Section 3: Vision, Ecosystem Management Objectives, and Indicators

3.1 Introduction

The Lake Erie LaMP has adopted a generalized ecosystem approach, as outlined in the 1987 amendments to the Great Lakes Water Quality Agreement (GLWQA). This approach recognizes that all components of the ecosystem are interdependent, including the water, biota, surrounding watershed and atmosphere. Humans are considered an integral part of the system. The GLWQA calls for the development of ecosystem objectives and indicators for all the Great Lakes. These would be used to facilitate effective management and co-ordination within and between agencies working in the Lake Erie watershed. There are three steps involved in setting a direction for the Lake Erie ecosystem: 1) a preferred ecosystem management alternative must be selected; 2) ecosystem vision and management objectives must be developed that describe in narrative form more details to set the stage for the actions needed to achieve the preferred alternative; and 3) indicators must be developed to measure progress in achieving the desired ecosystem alternative.

3.2 Selection of a Lake Erie Ecosystem Management Alternative

Ecosystem Alternative Development Process

For Lake Erie, the level of change in the ecosystem has been extensive, and in many cases appears irreversible (Burns 1985). We cannot return to the pre-settlement conditions of the 1700s, but we can work toward achieving a healthier, more diverse and less contaminated ecosystem.

The Lake Erie LaMP Ecosystem Objectives Subcommittee (EOSC) was charged with the task of developing ecosystem management objectives for Lake Erie. The EOSC is a binational group of about 15 individuals with expertise in limnology, water quality, and fisheries and wildlife management. Three members of the Lake Erie Binational Public Forum worked closely with the committee throughout the exercise. The first step in the process was to identify ecosystem management alternatives. The committee began the exercise by holding four public workshops around the basin to gain ideas on the desired

state of the Lake Erie ecosystem. This was followed by an expert workshop where published information and expert opinion were solicited concerning key relationships in the ecosystem.

A conceptual model of three ecosystem alternatives was developed for initial discussion. Several other attempts were made at developing a model that could be used for Lake Erie. As a result, a fuzzy cognitive map (FCM) approach was adopted to model ecosystem alternatives for Lake Erie. A FCM model is one way to analyze a complex system by representing the most important components of the system as nodes of a network. A change at one node will affect all connected nodes, and then all the nodes connected to those nodes, generating a ripple effect. Taking an FCM approach required more data and, therefore, a second expert workshop was held. The results of the second workshop led to the development of an FCM model for the lake dubbed the Lake Erie Systems Model. The model is being used as a tool to help understand how various components of the ecosystem interact, but it is not a panacea to predict future conditions.

Photo: Michelle Fletcher

Three major categories of actions and reactions are used to explain the output of the Lake Erie Systems Model: 1) management levers; 2) