muskegon Lake. The report will include monitoring and quality assurance data demonstrating that the data quality objectives of the QAPP and the delisting targets were achieved. The MLPAC will submit a request for formal delisting of the Eutrophication and Undesirable Algae BUI to the MDEQ when the TMDL process results in the removal of Bear Lake from the 303(d) list and the targets for Muskegon Lake are achieved.

4.4.6 References

AWRI 2006. Muskegon Lake Monitoring Program Data. Annis Water Resources Institute. Grand Valley State University. Muskegon, MI.

Carlson. R.E. 1977. A trophic state index for lakes. Limnology and Oceanography 22:361-369.

Freedman, P. L., R. P. Canale and M. T. Auer. 1979. Applicability of land treatment of wastewater in the Great Lakes area basin: Impact of wastewater diversion, spray irrigation on water quality in the Muskegon County, Michigan, lakes. EPA-905/9-79-006-A. Great Lakes National Program Office, U.S. Environmental Protection Agency, Chicago, IL.

USEPA 1975. National Eutrophication Survey of Muskegon Lake, Muskegon County, Michigan. Working Paper No. 203. Pacific 'Northwest Environmental Research Laboratory, Corvallis, Oregon. 38 pp.

4.5 Target of Delisting the Restrictions on Fish Consumption Beneficial Use Impairment

4.5.1 Introduction

Muskegon Lake is a 16.8 km^2 drowned river mouth lake located in western Michigan. The lake was listed as an Area of Concern (AOC) by the International Joint Commission (IJC) in 1987 because of severe environmental impairments related to the historic discharge of municipal and industrial wastes. The Beneficial Use Impairment (BUI), Restrictions of Fish and Wildlife Consumption, was listed because of elevated PCB levels in carp and mercury in walleye and bass. At the time of AOC listing, the MDEQ was unable to determine if the contamination originated from atmospheric sources or contaminated sediments. Recommendations were made in the 1987 Remedial Action Plan to conduct an assessment of contaminated sediment and to continue fish tissue monitoring. Subsequent environmental surveys found localized areas of sediment contaminated with mercury in the vicinity of the Division Street Outfall and at the mouth of Ryerson Creek (Rediske et al 2002). Elevated PCB residues only were found in Ruddiman Creek (a small tributary of Muskegon Lake). Contaminated sediments in Ruddiman Creek were recently removed. The areas of sediment contaminated with mercury total <100 m^2 and are currently being evaluated for remediation by the MDEQ. Fish tissue monitoring was conducted in 1986/87, 1993, and 2000/01 (MDEQ 2006). Comparisons of historic and recent data for PCBs and mercury are shown in Figures 4 and 5, respectively.

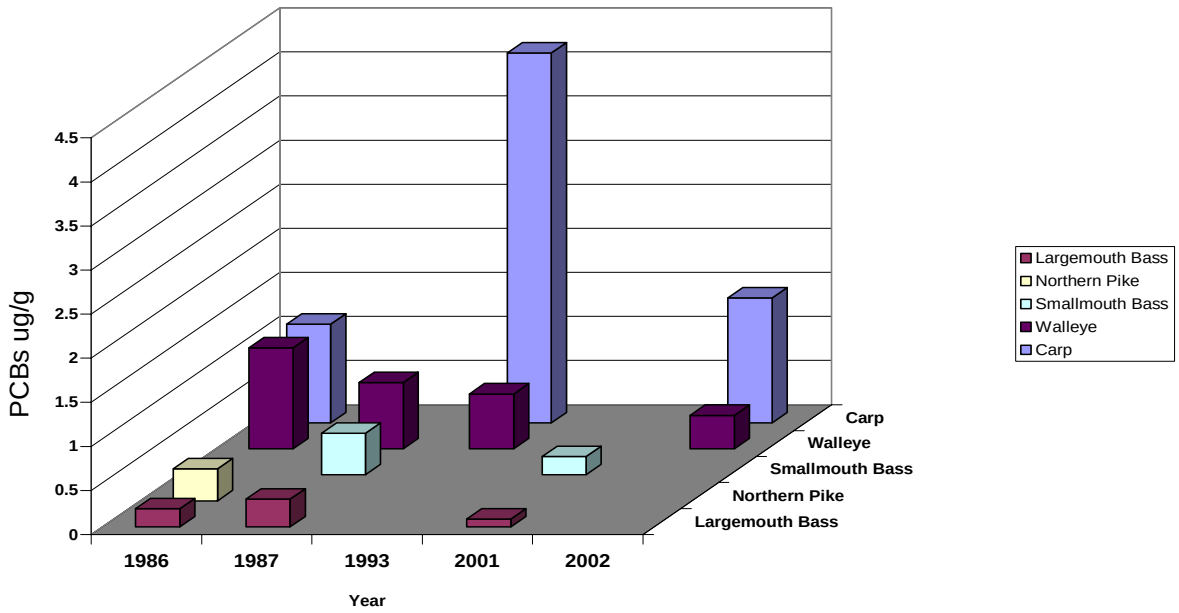


Figure 4. Mean PCB Concentrations in Muskegon Lake Fish (MDEQ Fish Contaminant Monitoring Program, n=10. The absence of data indicates that the fish species was not collected in the corresponding year.)

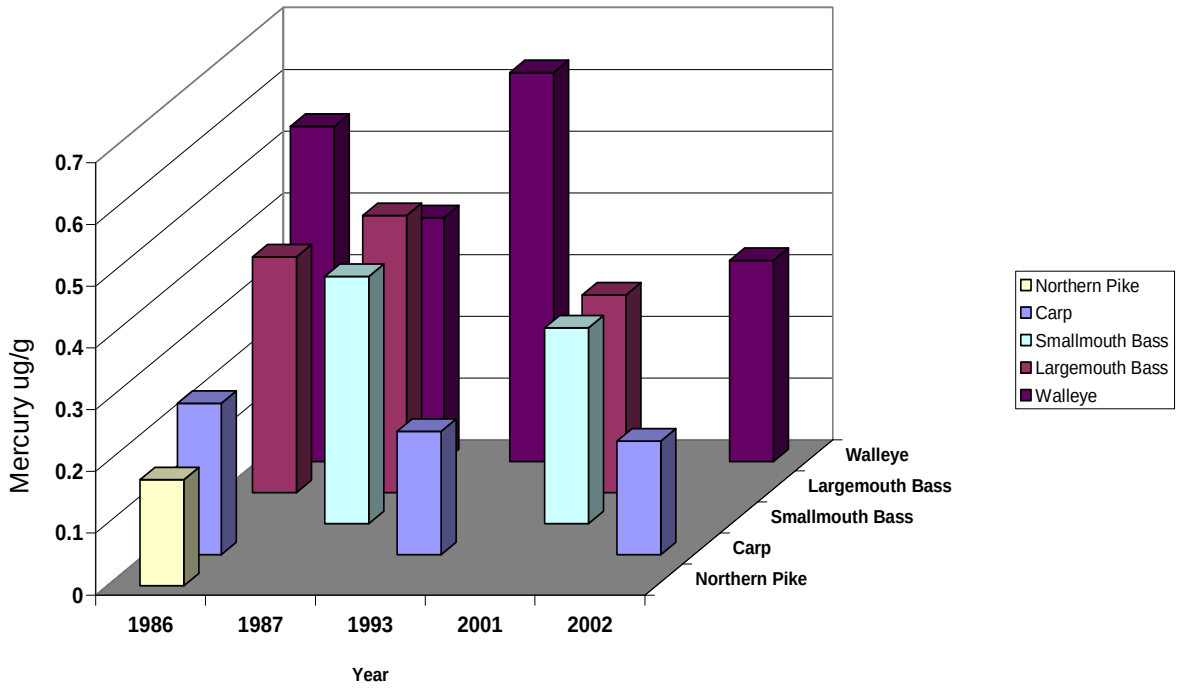


Figure 5. Mean Mercury Concentrations in Muskegon Lake Fish (MDEQ Fish Contaminant Monitoring Program, n=10. The absence of data indicates that the fish species was not collected in the corresponding year.)

From 1986 to 2002, mean PCB levels in Muskegon Lake fish appear to be declining for all species except carp. The data for carp may be biased high due to the presence of 3 fish in the 1993 data that were above 6 µg/g. Mercury appears to show a slight decreasing trend for all species during the same time period.

4.5.2 Available Guidance

The IJC criteria for listing the Restrictions on Fish Consumption BUI are provided below:

> "An impairment will be listed when contaminant levels in fish or wildlife populations exceed current standards, objectives or guidelines, or public health advisories are in effect for human consumption of fish or wildlife. Contaminant levels in fish and wildlife must be due to contaminant input from the watershed."

The MDEQ provides the following guidance for delisting:

> "The restoration criteria for this BUI use a tiered approach for restoration success. This BUI will be considered restored when:
>
> - The fish consumption advisories in the AOC are the same or less restrictive than the associated Great Lake.
>
> - or, a comparison study of fish tissue contaminant levels demonstrates that there is no statistically significant difference in fish tissue concentrations of contaminants causing fish consumption advisories in the AOC compared to a control site.
>
> - or, if a comparison study is not feasible because of the lack of control site, analysis of trend data for fish with consumption advisories similar trends to other appropriate Great Lakes trend sites."

4.5.3 Delisting Target

Muskegon Lake is included in the regional fish consumption advisory for PCBs and mercury. The PAC believes that an assessment of contaminant levels in game fish is necessary for delisting this BUI because there is insufficient data available to determine if fish contaminant levels of PCBs and mercury in the AOC exceed other sites in the Great Lakes. The Muskegon Lake Public Advisory Council (PAC) voted to adopt a target for delisting the Restrictions on Fish Consumption BUI that is functionally equivalent to the State of Michigan criteria. Since it is not possible to select a control location from within Muskegon Lake, a comparison of contaminant concentrations in fish from a similar drowned river mouth lake (Pentwater Lake) in combination with historical contaminant trend analysis will be used for delisting. The specific components of the proposed fish contaminant program are given below:

- Key fish species: largemouth bass, and carp
- Sample design: 10-20 fish of each species collected in July-September
- Tissue analyzed: edible portion
- Reference system: Pentwater Lake
- Restoration target end: BUI will be considered restored when contaminant levels in edible portion analyses of key fish species are not significantly different from Pentwater Lake for 2 consecutive 5 year sampling periods. An analysis of covariance (ANCOVA) will be conducted to determine if there are statistically significant differences between the two lakes. Fish size will serve as the covariate. To the greatest extent possible, analyses will include populations that overlap in size will be used for statistical comparison. If a significant difference between fish contaminant levels in Muskegon Lake and Pentwater Lake is present at the end of the monitoring period, all available fish contaminant monitoring data for Muskegon Lake will be evaluated for a decreasing trend in concentration. In

this situation, the BUI will be considered restored when edible portion analyses of key fish species in Muskegon Lake show a similar decreasing trend as other appropriate Great Lakes trend sites.

Largemouth bass was selected as an important resident game fish species in Muskegon Lake. Carp are consumed by subsistence fishermen and have a greater exposure to contaminated sediments than most game fish due to their feeding behavior. If statistically significant increases in contaminant levels are noted in these fish species from the AOC compared to the reference site, bioavailability issues or an unidentified source may be present in Muskegon Lake. The fish species as well as the number of organisms selected for analysis comply with the MDEQ Fish Contaminant Monitoring Program and the delisting criteria for this BUI.

4.5.4 Functional Equivalence

The proposed targets for the Muskegon Lake AOC are functionally equivalent to the MDEQ as they use a reference site to compare fish contaminant levels with and trend data.

4.5.5 Programs for Monitoring and Assessing Restoration Success

The Annis Water Resources Institute (AWRI) will conduct the initial fish contaminant monitoring of Muskegon Lake and Pentwater Lake in 2006 as part of the program developed for a CMI grant. A Quality Assurance Project Plan for Muskegon Lake fish contaminant monitoring activities was prepared and approved by the MDEQ. If a second set of monitoring results are required in 2011, the MLPAC will request that these analyses be included as part of the MDEQ's Fish Contaminant Monitoring Program.

When monitoring data meet the above targets for Muskegon Lake, the MLPAC will submit a summary report to the MDEQ along with a request for formal delisting of the Restrictions on Fish Consumption BUI. The report will include monitoring and quality assurance data demonstrating that the data quality objectives of the QAPP and the targets concentrations and or trends were achieved.

4.5.6 References

MDEQ 2006. The Michigan Fish Contaminant Monitoring Program. http://www.michigan.gov/deq/0,1607,7-135-3313_3686_3728-32393--,00.html. Accessed on April 28, 2006.

Rediske R., Thompson C., Schelske C., Gabrosek J., Nalepa T. F., and Peaslee G. 2002. *Preliminary investigation of the extent of sediment contamination in Muskegon Lake, MI*. U. S. Environmental Protection Agency, Great Lakes National Program Office, Chicago IL. GL-97520701-01. http://www.epa.gov/glnpo/sediment/muskegon/index.html

5. White Lake Area of Concern Delisting Targets

5.1 Target for Delisting the Degradation of Aesthetics Beneficial Use Impairment

5.1.1 Introduction

Improvements in the water quality of White Lake have resulted in increased public usage of the resource and community interest in the enhancement of both access and habitat quality of the shoreline. At the time of AOC listing, the MDEQ included the Degradation of Aesthetics Beneficial Use Impairment (BUI) because of surface scum from the tannery discharge and the dumping of hides in Tannery Bay. The closing of the Tannery and remediation of Tannery Bay sediment have improved the aesthetics of White Lake and its shoreline. Deposits of hides are still present in the bay east of the tannery and in several areas of the wetlands and one of the tributaries. In addition, recent algal blooms have resulted in surface scums being observed in many areas of the open lake and the shoreline. These surface scums and deposits impede the safe access and enjoyment of White Lake by the public and the ability to conduct shoreline habitat improvement efforts.

5.1.2 Available Guidance

The IJC criteria for listing the Degradation of Aesthetics are provided below:

> "When any substance in water produces a persistent objectionable deposit, unnatural color or turbidity, or unnatural odor (e.g. oil slick, surface scum)."

The MDEQ provides the following guidance for delisting:

> "This BUI will be considered restored when monitoring data for two successive monitoring cycles indicates that water bodies in the AOC do not exhibit persistent, high levels of the following "unnatural physical properties" (as defined by Rule 323.1050 of the Michigan WQS) in quantities which interfere with the State's designated uses for surface waters:
>
> - turbidity
> - color
> - oil films
> - floating solids
> - foams
> - settleable solids
> - suspended solids
> - deposits
>
> For the purposes of this criteria, these 8 properties impair aesthetic values if they are unnatural – meaning those that are manmade (e.g., garbage, sewage), or natural properties which are exacerbated by human-induced activities (e.g., excessive algae growth from high nutrient loading). Persistent, high levels are those defined as long enough in duration, or elevated to the point of being injurious, to any designated use listed under Rule 323.1100 of the Michigan WQS."

5.1.3 Delisting Target

Because of the importance White Lake as a recreational resource and the presence of excessive deposits of metal and concrete scrap in shoreline areas, the White Lake Public Advisory Council (PAC) voted to adopt a target for delisting the Degradation of Aesthetics BUI that is functionally equivalent the State of Michigan criteria. The PAC has identified priority restoration sites for the BUI that enhance public access and enjoyment of White Lake and are consistent with future habitat improvement projects and municipal planning. The target is presented below:

> The **Degradation of Aesthetics BUI** will be considered restored when monitoring data for two successive monitoring cycles indicates that important public areas in the White Lake AOC do not exhibit persistent, high levels of the following "unnatural physical properties" (as defined by Rule 323.1050 of the Michigan WQS) in quantities which interfere with the State's designated uses for surface waters:
>
> - turbidity
> - color
> - oil films
> - floating solids
> - foams
> - settleable solids
> - suspended solids
> - deposits
>
> Important public locations in White Lake include: the Bush Creek/east bay and Genesco property where hides are present and the abandoned Whitehall and Montague dumps in the wetlands. In addition, no more than 10% of the lake should be covered with algal scum for 5 consecutive days. Three consecutive years of monitoring will be required to demonstrate compliance with the algal scum target.

5.1.4 Programs for Monitoring and Assessing Restoration Success

The WLPAC will solicit funding for assessment and restoration activities by the submission of grants and requests for assistance from the following sources:

- Michigan Department of Environmental Quality Clean Michigan Initiative (CMI) Fund
- Environmental Protection Agency Great Lakes National Program Office (GLNPO)
- Local foundations, conservation groups, municipalities, business, and industry.

The WLPAC will obtain approval from the MDEQ for all restoration activities involving the removal of submerged rubble and debris. The WLPAC will request that MDEQ conduct the final monitoring of these locations as part of their 5 Year Basin Program. If this request is not possible, additional funds will be solicited by the WLPAC from the MDEQ CMI Program and GLNPO. Quality Assurance Project Plans will be prepared for all supplemental assessment activities and agency approval will be obtained for all

monitoring programs. The PAC will prepare an assessment protocol and Quality Assurance Project Plan for the monitoring of algal scum on White Lake. Funding for monitoring will be obtained by the submission of grants to the MDEQ CMI Program and GLNPO by the WLPAC.

The WLPAC will submit a report of the monitoring data and documentation that the restoration activities at each site were completed. The report will include quality assurance data demonstrating that the data quality objectives of the QAPP and delisting targets were achieved. The WLPAC will submit a request for formal delisting of the Degradation of Aesthetics BUI to the MDEQ along with the above report.

5.2 Target for Delisting the Degradation of Benthos Beneficial Use Impairment

5.2.1 Introduction

White Lake is a 10.4 km^2 drowned river mouth lake located in western Michigan. The lake was listed as an Area of Concern (AOC) by the International Joint Commission (IJC) in 1987 because of severe environmental impairments related to the historic discharge of municipal and industrial wastes. The Beneficial Use Impairment (BUI), Degradation of Benthos, was listed because sediment toxicity related to heavy metals and organic chemicals and impacts to species diversity from the discharge of municipal sewage. Data from 1972 showed that pollution tolerant oligochaete worms comprised 95% of the total benthic population, chironomid numbers were low (< 100/m^2), and Shannon Weaver species diversity (SW) only was 0.68 (Evans 1976). In 1974, the direct discharge of municipal and industrial wastewater to White Lake was eliminated by the construction of an advanced tertiary treatment facility. In addition, industrial pretreatment programs, hazardous waste site remediation projects, and numerous conservation and non point source reduction efforts have resulted in large improvement in water quality. By 2001, Shannon Weaver diversity improved to 1.37, oligochaetes were reduced to 82% of the total population, and chironomid numbers increased to over 500/m^2 (Rediske et al. 2004).

5.2.2 Available Guidance

The IJC criteria for listing the Degradation of Benthos are provided below:

> "When the benthic macroinvertebrate community structure significantly diverges from unimpacted control sites of comparable physical and chemical characteristics. In addition, this use will be considered impaired when toxicity (as defined by relevant, field-validated, bioassays with appropriate quality assurance/quality controls) of sediment associated contaminants at a site is significantly higher than controls"

The MDEQ provides the following guidance for delisting:

> "This BUI will be considered restored when:
>
> An assessment of benthic community, using either MDEQ's SWAS Procedure #51 for wadeable streams or MDEQ's pending rapid assessment procedure for non-wadeable rivers yields a score for the benthic metrics which meets the standards for aquatic life in any 2 successive monitoring cycles (as defined in the two procedures).
>
> OR, in cases where MDEQ procedures are not applicable and benthic degradation is caused by contaminated sediments, this BUI will considered restored when:
>
> All remedial actions for known contaminated sediment sites with degraded benthos are completed (except for minor repairs required during operation and maintenance) and monitored according to the approved plan for the site. Remedial actions and monitoring are conducted under authority of state and federal programs, such as Superfund, Resource Conservation and Recovery Act, Great Lakes Legacy Act, or Part 201 of Michigan's National Resource and Environmental Protection Act (NREPA) of 1994."

5.2.3 Delisting Target

The MDEQ provides two options for target development: using SWAS Procedure #51 and completing all necessary remedial actions. SWAS Procedure #51 is not applicable to lakes and while completing sediment remediation projects at individual sites is important, White Lake has been impacted on a system wide basis by chemical and nutrient pollution. Because of the importance White Lake as a recreational resource and public concern related to sustaining the current trend of improving water quality, the White Lake Public Advisory Council (PAC) voted to adopt a target for delisting the Degradation of Benthos BUI that exceeds the State of Michigan criteria. The target is presented below:

> The **Degradation of Benthos BUI** will be considered restored when all remedial actions for known contaminated sediment sites with degraded benthos are completed (except for minor repairs required during operation and maintenance) and monitored according to the approved plan for the site. Remedial actions and monitoring are conducted under authority of state and federal programs. The known contaminated sediment sites with degraded benthos are Tannery Bay and the Hooker/Occidental Outfall. In addition, average benthic macroinvertebrate populations in White Lake should reflect the following conditions:

Indicator	Target
Sediment Toxicity	Amphipod Survival >60%
Hexagenia	Present in river mouth littoral zone with an increasing trend over 3 years
Amphipods	Present in river mouth littoral zone with an increasing trend over 3 years
% Oligochaeta	< 75% or a decreasing trend
Chironomidae (#/m^2)	> 500 or an increasing trend
Diversity (SW)	1.5 or an increasing trend

Compliance with the sediment toxicity indicator in White Lake will be determined by review of pre and post remediation data for Tannery Bay and Occidental Chemical. Compliance with the Oligochaete, Chironomid, and Diversity indicators will be based on a benthic survey conducted at a majority of the same stations examined in 2001 (Rediske et al. 2004). If these targets are not achieved, a second survey will be conducted in 5 years. The proposed locations of the White Lake benthos monitoring stations are shown in Figure 7. Compliance with the *Hexagenia* and amphipod targets will be based on three consecutive years of monitoring at stations that will be established in the littoral zone near the mouth of the White River. If any station shows an indication of statistically significant degradation from the previous sampling event, the area will require re-sampling and analysis to determine the source of the problem within one year of the report.

5.2.4 Functional Equivalence

The proposed targets for the White Lake AOC are functionally equivalent to the MDEQ guidance in that it requires that all remedial actions at Tannery Bay and the Hooker/Occidental Outfall are completed (except for minor repairs required during operation and maintenance) and monitored according to the approved plan. No other locations in the AOC are currently being considered for the removal/remediation of contaminated sediments. The targets exceed the MDEQ guidance as they require specific conditions in the benthic macroinvertebrate community be achieved prior to delisting.

5.2.5 Programs for Monitoring and Assessing Restoration Success

The monitoring and assessment of Tannery Bay is being performed by MDEQ. The monitoring and assessment of the Hooker/Occidental Outfall is being performed by the responsible party and reviewed by the EPA/MDEQ. The WLPAC will request that the monitoring of benthos in White Lake be included in the MDEQ's 5 Year Basin Monitoring Program. If this request is not feasible, additional funds will be solicited by the WLPAC and/or Annis Water Resources Institute from the MDEQ CMI Program and GLNPO. Quality Assurance Project Plans will be prepared for all supplemental assessment activities and agency approval will be obtained for all monitoring programs.

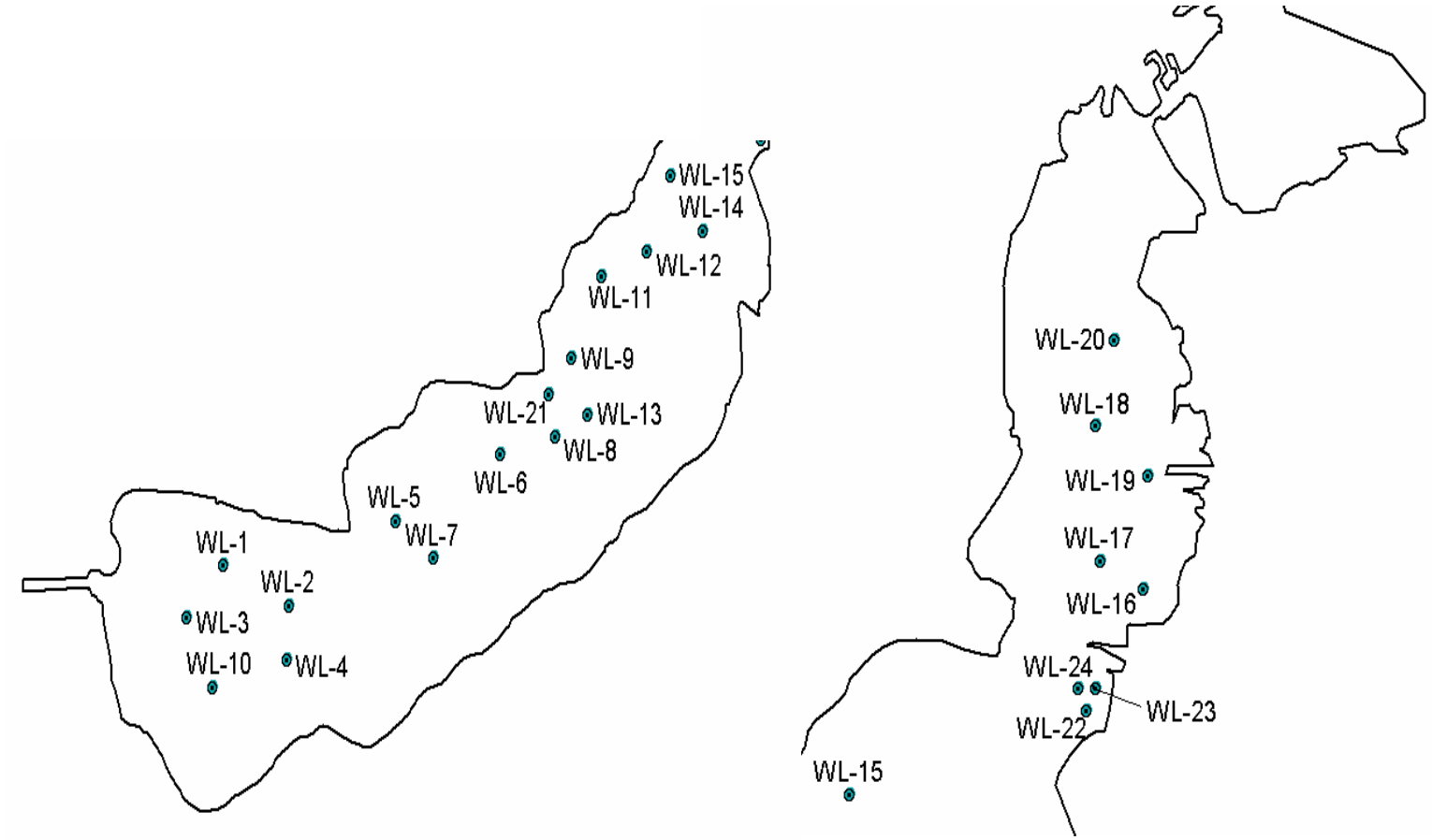


Figure 6. Proposed Locations for White Lake Benthos Monitoring

The WLPAC will submit a status report and request for formal delisting of the Degradation of Benthos BUI to the MDEQ when post remediation monitoring at Tannery Bay and the Hooker/Occidental Outfall show that sediment toxicity is not present at these locations and the results of benthic macroinvertebrate monitoring in White Lake meets the proposed targets. The report will include the monitoring data, numerical analyses, and quality assurance information demonstrating that the data quality objectives of the project QAPPs and delisting targets were achieved.

5.2.6 References

Evans, E. 1976. Final report of the Michigan Bureau of Water Management's investigation of the sediments and benthic communities of Mona, White, and Muskegon Lakes, Muskegon County, Michigan, 1972.

Rediske, R., M, Chu,, D. Uzarski, G. Peaslee, J. Gabrosek. 2004. Phase II Investigation of Sediment Contamination in White Lake. EPA-905-R-04-001.

5.3 Target for Delisting the Eutrophication and Undesirable Algae Beneficial Use Impairment

5.3.1 Introduction

White Lake was listed as an Area of Concern (AOC) by the International Joint Commission (IJC) in 1987 because of severe environmental impairments related to the historic discharge of municipal and industrial wastes. The Beneficial Use Impairment (BUI), Eutrophication or Undesirable Algae, was listed because of high nitrogen and phosphorus levels were present in the lake due to the discharge of municipal sewage and tannery wastes. Surface water total phosphorus (TP) concentrations averaged nearly 50 µg/L in 1972, chlorophyll *a* averaged 12 µg/L, and Secchi disk transparencies were below 1.7 m (Freedman et al 1979). White Lake was in the middle of the eutrophic range as listed by the Carlson Index (Carlson 1977). The lake also experienced frequent, late summer blooms of cyanobacteria. Water quality studies in 2005 found that surface water TP concentrations averaged 30 µg/L, chlorophyll *a* averaged 8 µg/L, and Secchi disk transparency was near 2 m (AWRI 2006). Transparency in White Lake during 2003-04 exceeded that of nearby Pentwater Lake while total phosphorus and chlorophyll a concentrations were similar. Pentwater is a drowned river mouth lake with a rural watershed that can be considered as a reference site. Based on the above data, White Lake is currently at the mesotrophic/eutrophic border line based on the Carlson index (Carlson 1977).

5.3.2 Available Guidance

The IJC criteria for listing the Eutrophication or Undesirable Algae is provided below:

> "When there are persistent water quality problems (e.g. dissolved oxygen depletion of bottom waters, nuisance algal blooms or accumulation, decreased water clarity, etc.) attributed to cultural eutrophication."

The MDEQ provides the following guidance for delisting:

> "This BUI will be considered restored when:
>
> • no waterbodies within the AOC are included on the list of impaired waters due to nutrients or excessive algal growths in the most recent Clean Water Act *Water Quality and Pollution Control in Michigan: Section 303(d) and 305(b) Integrated Report*, which is submitted to U.S. EPA every two years."

5.3.3 Delisting Target

White Lake and its tributaries within the AOC boundary are not included on the 2006 303(d) and 305(b) lists for nutrient pollution or algal growths. Mean surface total phosphorus concentrations are near the MDEQ's recommendation of 30 µg/l for White Lake. Improvements in the water quality of White Lake have resulted in increased public usage of the resource and community interest in sustaining the progress of restoration and preventing future adverse environmental impacts from cultural eutrophication. Because of the importance of White Lake as a recreational resource and public concern related to sustaining the current trend of improving water quality, the White Lake Public Advisory Council (WLPAC) voted to adopt targets for delisting the Eutrophication or Undesirable Algae BUI that exceed the State of Michigan criteria.

> The **Eutrophication and Undesirable Algae BUI** will be considered restored when: (1) no waterbodies within the AOC are included on the list of impaired waters due to nutrients or excessive algal growths in the current Clean Water Act Water Quality and Pollution Control in Michigan: Section 303(d) and 305(b) Integrated Report and (2) the following average annual concentrations/values are achieved in White Lake for two consecutive monitoring events at 5 year intervals:

Indicator	Target	Reasoning
Average Surface Total Phosphorus Concentration	25 ppb	Mesotrophic Conditions
Chlorophyll *a*	8 ppb	Mesotrophic Conditions
Secchi Disk depth	2.5 m	Mesotrophic Conditions
Trophic Status Index	45-50	Closer to Statewide Average

The proposed locations of water quality monitoring sites are shown in Figure 7.

No waterbodies in the White Lake AOC are listed on the current 303(d) and 305(b) Integrated Report for nutrients or excessive algal growths. The PAC will use the 2006 Integrated Report for documentation of compliance of the MDEQ criteria. The WLPAC also recognizes that the more restrictive targets selected for total phosphorus, Secchi Disk depth, and trophic status will require additional reductions in nutrient loading in the AOC boundary to achieve the desired improvement in water quality. Public concerns were expressed regarding the recent occurrence of late summer cyanobacteria blooms and the presence of the toxin, microcystin. Cyanobacteria blooms are becoming more frequent in the Great Lakes basin due to nonpoint source pollution, cultural eutrophication, and the selective feeding of zebra mussels. A detailed investigation of cyanobacteria and their toxins will be conducted by the Annis Water Resources Institute (AWRI) in 2006. The WLPAC will review these data and determine if numerical targets for cyanobacteria and their toxins are necessary.

5.3.4 Functional Equivalence

The proposed targets for the White Lake AOC are functionally equivalent to the MDEQ guidance because they require that no waterbodies in the AOC are included on the 2006 303(d) list for phosphorus and/or excessive algal growth. It should be noted that waterbodies in the White Lake AOC currently meets this guideline. The targets exceed the MDEQ guidance as they require specific concentrations/values for water quality parameters to be achieved in White Lake, which is not on the 303(d) list.

5.3.5 Programs for Monitoring and Assessing Restoration Success

AWRI will conduct an initial assessment of nutrient loading in White Lake as part of a CMI Local Monitoring Grant. AWRI will prepare a Quality Assurance Project Plan for White Lake monitoring activities and obtain MDEQ approval for the methods and data quality objectives associated with the program. The WLPAC will request that monitoring for subsequent assessments of White Lake be conducted as part of the MDEQ's 5 Year Basin Monitoring Program. If this is not feasible, additional funds for supplemental monitoring and outreach programs will be solicited by the WLPAC and/or AWRI by the submission of grants and requests for assistance to the MDEQ Clean Michigan Initiative Fund Local Monitoring Grants and/or the EPA's Great Lakes National Program Office. Quality Assurance Project Plans will be prepared for all supplemental assessment activities and agency approval will be obtained for all monitoring programs.

After two successive sets of monitoring data at five year intervals meet the above targets for White Lake, the WLPAC will submit a report and request for formal delisting of the Eutrophication and Undesirable Algae BUI to the MDEQ. The report will include monitoring and quality assurance data demonstrating that the data quality objectives of the QAPP and the delisting targets were achieved.

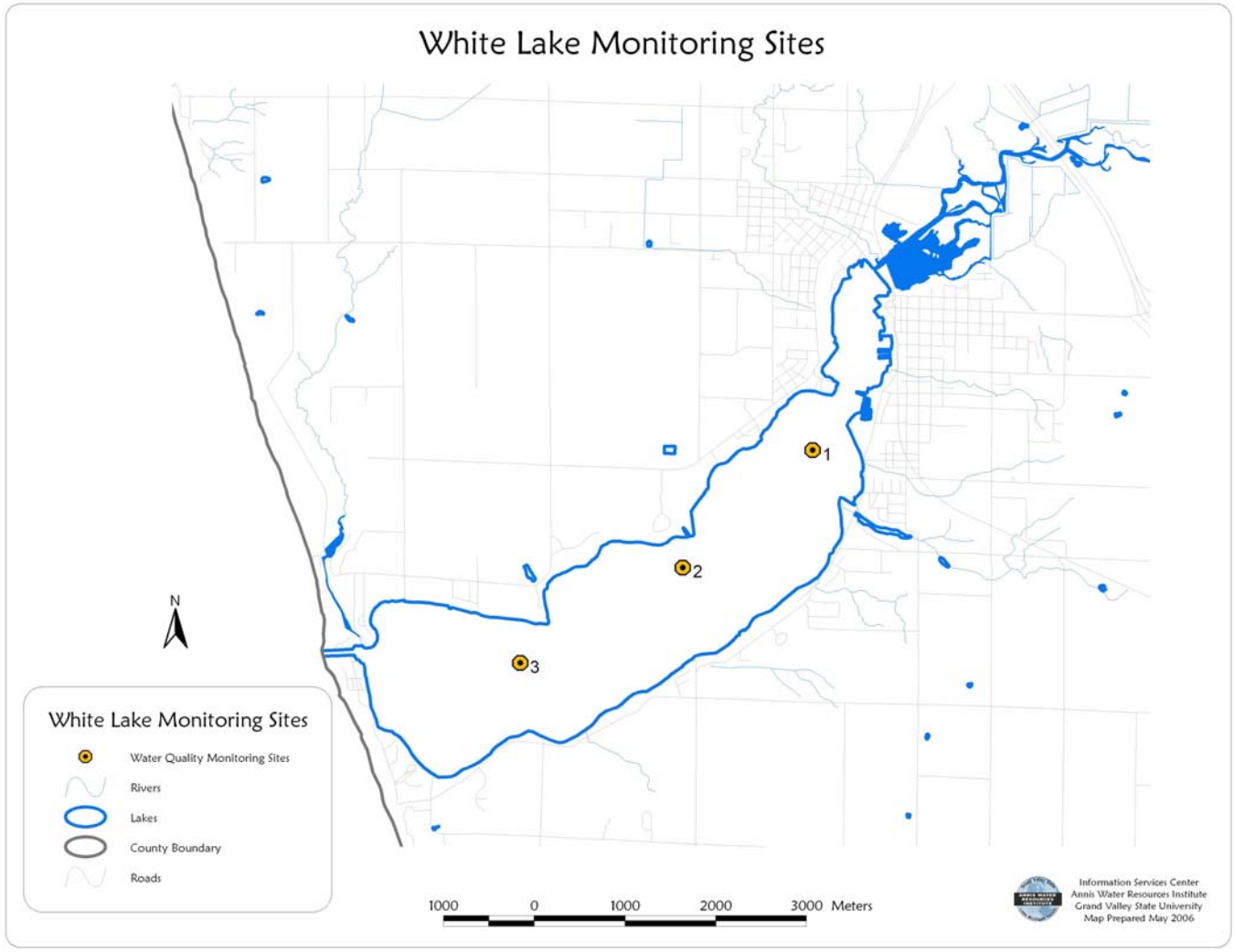


Figure 7. Proposed Location of White Lake Water Quality Monitoring Sites.

5.3.6 References

AWRI 2006. White Lake Monitoring Program Data. Annis Water Resources Institute. Grand Valley State University. Muskegon, MI.

Carlson. R.E. 1977. A trophic state index for lakes. Limnology and Oceanography 22:361-369.

Freedman, P. L., R. P. Canale and M. T. Auer. 1979. Applicability of land treatment of wastewater in the Great Lakes area basin: Impact of wastewater diversion, spray irrigation on water quality in the Muskegon County, Michigan, lakes. EPA-905/9-79-006-A. Great Lakes National Program Office, U.S. Environmental Protection Agency, Chicago, IL.

5.4 Target for Delisting the Restrictions on Drinking Water Consumption or Taste and Odor Problems Beneficial Use Impairment

5.4.1 Introduction

The White Lake Area of Concern has a history of serious groundwater problems associated with the improper disposal of hazardous chemicals at Resource Conservation Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) sites. Public surface water supplies of drinking water are not available and consequently, the integrity and protection of groundwater resources are important to insure the availability of potable water in the AOC.

5.4.2 Available Guidance

The Michigan Department of Environmental Quality has established the following restoration criteria for the Restrictions on Drinking Water Consumption or Taste and Odor Problems Beneficial Use Impairment:

> "This BUI will be considered restored when monitoring data for 2 years indicate:
> • public surface water supplies meet the current and most stringent human health standards, objectives, or guidelines (at the point of distribution into the water system) for levels of disease-causing organisms, hazardous or toxic chemicals, or radioactive substances; and
> • treatment needed to make raw water potable and palatable does not exceed standard treatment methods."

5.4.3 Delisting Target

No public surface drinking water supplies are currently present in the White Lake area, and consequently, the MDEQ guidance does not directly apply to the AOC. All public drinking water supplies utilize groundwater resources. Because of the importance of groundwater as the only potable water source currently available in the White Lake AOC, the history of severe groundwater contamination, and the presence of large areas of contaminated groundwater that are undergoing remediation and further delineation, the White Lake Public Advisory Council has voted to adopt a target for delisting the Restrictions on Drinking Water Consumption BUI that is more restrictive than the State of Michigan criteria and includes the protection of critical groundwater resources. The proposed delisting target is:

> This BUI will be considered restored when monitoring data for 2 consecutive years indicates:
>
> > Private groundwater supplies in the vicinity of Resource Conservation Recovery Act and Comprehensive Environmental Response Compensation and Liability Act sites meet the MDEQ criteria for potable water based on annual monitoring. For areas where groundwater contamination exceeds MDEQ criteria for drinking water, an alternate supply source (public or private) of potable water must be available. In addition, plume migration from these sites must been controlled by an approved MDEQ/EPA remediation plan and the effectiveness confirmed by annual monitoring. The WLPAC identifies the former DuPont, Muskegon/Koch Chemical, and Hooker/Occidental Chemical sites as locations where contaminated groundwater poses a threat to private drinking water wells.

5.4.4 Functional Equivalence

The proposed targets for the White Lake AOC are functionally equivalent and exceed the MDEQ restoration criteria. The PAC will use the fact that no surface water supplies are present in the AOC as documentation of compliance of the MDEQ criteria.

5.4.5 Programs for Monitoring and Assessing Restoration Success

Groundwater monitoring programs currently are active at the former DuPont, Muskegon/Koch Chemical, and Hooker/Occidental Chemical sites sites. The White Lake PAC will review the annual monitoring reports and determine when remediation at a particular site has been completed and the contamination no longer presents a threat to groundwater supplies. Monitoring data with an EPA/MDEQ approved Quality Assurance Project Plans will be used to determine compliance with this BUI. A sub group of the PAC will review the monitoring data and submit an annual report. Funding for the data review and preparation of the annual report will be by submitting grant requests to the MDEQ and/or EPA.

After two successive years of monitoring data meet the above targets for the former DuPont, Muskegon/Koch Chemical, and Hooker/Occidental Chemical sites, the WLPAC will submit a report and request for formal delisting of the Restrictions on Drinking Water Consumption or Taste and Odor Problems BUI to the MDEQ. The report will include monitoring and quality assurance data demonstrating that the delisting targets were achieved.

5.5 Target of Delisting the Restrictions on Fish Consumption Beneficial Use Impairment Delisting Target

5.5.1 Introduction

White Lake is a 10.4 km^2 drowned river mouth lake located in western Michigan. The lake was listed as an Area of Concern (AOC) by the International Joint Commission (IJC) in 1987 because of severe environmental impairments related to the historic discharge of municipal and industrial wastes. The Beneficial Use Impairment (BUI), Restrictions of Fish and Wildlife Consumption, was listed because of elevated PCB and chlordane levels found in carp. At the time of AOC listing, the MDEQ was unable to determine if the contamination originated from atmospheric sources or contaminated sediments. Recommendations were made in the 1987 Remedial Action Plan to conduct an assessment of contaminated sediment and to continue fish tissue monitoring. Subsequent environmental surveys found localized areas of sediment contaminated with mercury in Tannery Bay (Rediske et al. 2004). Elevated PCB residues were only found near the outfall of the Hooker Chemical (Occidental Chemical) site (Rediske et al. 2004). Contaminated sediments in Tannery Bay and the Hooker Chemical Outfall were removed in 2004. Some areas of mercury contamination above 1 mg/kg were still present in Tannery Bay after remediation. A source of chlordane was not found in White Lake. Fish tissue monitoring was conducted in 1980, 1984, 1987, 1991, and 2004 (MDEQ 2006). Comparisons of historic and recent data for PCBs and mercury are shown in Figures 9 and 10, respectively.

From 1984 to 2004, mean PCB levels in White Lake fish appear to be declining while mercury appears to be at steady state for all species except for walleye. Mercury levels in walleye appear to be increasing.

5.5.2 Available Guidance

The IJC criteria for listing the Restrictions on Fish Consumption BUI are provided below:

> "An impairment will be listed when contaminant levels in fish or wildlife populations exceed current standards, objectives or guidelines, or public health advisories are in effect for human consumption of fish or wildlife. Contaminant levels in fish and wildlife must be due to contaminant input from the watershed."

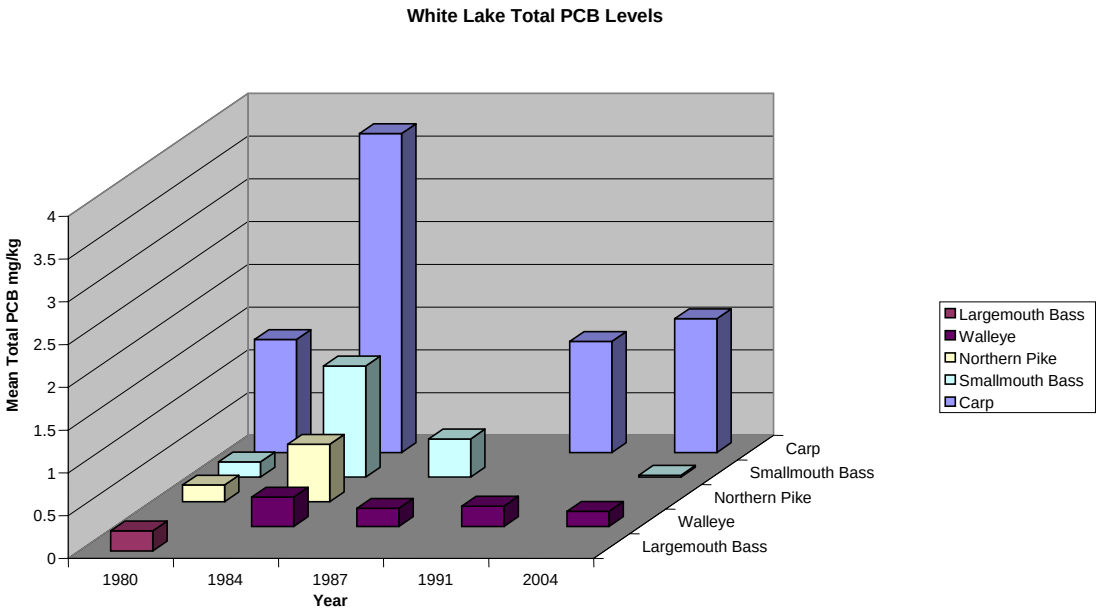


Figure 8. Mean PCB Concentrations in White Lake Fish (MDEQ Fish Contaminant Monitoring Program. n=10)

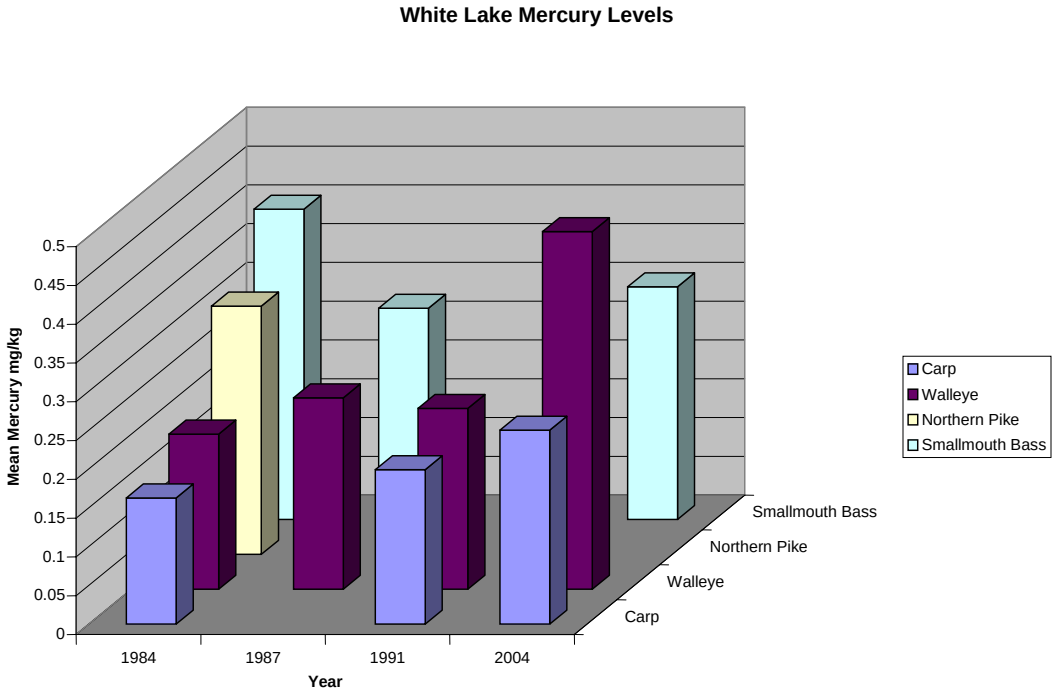


Figure 9. Mean Mercury Concentrations in White Lake Fish (MDEQ Fish Contaminant Monitoring Program. n=10)

The MDEQ provides the following guidance for delisting:

> "The restoration criteria for this BUI use a tiered approach for restoration success. This BUI will be considered restored when:
>
> - The fish consumption advisories in the AOC are the same or less restrictive than the associated Great Lake.
>
> - or, a comparison study of fish tissue contaminant levels demonstrates that there is no statistically significant difference in fish tissue concentrations of contaminants causing fish consumption advisories in the AOC compared to a control site.
>
> - or, if a comparison study is not feasible because of the lack of control site, analysis of trend data for fish with consumption advisories similar trends to other appropriate Great Lakes trend sites."

5.5.3 Delisting Target

White Lake is included in the regional fish consumption advisory for PCBs and mercury. The PAC believes that an assessment of contaminant levels in game fish is necessary for delisting this BUI because there is insufficient data available to determine if fish contaminant levels of PCBs and mercury in the AOC exceed other sites in the Great Lakes. Since chlordane has been discontinued for use as a pesticide since 1980 and no source for the compound was found, the PAC proposes to not include the chemical in the fish tissue monitoring program. Although mercury levels were not elevated in pre-1987 monitoring, the continued presence of mercury in Tannery Bay sediment supports the need for fish tissue monitoring. The White Lake Public Advisory Council (PAC) voted to adopt a target for delisting the Restrictions on Fish Consumption BUI that is functionally equivalent to the State of Michigan criteria. Since it is not possible to select a control location from within White Lake, a comparison of contaminant concentrations in fish from a similar drowned river mouth lake (Pentwater Lake) in combination with historical contaminant trend analysis will be used for delisting. The specific components of the proposed fish contaminant program are given below:

- Key fish species: largemouth bass, and carp
- Sample design: 10-20 fish of each species collected in July-September
- Tissue analyzed: edible portion
- Reference system: Pentwater Lake
- Restoration target end: BUI will be considered restored when contaminant levels in edible portion analyses of key fish species are not significantly different from Pentwater Lake for 2 consecutive 5 year sampling periods. An analysis of covariance (ANCOVA) will be conducted to determine if there are statistically significant differences between the two lakes. Fish size will serve as the covariate. To the greatest extent possible, analyses will include populations that

overlap in size. If a significant difference between fish contaminant levels in White Lake and Pentwater Lake is present at the end of the monitoring period, all available fish contaminant monitoring data for White Lake will be evaluated for a decreasing trend in concentration. In this situation, the BUI will be considered restored when edible portion analyses of key fish species in White Lake show a similar decreasing trend as other appropriate Great Lakes trend sites.

Largemouth bass was selected as an important resident game fish species in White Lake. Carp are consumed by subsistence fishermen and have a greater exposure to contaminated sediments than most game fish due to their feeding behavior. If statistically significant increases in contaminant levels are noted in these fish species from the AOC compared to the reference site, bioavailability issues or an unidentified source may be present in White Lake. The fish species as well as the number of organisms selected for analysis comply with the MDEQ Fish Contaminant Monitoring Program and the delisting criteria for this BUI.

5.5.4 Functional Equivalence

The proposed targets for the White Lake AOC are functionally equivalent to the MDEQ as they use a reference site to compare fish contaminant levels with and trend data.

5.5.5 Programs for Monitoring and Assessing Restoration Success

The Annis Water Resources Institute (AWRI) will conduct the initial fish contaminant monitoring of White Lake and Pentwater Lake in 2006 as part of the program developed for a CMI grant. A Quality Assurance Project Plan for Muskegon Lake fish contaminant monitoring activities was prepared and approved by the MDEQ. If a second set of monitoring results are required in 20011, the WLPAC will request that these analyses be included as part of the MDEQ's Fish Contaminant Monitoring Program.

When monitoring data meet the above targets for White Lake, the WLPAC will submit a summary report to the MDEQ along with a request for formal delisting of the Restrictions on Fish Consumption BUI. The report will include monitoring and quality assurance data demonstrating that the data quality objectives of the QAPP and the targets concentrations and or trends were achieved.

5.5.6 References

MDEQ 2006. The Michigan Fish Contaminant Monitoring Program. http://www.michigan.gov/deq/0,1607,7-135-3313_3686_3728-32393--,00.html. Accessed on April 28, 2006.

Rediske, R., M, Chu,, D. Uzarski, G. Peaslee, J. Gabrosek. 2004. Phase II Investigation of Sediment Contamination in White Lake. EPA-905-R-04-001.

6. Discussion

The delisting target setting process represented a philosophical shift in focus of both PACS from identifying current problems to developing restoration endpoints. In 2002, the RAP update for Muskegon Lake identified four new Beneficial Use Impairments in the AOC and deteriorating conditions for water quality. The RAP update for White Lake also identified concerns related to degraded water quality from nonpoint source pollution. Both updates contained a series of restoration goals for the AOCs that required a 50% reduction in nutrient loading to the lakes from current levels. These perceptions and goals were very subjective in nature and not based on monitoring data. While some PAC members were receptive to the concept of developing targets, a number of individuals felt there were too many problems in the AOC to consider removing BUIs and that future opportunities for restoration funding would be lost. Because of this divergence in opinion, the target development process for each BUI was phased over three PAC meetings to facilitate a thorough discussion of the issues and to obtain consensus. The initial meeting for each BUI was devoted to reviewing recent and historical data and soliciting the opinion of the members on the severity of current impacts. In many cases, public concerns were related to historical issues, the lack of public availability of relevant data, and the effects of regional problems such as invasive species and atmospheric deposition. These concerns were incorporated into the presentation of the preliminary targets for each BUI in a second meeting and members were offered an additional opportunity to voice concerns and suggest revisions. Options for consensus were discussed and often centered on extending the monitoring period or initiating supplementary program if the targets were not achieved. The only negative aspect of this approach was that the extended discussion and opportunity for comment on each BUI provided an opportunity to increase the complexity of the targets. For example, walleye and northern pike were added to the list of species to monitor for the Restrictions on Fish Consumption BUI because of member concerns. Later, these species were removed from the list after a review of the MDEQ staff comments with the MLPAC. With the exception of the Eutrophication and Undesirable Algae BUI, a unanimous consensus was reached for the delisting targets. For the Muskegon Lake AOC, the vote was 10 in favor and 2 against the proposed targets which established a water quality goal for total phosphorus, Secchi Depth, and chlorophyll *a* at the low end of the Carlson Index ranking for eutrophic classification. A similar set of eutrophication targets were proposed for the White Lake AOC, however the PAC unanimous voted to adopt targets that were in the mesotrophic range. The WLPAC was advised that the mesotrophic targets may not be achievable because a majority of the nutrient loading to the lake originates from outside the AOC boundary. Even with this consideration, the WLPAC still felt it was important to continue to stress the need for further loading reductions in the watershed and wanted to use the AOC designation as leverage to obtain funding for nutrient minimization programs.

The peer review process produced mixed results for the delisting targets. While no serious problems were identified in the reviews, concerns were expressed related to the scientific rigor of the proposed monitoring programs and our ability to defend the numerical values selected for the targets. For example, the review of the eutrophication

targets by Dr. Karl Havens (Appendix III) recommended that the MLPC should conduct a detailed paleolimnology study of Muskegon Lake to determine nutrient loading during presettlement conditions and to track the changes over the last 50 years. While this type of investigation would provide important information to strengthen the targets, it would be cost prohibitive within the current funding environment. Dr. Havens also felt that there was justification to consider lower targets for chlorophyll *a* and total phosphorus and that multiple years of intensive monitoring would be required to accurately assess the true trophic status. The current funding deficit for monitoring at the State and federal level makes it very difficult for PACs to develop scientifically rigorous monitoring programs and data sets. The peer reviews were useful in identifying potential shortcomings with respect to the individual values for the targets and the proposed approach for monitoring. In addition, the suggestion was made to use public surveys to help quantify the extent and status of the BUIs. Since BUIs have no promulgated standards for restoration, a scientific assessment of public perception may be useful to help determine the current status.

The MDEQ finalized their guidance for the development of delisting targets in January 2006. The targets were presented as minimum criteria and guidelines that all Michigan AOCs had to meet. AOCs were given the option of developing more restrictive targets, however the MDEQ identified that funding may not be available for monitoring and restoration programs that exceed the State guidelines. The MDEQ guidance plus the staff review provided a reality check with respect to the feasible of achieving the targets for delisting BUIs. The targets for Beach Closings, Degradation of Benthos, and Eutrophication exceed the MDEQ guidance for the Muskegon Lake AOC. Additional resources for monitoring these targets were not required because of existing funding from private sources, research grants, and local agencies. The MLPAC was able to obtain staff approval for their set of targets because they met State guidelines and credible sources of funding were identified to cover assessment programs that exceeded MDEQ requirements. The targets developed for Restrictions on Drinking Water Consumption, Degradation of Benthos, and Eutrophication in the White Lake AOC exceed the MDEQ guidance. MDEQ Staff were in agreement with the targets for Drinking Water and Benthos because industry led monitoring programs were in place for groundwater plumes and grant opportunities were available for benthic invertebrate monitoring. Concerns were expressed by the MDEQ about the WLPAC's ability to achieve the 25 µg/l desired target of for total phosphorus (currently 30 µg/l) in White Lake when 95% of the loading originated outside the AOC boundary. The WLPAC felt that a lower target was necessary to stress the importance of nutrient management in the AOC and that if the level was not achieved, the target could be revised in the future. It was the position of the MDEQ that the State would rather have PACs develop achievable targets and not propose something that may require future revision due to failure. Possible revisions to the Eutrophication target will be discussed during the December WLPAC meeting.

7. Conclusions and Recommendations

The process of target setting is an important undertaking for AOCs and their PACs. AOCs were created by neglect and pervasive disregard for the environment. In contrast, PACs were formed with the intent that the public take ownership of the problem, establish goals for restoration, and actively seek solutions to the Beneficial Use Impairments. The MLPAC and WLPAC approached the restoration of their respective AOCs in a holistic manner and set high goals for the desired quality of the environment. The challenge of the delisting target setting process was that PACs must step back form the big picture and focus on a defined point along the restoration continuum. While scientific rigor is an important part of the target setting process, scientific opinion can be diverse as public opinion with respect to what an individual target should be. Based on the results of the target setting process in the Muskegon Lake and White Lake AOCs, the following recommendations can be made to address the above issues:

1. Approach targets setting as a two way street where it is an opportunity to for public education and to be educated by the public;
2. Take the time to build consensus and ownership; and
3. Look beyond the target and identify how additional restoration will be accomplished outside of the AOC program.

Taking the time for education, listening, and consensus building cannot be overemphasized. In many several cases, initial road blocks were over come by minor changes in language or adjustments in monitoring frequency. The third point was not reflected in the actual targets, however played a key role in developing both consensus and ownership. Restoration is a work in progress that will always be subject to adjustment, refinement, and the new challenges. The difficultly associated with target setting was not necessarily agreeing on a numerical value, but rather developing a sense of assurance with PAC members and the public that restoration and problem resolution would continue after delisting. A discussion of what happens after delisting was framed into the deliberations for each BUI. A summary of how restoration activities would continue after delisting is provided below:

BUI	AOC	Programs for Continued Restoration
Restrictions on Fish Consumption	Muskegon and White Lakes	MDEQ Fish Contaminant Monitoring Program, Great Lakes Initiative, LAMP
Degradation of Aesthetics	Muskegon and White Lakes	Local zoning regulations, MDEQ programs for wetlands and dredging, federal and state conservation programs
Eutrophication and Undesirable Algae	Muskegon Lake	Muskegon Lake Monitoring Endowment Fund, Muskegon River Watershed Assembly environmental programs, LAMP, MDEQ TMDL for Bear Lake
Beach Closings	Muskegon Lake	MDEQ TMDL for Ruddiman Creek, Muskegon County Health Department Beach Monitoring Program

These targets developed will serve as a roadmap and an assessment tool to measure progress toward delisting. Using these targets as restoration endpoints, the PACs can proceed in a focused manner to restore each BUI and ultimately, document sufficient progress to petition for the delisting of the Area of Concern designation. This focus will result in a cost effective approach to achieve successful and lasting restoration of the BUIs that have impacted the AOC. These targets will incorporate the RAP and progress will be reported on an annual basis. Restoration targets for the remaining 4 BUIs need to be established. Targets for Loss of Fisheries and Wildlife Habitat and Degradation of Fish and Wildlife Populations are currently being developed as part of a grant from the Nation Fisheries and Wildlife Foundation. The PACs are currently discussing target setting options for the Restrictions on Dredging and Restrictions on Drinking Water Consumption BUIs. We celebrate the efforts all individuals that have participated in the target setting and restoration process. The health and restoration of Muskegon Lake and White Lake will benefit the Great Lakes Ecosystem, the local economy, and enhance the quality of life for all who enjoy this important resource.

Appendix 1

Peer Review Comments for the Degradation of Benthos Targets

From: Tom Nalepa <Thomas.Nalepa@noaa.gov>
To: Rick Rediske <redisker@gvsu.edu>
Date: Mon, April 17, 2006 4:11 PM
Subject: Benthos Targets

Rick,

Thanks for letting me review the delisting targets for benthos in the Muskegon Lake AOC. Benthic macroinvertebrates are found in most habitats and relatively easy to sample quantitatively (Canfield et al. 1996; Wiederholm 1980). Moreover, they form stable communities that integrate and reflect conditions of both pelagic and benthic regions over relatively long periods of time (Nalepa 1987; Wiederholm 1980). Since macroinvertebrates are confined to habitats that continually receives autochthonous and allochthonous material, they serve as integral measures of both autotrophic and heterotrophic processes in lakes (Wiederholm 1980). For Muskegon Lake, there are four overarching factors that influence the benthic community:

- Eutrophication
- Anoxia
- Organic deposition from the Muskegon River
- Littoral zone impacts

Muskegon Lake has shifted from highly eutrophic conditions in the 60s and 70s to the mesotrophic/eutrophic border. Current data from AWRI indicates that summer anoxia is present, however, the spatial magnitude of oxygen depletion is considerably less than historic conditions (Evans 1976; Peterson 1951; Surber 1954). Consequently, Muskegon Lake will still exhibit a benthic community indicative of enriched conditions. Two additional influencing factors were observed in our 1999 investigation: accelerated organic deposition and enrichment near the Muskegon River mouth and impacted benthic communities in certain areas of the littoral zone (Carter 1972).

While benthic communities provide a “snapshot” of trophic conditions in a lake at the time samples are collected, and community composition may reflect recent events, comparisons to historical communities are useful in assessing long-term trends in

environmental conditions and trophic state (Nalepa et al. 2000). Shifts in relative abundances of indicator species have been particularly effective in assessing changes in environmental conditions (Carr and Hiltunen 1965; Harman 1997; Krieger and Ross 1993; Lang 1998; Nalepa 1991). For instance, prior to phosphorus abatement programs in the mid-1970s, increased densities of most benthic groups and reduced densities of intolerant taxa in the Great Lakes generally reflected increased system productivity from increased nutrient loads (Carr and Hiltunen 1965; Robertson and Alley 1966). After abatement efforts were initiated, the abundance of less-tolerant species increased, and overall abundances of most benthic taxa declined in Lakes Michigan, Erie, and Ontario (Nalepa 1987, 1991; Schloesser et al. 1995). Given the difficulty of lake-wide experimental manipulations, comparing past and present communities may be the only practical method to assess changes resulting from human activities (Barton and Anholt 1997). In addition, these comparisons provide the only opportunity to gauge the progress of ecosystem restoration when monitoring data are limited.

The PAC proposes to use the 1999 data as a baseline to judge recovery from historical conditions and track future changes. Scientific studies commonly use reference systems to compare the degree of recovery and the extent of environmental impacts. I am not familiar with the availability of benthic macroinvertebrate data from similar drowned river mouth systems. In addition, Muskegon Lake is relatively unique with respect to its geomorphic character and history of anthropogenic stress. While the use of reference systems represents a more traditional approach to assess recovery, the use of historical data also is acceptable. The targets proposed by the PAC are presented below:

> This BUI will be considered restored when average benthic macroinvertebrate populations Muskegon Lake and Bear Lake reflect the following conditions:

Indicator	Target
Sediment Toxicity	**Amphipod Survival >60%**
Hexagenia	**Present in river mouth littoral zone**
% Oligochaeta	**< 75%**
Chironomidae (#/m^2)	**> 500**
Diversity (SW)	**> 1.5**

The use of sediment toxicity indicator is appropriate for Ruddiman Creek, Ryerson Creek, and the Division Street Outfall. These areas have historic anthropogenic contamination and the recovery of the benthic community will continue to be impacted as long as toxic chemicals remain at environmentally significant levels near the surface. We are lacking historical data regarding the presence and distribution of *Hexagenia* in Muskegon Lake. While the presence of *Hexagenia* in commonly used as an indicator of in improving benthic community, other factors such as substrate and lake hydrodynamics may influence its distribution. Without more data on historic/present distribution, I only can support the use of this indicator as a qualitative target.

Targets for oligochaetes, chironomids, and Shannon Weaver diversity are consistent with the 1999 survey. Considering that wastewater diversion was complete by the mid 70s, the benthic community observed in 1999 reflected almost 25 years of recovery. Current eutrophic conditions, anoxia, and organic deposition from the Muskegon River may limit future changes to the benthic community. The proposed target proposes to use one additional benthic survey to determine compliance. While the use of one survey may be driven by monetary considerations, most benthic invertebrate monitoring programs conducted in the Great Lakes utilize biannual surveys and are conducted over a period of 10 years. Since we currently have no data on temporal variability, it will be difficult to determine why changes are observed between surveys. I also recommend that physical and chemical analyses be conducted on sediments collected from the locations used for benthic invertebrate monitoring. These data may

help in the interpretation of community structure, especially if a significant change has occurred.

I have no information to assess the validity of these targets for Bear Lake. Bear Lake is shallow and more eutrophic than Muskegon Lake. It may be more appropriate to conduct an initial assessment of the benthic community and sediment quality to determine current status. A second survey could be collected 5 years after major water quality improvements were completed. This would follow the rep and post approach the PAC is using for Muskegon Lake. If you have any questions, please contact me.

Regards, Tom

Appendix II

Peer Review Comments for the Restrictions on Fish Consumption Targets

Comments on: Restrictions on Fish Consumption Delisting Target for the Muskegon Lake Area of Concern

David J. Jude, Research Scientist
University of Michigan

INTRODUCTION

Muskegon Lake is a drowned, river-mouth lake located along the shoreline of Lake Michigan in western Michigan. The lake was listed as an Area of Concern (AOC) by the International Joint Commission (IJC) in 1987 because of severe environmental impairments related to the historical discharge of municipal and industrial wastes. The Beneficial Use Impairment (BUI) of Restrictions of Fish and Wildlife Consumption, was listed for Muskegon Lake because of elevated PCBs concentrations in common carp and mercury in walleye and bass. Recommendations were made in the 1987 Remedial Action Plan to conduct an assessment of contaminated sediment and to continue fish tissue monitoring. Subsequent environmental surveys found localized areas of sediment contaminated with mercury in the vicinity of the Division Street Outfall and Ryerson Creek. Elevated PCBs residues were only found in Ruddiman Creek (a small tributary of Muskegon Lake), where dredging is scheduled to remove contaminated sediments. Other mercury-contaminated sediments are being evaluated for remediation by the MDEQ. The Public Action Committee, a local group formed to monitor progress and delist BUIs, believes that the Restrictions of Fish and Wildlife Consumption should be delisted based on available and future data.

CHOICE OF FISH SPECIES FOR MONITORING

The fish used for PCBs and mercury analyses included: common carp, smallmouth bass, northern pike, walleye, and largemouth bass. Smallmouth and largemouth bass, northern pike, and common carp are usually considered resident species and hence should be excellent candidates for tissue monitoring. Common carp, however, may migrate long distances and because of unknown exposure to other contaminated sites, may bias analyses. We have collected large numbers of common carp at the Cook Plant, Stevensville, MI along the Lake Michigan shoreline. The nearest river is 10 miles away from that spot, strongly suggesting that this species can leave connecting water bodies, migrate along the shoreline, and enter other tributaries and drowned, river-mouth sites, confounding contaminant results. Another species that was sampled for contaminants was walleye. Walleyes are strong natal homers to spawning sites, but many leave those sites and migrate out of the systems in which they spawn. The Muskegon estuary is home to the largest concentration of walleyes along the eastern coast and has a history of successful spawning in the Muskegon River system through the 1950s, when various pressures reduced recruitment, forcing the MDNR to begin stocking them in 1978. We have trawled large walleyes from Lake Michigan south of Muskegon, caught them at the mouth of the Muskegon Harbor in late fall studies, and have heard reports of walleyes that spawn in Muskegon Lake being caught in Indiana waters of Lake Michigan.

Recent studies by University of Michigan researchers (Chris Diana), who placed sonar tags in several walleyes and monitored their movements in Muskegon Lake, demonstrated that many left the lake after spawning. Hence, walleyes may not be an optimal choice for contaminant analyses or at best, results should be examined closely for anomalies, for both walleyes and common carp.

Secondly, a long-lived species like common carp and walleye, which can live up to 30 and 15 yr respectively, will reflect their contaminant history and probably contain high levels long after local sources of contamination are ameliorated. Hence, important decisions regarding trends in contamination may be better based on resident species that do not have long lives, such as moderate-sized largemouth and smallmouth bass, which may better reflect local contamination sources. One should also consider alternative means to evaluate these trends, using members of the lower food chain (see SOME SUGGESTED ALTERNATIVES FOR CONTAMINANT MONITORING).

Third, food web dynamics have changed dramatically in the last 10 years. Muskegon Lake, like many other connecting water bodies throughout the Great Lakes area, has been colonized by exotic species, the most notable for this discussion being dreissenids and round gobies. Dreissenids entered Lake Michigan in the late 1980s and filter large quantities of water, including contaminants adsorbed to particles. They may have changed contaminant pathways after this time period; hence comparisons of contaminant levels prior to and during the dreissenids presence should be made with these temporal changes in mind. Round gobies have invaded water bodies and their proliferation has been aided by dreissenids, which they use for food and sometimes cover. Round gobies have extirpated sculpins and greenside darters in areas of overlap and probably impact other species as well. In addition, they have expanded their range into most habitats within and adjacent to the Great Lakes, with particular preference for rocky, rip rapped, and warm water sites, but are found out to 60 m in Lake Michigan, on sandy substrate, and in vegetation. Because they feed on dreissenids, which probably bioaccumulate toxic substances at higher levels than natural prey, round gobies may accumulate higher concentrations of these substances in AOCs than if they fed on native prey. Because of their prolific spawning behavior (they spawn every 2 wk, guard their nests, and have a high fertilization rate), they produce large numbers of young, which, after they reach about 50 mm, feed almost exclusively on dreissenids, resulting in large populations. Top predators have learned to feed on round gobies, since they are so abundant, and published studies have stated that smallmouth bass young have profited from this newly available prey in their environment. Juveniles and adults of all predators probably also feed on round gobies to some degree or another. Thus, contaminant pathways for smallmouth and largemouth bass have probably changed from when round gobies were first found in this system (ca. 2000) and the present. This situation could also change contaminant levels in these top predators, which may have previously fed on native fish species or the pelagic alewives and may now be feeding extensively on round gobies, a more benthic-oriented fish.

THE SIZE VS. AGE CONUNDRUM FOR FISHES

Some species of fishes, especially common carp, can be large and young or old and small. Ageing of these fish can provide a more reliable index of contamination, so

one only compares the same ages or at least has the option of evaluating each fish's contaminant level based on its age and/or its length or weight. Unfortunately, common carp are notoriously difficult to age; we were involved with ageing them using opercula in a Kalamazoo River DEQ assessment. Although we became quite proficient in ageing common carp using these structures, we are unaware of how accurate we were. Other structures, such as otoliths, fin rays, and scales have also been used to age fish, but results have remained variable, based on the people we contacted for assistance in doing the project. Although we are unaware of the final results of the ageing study we did (how it compared with lengths and weights and with another evaluation of which we were not made a party), we believe them to be unreliable. However, other fish species on the list for this contaminant study are usually more amenable to ageing and such data would enhance the analysis of the dataset, allow the identification of outliers, and promote comparisons among same-age fish. Age-length keys are also available as a shortcut to obtain these data and evaluate whether age had an effect on contaminant relationships.

I agree with the suggestion of using fishes from adjacent, non-AOC lakes to compare with fishes from Muskegon Lake. One would predict that resident species of choice, large and smallmouth bass and northern pike, might have high mercury levels in these lakes from the well known atmospheric sources. They should also have relatively lower PCBs levels, allowing a valid comparison with Muskegon Lake fishes in both cases. Should Muskegon Lake fishes also reflect those lowered contaminant levels, one would be able to conclude that contaminant levels in Muskegon Lake have been reduced to background levels and delisting for that compound could proceed.

AVAILABILITY OF DATA

I see two issues with the current data made available for reaching conclusions about contaminant levels in Muskegon Lake. First, there are missing data points for various species and contaminants. For example, almost half (12 of 25) of the data points required for the year (5 yr) x species (five) matrix are missing for both the PCBs data and the mercury data. This lessens the power of the final conclusions, may obviate statistical comparisons, and compromises the integrity of interpretations. Second, the most recent data available for making decisions originated in 2002 and there are only two fish species (common carp and walleye) out of the five with data for PCBs and mercury; the full suite of species is not available to confirm trends for all species to the most recent time. Third, more recent data are required, since it has been 4 years since the last data points were obtained. When these data are obtained, they must be evaluated in light of the food web dynamics discussed elsewhere.

STATISTICAL ANALYSES

I assume that at some point additional statistical analyses will be performed using these datasets. With a sample size of ten, good statistical power should be observed, providing that variability is moderate. In addition, standard errors/deviation should be provided somewhere to gauge variability of each data point. The most obvious statistical procedure that comes to mind is a linear regression of contaminant concentrations over time (yr), which will show whether there is a declining trend in contaminants and which

can be tested to determine if there is a statistically significant relationship. No trend in the regression equations would indicate no changes in current concentrations of interest over time. For example, the concentrations of PCBs for walleyes should show a significant declining trend over the years of the study.

SOME SUGGESTED ALTERNATIVES FOR CONTAMINANT MONITORING

I have some suggestions for a radical change in monitoring, which would take a major shift in emphasis in this work plus some research to set up a comparative matrix. I would continue with the present format and keep the common carp and in-lake top predators (bass, pike) until my suggested procedures are proven or accepted as a supplementary and complementary assessment of contaminant levels in AOCs. I suggest three additional initiatives: 1) Use round gobies as indicators of contaminant levels. They are very abundant, so one can composite large numbers of them to reduce contaminant variability, one could select for appropriate sizes (which might not be the largest from our findings) and/or sexes if this proves to be important, and one could do seasonal and site-specific work with them, since they will usually stay in enclosed water bodies like Muskegon Lake. They seem to reflect ambient levels of PCBs based on our study of four AOCs in the Great Lakes (e.g., round gobies in the Raisin River had ca. 5 µg/g, while those from Lake Michigan off Muskegon had only trace concentrations). 2). Use zebra/Quagga mussels (dreissenids) *in situ* as contaminant indicators. We also have data on dreissenids from the above noted AOCs and there are other datasets throughout the Great Lakes (one funded by NOAA I believe), which can provide comparative data to ensure reliability of the program. Dreissenids are usually present in most sites where contaminants are present or one could place structures in those areas to ensure colonization. Cages with control dreissenids present could also be placed at sites of interest and bioassays completed. (One drawback of course is that these indicators for dreissenids are not directly related to human consumption, but could provide excellent tracking of contaminant availability and trends in a water body). 3.) Use spottail shiners as indicators of contaminants. We have captured large numbers of this species in Muskegon Lake, but they may not be available at all the sites and depths where contaminant monitoring may be of interest. Spottail shiners have been used for and proposed as a near shore index of near shore contaminant exposure and at least two papers have been published on their use in Lake Ontario I believe (see Suns et al. in J. Great Lakes Res.).

PCBs CONGENERS

I am unaware of whether PCBs congeners data were generated for each fish species analyzed or just total PCBs. If congener data are available, then a discussion of which congeners were dominant and which increased or declined over time should be part of the data presentation. I am concerned that some of the recent trends observed in other parts of the Great Lakes may be ongoing in Muskegon Lake. These include a decline in total PCBs, but an increasing proportion of those remaining are co-planar congeners, which are the most toxic congeners.

Appendix III

Peer Review Comments for the Eutrophication and Undesirable Algae Targets

Review of Draft Targets for Eutrophication / Harmful Algal Bloom Beneficial Use Impairment of Muskegon Lake Area of Concern

Karl E. Havens, Ph.D., Professor and Chair
Department of Fisheries and Aquatic Sciences
University of Florida
7922 NW 71st Street
Gainesville, FL 32563
E-mail: khavens@ifas.ufl.edu

This review is provided as a deliverable in a contractual relationship between the Annis Water Resources Institute, Grand Valley State University and the Department of Fisheries and Aquatic Sciences, University of Florida, dated August 12, 2005.

1. Scope of the Review

This review focuses on targets and indicators related to eutrophication and harmful algal blooms that have been proposed for use in the process of delisting Muskegon Lake, Michigan as an Area of Concern (AOC). Delisting occurs when a water body is shown to have improved to the point where there no longer is beneficial use impairment (BUI). The Michigan Department of Environmental Quality (MDEQ 2004) notes that this is not the same thing as full restoration of an ecosystem – delisting is just a point along a restoration continuum. This review is organized into three parts: (1) general background information regarding eutrophication of Muskegon Lake; (2) restoration actions completed to date and responses observed; and (3) indicators and targets proposed for assessment of eutrophication / harmful algal bloom BUI.

2. Background Information

Information presented in the 2002 Muskegon Lake Community Action Plan (CAP) indicates that this water resource experienced high point-source inputs of nutrients from residential, urban and industrial sources prior to the mid-1970s. Surface water total phosphorus (TP) concentrations averaged nearly 70 µg/L in 1972, soluble reactive P (SRP) concentrations averaged 20 µg/L, chlorophyll *a* averaged 25 µg/L, and Secchi disk transparencies were below 1.5 m. Carlson's (1977) trophic state index values indicate that the lake was in the eutrophic range and that phytoplankton algae was responsible for the low transparency (TSI-CHL > TSI-SD). The lake experienced late summer blooms of the cyanobacteria *Microcystis aeruginosa*, which produces toxins that can disrupt liver function in humans and other animals that consume the lake water.

The 1970's condition of Muskegon Lake is typical of what is observed across the USA in lakes experiencing 'cultural eutrophication,' i.e., accelerated enrichment due to excessive nutrient loading from human-related sources. Other factors simultaneously occurring in the lake, including loss of shoreline aquatic plant communities, may have contributed to the water quality problems by reducing natural assimilative processes (plant and benthic algae nutrient uptake, sediment stabilization, etc.) that occur in healthy lake ecosystems. Although not explicitly covered in this review, it is important then to note that rehabilitation of the lake's aquatic plants is likely to do more than provide habitat for fish and other biota – it also may significantly contribute to improved water quality in shoreline areas.

3. Actions Completed and Lake Responses

Since 1974, sanitary wastewater from around the lake has been diverted into the Muskegon County Wastewater Management System (WMS). Heavily urbanized areas are regulated by the Michigan Department of Environmental Quality (MDEQ) and most pollutant discharges go into the WMS. As noted in the CAP there continues to be a problem with some areas on septic systems and with potential leaks from older connections between storm and sanitary sewerage systems. There have been periodic discharges of raw sewage into the lake due to blockage in these pipes. Nevertheless, there has been a significant improvement in water quality, from the standpoint of nutrients, algal biomass and transparency since the 1970s. Surface water TP concentrations in 2003-04 averaged less than 30 µg/L, SRP averaged 5 µg/L, chlorophyll *a* averaged just over 5 µg/L, and Secchi disk transparency was greater than 2 m. Transparency in Muskegon Lake during 2003-04 exceeded that in nearby Pentwater Lake, which is considered a reference site. Muskegon Lake now is borderline mesotrophic / eutrophic based on Carlson's trophic state index. In addition to these water quality changes, the benthic invertebrates in Muskegon Lake have displayed a reduction in dominance by oligochaetes and increased overall taxonomic diversity; both indicate that the system is recovering from cultural eutrophication.

Although there are substantive improvements in lake condition, summer phytoplankton continues to be dominated by cyanobacteria, including blooms of *Microcystis* with associated high concentrations (sometimes >200 µg/L) of microcystin. This is not surprising, and reflects an adaptation (buoyancy regulation) that allows this bacterium to sequester large amounts of P in nutrient-rich waters near the sediment-water interface and then rise to the water surface during stable summer stratification. A *Microcystis* bloom can form a thick layer that blocks light to algae lying below. By this process *Microcystis* out competes the other algae for both P and light. A number of authors have commented on the difficulty of reducing the dominance of this alga in lakes recovering from cultural eutrophication. For example, Dokulil and Teubner (2000), in a review of cyanobacteria dominance in lakes, note that *"nutrient reduction will only reduce the maximum biomass of Microcystis, but not its dominant position in the phytoplankton community."*

4. Indicators and Targets for BUI

3.1 General Overview

The Annis Water Resources Institute recommends five indicators of eutrophication / harmful algal bloom BUI for Muskegon Lake, and has identified associated targets:

- total phosphorus — target 30 µg/L
- chlorophyll *a* — target 10 µg/L
- percent *Microcystis* — target not established
- Secchi disk transparency — target 2.0 m or greater
- Carlson's trophic state index — target range 50 to 55

Attainment of these conditions would place the lake somewhere in the region between mesotrophic and eutrophic. As noted above, the 2003-04 data for TP, chlorophyll *a,* Secchi transparency and Carlson's trophic state index already meet these targets. However, there is not sufficient data available to say whether the data reflect a lasting condition or just a particularly 'good year.' Water quality in lakes displays some inherent amount of variability from year-to-year in response to changes in climate, water inflow, flushing rate, and other factors. Therefore it will be important to collect a number of years of data to determine whether these conditions actually are being met. The targets for Muskegon Lake are relatively high, suggesting a view that ecosystem services can be provided with relatively high levels of TP and chlorophyll *a*. It seems prudent to obtain paleolimnological data to estimate the historical trophic state of Muskegon Lake – this will allow an assessment of just how far delisting actually is along a restoration continuum for this particular ecosystem. Likewise, it makes sense to examine relationships between public uses of the water resource and water quality attributes, similar to what has been done for Wisconsin lakes (Heiskary and Walker 1988). By combining a relatively simple survey with water quality sampling, one can gain useful insight that can help to set numeric targets. That process is consistent with ensuring that there is not impairment of beneficial uses.

The following sections focus in greater detail on the five proposed indicators and their targets, taking into consideration (where available) information on targets used for other lake ecosystems and public comments provided on the Muskegon Lake plan.

3.2 Total Phosphorus

Total phosphorus is the logical choice for a BUI nutrient indicator in Muskegon Lake. Phosphorus is the nutrient most often limiting to phytoplankton growth in temperate freshwater lakes, and excessive phosphorus inputs and concentrations are generally linked with increased chlorophyll *a*, reduced transparency, and increased algal blooms in freshwaters (Schindler 1977, Downing et al. 2001). Hecky and Kilham (1988) note that *"P limitation of freshwater environments can be demonstrated rigorously at several hierarchical levels of system complexity, from algal cultures to whole lakes."*

Identification of 30 µg/L TP as a delisting target is not as clearly justified, primarily due to a lack of information on how this concentration of TP relates to associated impacts to fish and human uses of the resource. In order to have a scientifically defensible and publicly acceptable TP target, there is a need for data that link use impairment with concentration of TP. Does 30 µg/L mean TP provide for water that is good for contact recreation? Is contact recreation an important use of the resource? Does it provide for good fishing? Does it protect native flora and fauna? Research / data collection is needed to answer these questions. Until that time, the 30 µg/L TP target should be considered provisional and subject to change when data are obtained to address these issues. There is precedent for setting a lake-specific TP goal rather than accepting a generic goal from the Michigan Department of Environmental Quality (MDEQ). For example, consider the following text from the Ore Lake, Michigan TMDL document (MDEQ 1999): *"A goal of 30 µg/L in-lake total phosphorous concentration was originally recommended in the draft TMDL for Ore Lake…After reviewing the considerable public comments received and reviewing the existing conditions of Ore Lake a goal in-lake concentration of 25 µg/L was established…"*

3.2 Chlorophyll a

Chlorophyll *a* is a surrogate for algal biomass in the water column of lakes. It is widely accepted as an indicator of eutrophication (Carlson 1977). It correlates with reduced transparency, propensity for algal blooms, aesthetic issues, and ecosystem effects ranging from shading of plants to anoxia of bottom waters. In Muskegon Lake, the fact that TSI-CHL exceeds TSI-SD indicates that algae are the primary factor responsible for light attenuation in the water column, rather than suspended sediment or some other factor. For these reasons, chlorophyll *a* is good indicator of eutrophication BUI for Muskegon Lake.

As was the case for TP, however, the recommended chlorophyll *a* target of 10 µg/L is not clearly justified. In fact, if the 2003-04 data are representative of current conditions, a target of 10 µg/L will allow the lake to degrade from current conditions (near 5 µg/L). The USEPA guidance manual was used to arrive at the 10 µg/L target. That manual identifies 10 µg/L on the basis of an lower 25th percentile of data collected on Ecoregion VII lakes, and as such, may not be applicable for this particular lake – one really needs to know how chlorophyll *a* concentrations relate to impairment of fisheries and public uses of the resource. At this time all states across the nation have been presented with default goals for TP, chlorophyll *a*, and Secchi transparency by the EPA. They are not science-based, and it is clearly recognized that states will develop their own more appropriate goals. In the case of Muskegon Lake, I recommend that paleolimnological data be colleted to identify historic conditions (to identify where the proposed target lies along a restoration continuum), that an enhanced dataset be obtained to determine current conditions, and that a survey be conducted to identify how public perceptions of water quality relate to concentrations of chlorophyll *a*.

An additional recommendation regarding chlorophyll *a* is that the indicator move away from a focus on mean values, which are not something visible to the public or

clearly linked to ecological responses, and towards extreme events (blooms). This can be done quite simply by following the process in Heiskary and Walker (1988), where a concentration of chlorophyll *a* associated with visible bloom conditions is identified, and a target then is set in regard to the percent of water samples collected in a given period of time that will display bloom levels of chlorophyll *a*. As an example, Havens and Walker (2002) used a chlorophyll *a* concentration of 40 µg/L as the surrogate for a bloom in Lake Okeechobee, Florida, and looking at data from the early 1970s, prior to intensified P loading, identified a target of <5% of samples collected in a given year (monthly sampling at many sites) will have chlorophyll *a* >40 µg/L. This approach will better align the indicator and target with public values, but requires that a bloom criteria be established and a target identified. The former requires a user survey, as noted above. The later requires historic data on chlorophyll *a* or data from reference lakes.

3.3 Percent Microcystis

Although this indicator seems logical, given that the lake displays recurrent summer blooms of this potentially toxic bacterium, and the MDEQ (2004) guidance clearly indicates that lakes should not have "nuisance growth of bacteria," there are reasons noted above to select a different indicator – one that focuses on absolute rather than relative values. Studies of other eutrophic lakes (e.g., Dokulil and Teubner 2000) indicate that the relative abundance of *Microcystis* does not decline when nutrients are reduced in lake restoration programs. However, absolute concentrations of this nuisance alga do decline over time as P stores in surface sediments are reduced, because like all of the other phytoplankton, the biomass of this bloom-former depends ultimately on P availability. Thus, unless it is feasible to conduct additional in-lake actions like aeration to mix the water column so that algae are favored over *Microcystis* (unlikely in such a large lake), a reasonable expectation is that it will continue to dominate in late summer even if lake water TP falls below its present 30 µg/L value.

This lack of response in relative biomass really is not a cause for concern, because neither the public use of the lake or the ecological integrity depends on that particular indicator. Rather, it is the absolute biomass of *Microcystis* and other potentially toxic algae and the frequency and intensity of their blooming that are problematic. Thus, rather than focusing on relative biomass, I recommend indicators to address summer surface biomass of potentially toxic species and toxin concentrations. While toxin assays are costly, there is not sufficient information to quantitatively link their concentration with cyanobacterial biomass. Given the potential impacts of microcystin on aquatic biota, water fowl, and other animals around the lake shore (and potentially on humans using the lake for contact recreation), having data on actual toxin concentrations seems warranted in support of de-listing this AOC. An interim target could be set according to WHO guidelines (<20 µg/L), until research identifies a potentially lower or higher concentration for impacts on aquatic biota. There is an EPA workshop in September 2005 focused on ecological and human health effects of harmful cyanobacterial blooms, and results from that event might be helpful to this process (www.epa.gov/cyano_habs_symposium).

3.4 Secchi disk transparency

Secchi disk transparency is the most widely used indicator of water quality in freshwater lakes. Where light attenuation is primarily due to suspended algae (as appears to be the case in Muskegon Lake) it is a fast and inexpensive surrogate indicator for algal biomass, and many measurements can be taken in space and time because non-experts can easily be trained and equipped with this device for less than $30. Secchi transparency provides information on potential impairment of recreational uses and reductions in light for submerged plants – and thereby is a useful indicator for both societal and ecological values of the resource. I strongly endorse the use of Secchi disk transparency as a prime indicator of water quality related to eutrophication in Muskegon Lake, and encourage the agencies that manage the lake to take advantage of opportunities to use volunteers to help develop a comprehensive database for this particular attribute.

In this case, a nearby lake (Pentwater Lake) is used as a reference to establish the Secchi transparency goal for Muskegon Lake. I do not have sufficient knowledge of the limnology of Pentwater Lake or its history of land use changes to reach any conclusions regarding the validity of that reference site. However, I would recommend that other factors be taken into consideration. First, one might examine the Secchi disk transparency that is necessary to allow establishment of submerged plants over a desired region of the lake. This is the approach that was taken by the South Florida Water Management District (SFWMD) in setting a Secchi disk target for the Lake Okeechobee Protection Program. In that case, there is not a numeric target, but rather a narrative target of "Secchi disk visible on the lake bottom in shoreline areas known historically to support submerged plants." One also might consider how Secchi disk transparency relates to the public's perception of BUI. This would require a user survey as noted above. In this case, it would be very easy to perform, because unlike TP and chlorophyll *a*, which require laboratory analysis, citizens could be given Secchi disks and survey forms and within a short period of time (e.g., a year of sampling by 10-20 persons), data could be available to establish a relationship between transparency and BUI. A final issue to consider is the fact that the proposed targets for TP, chlorophyll *a* and Secchi disk transparency are incongruent. The proposed TP and Secchi disk targets correspond to current conditions, whereas the chlorophyll *a* target is two-fold higher.

3.5 Carlson's Trophic State Index (TSI)

Carlson (1977) developed the TSI index in an attempt to normalize measurements of TP, chlorophyll *a* and Secchi disk transparency in a manner that allows the public to readily understand how those attributes change along a nutrient enrichment gradient in lakes. The index values are used as targets in lake rehabilitation programs in every state in the nation, and although they provide somewhat redundant information for scientists who typically work with the underlying data, there are proven as a useful tool for conveying water quality changes to the general public. I have just one issue with the proposed target. Mirroring what has been said above it is unclear whether Pentwater Lake

is a suitable reference and whether the selected range of TSI values is consistent with preventing BUI in Muskegon Lake. Identifying a TSI of 50 to 55 as the target suggests that managers view the lower eutrophic range as not impaired for beneficial uses. In my opinion, there is not sufficient information to support that view.

4. Summary and Conclusions

The Annis Water Resources Institute has developed a set of five indicators of eutrophication and harmful algal bloom BUI for Muskegon Lake, and identified possible targets for delisting of this AOC. Four of the five proposed indicators (total phosphorus, chlorophyll *a*, Secchi disk transparency, and Carlson's trophic state index) are appropriate for this program and consistent with having a relevant, comprehensive and economically feasible set of indicators related to eutrophication. The fifth proposed indicator, percent *Microcystis*, is not considered to be appropriate by this reviewer because regardless of the level of reduction in nutrient inputs, this lake is likely to have phytoplankton dominated by that cyanobacterial taxon during late summer to autumn. More suitable indicators, which are more closely linked to BUI, are the absolute concentration of *Microcystis* and the concentration of the cyanobacterial toxin microcystin in the lake water. Based on other studies, it is reasonable to expect that both will decline with nutrient load reduction. In regard to BUI targets, my general sense is that they are arbitrary and might serve only as interim standards until adequate information is available from research on Lake Muskegon and comparable Michigan lakes to set lake-specific targets that will be protective of flora and fauna, as well as the main societal uses of this water resource. At this time, the limited data regarding water quality in the lake does not allow this reviewer to draw any conclusions as to whether or not the lake should be removed from the AOC list.

5. Literature Cited

Carlson. R.E. 1977. A trophic state index for lakes. Limnology and Oceanography **22**:361-369.

Dokulil, M.T. and K. Teubner. 2000. Cyanobacterial dominance in lakes. Hydrobiologia **438**:1-12.

Downing, J.A., S.B. Watson and E. McCauley. 2001. Predicting cyanobacteria dominance in lakes. Canadian Journal of Fisheries and Aquatic Sciences **58**:1905-1908.

Havens, K.E., and W.W. Walker. 2002. Development of a total phosphorus concentration goal in the TMDL process for Lake Okeechobee, Florida (USA). Lake and Reservoir Management **18**:227-238.

Hecky, R.E. and P. Kilham. 1988. Nutrient limitation of phytoplankton in freshwater and marine environments: a review of recent evidence on the effects of enrichment. Limnology and Oceanography **33**:796-822.

Heiskary, S., and W.W. Walker, Jr. 1988. Developing phosphorus criteria for Minnesota lakes. Lake and Reservoir Management **4**:1-10.

MDEQ. 1999. TMDL for Ore Lake, Michigan. Michigan Department of Environmental Quality.

MDEQ. 2004. Criteria for restoration of beneficial use impairments – Michigan's Great Lakes Area of Concern. Michigan Department of Environmental Quality. Report dated November 3, 2004 and marked "draft for discussion."

Schindler, D.W. 1977. Evolution of phosphorus limitation in lakes. Science **195**:20-262.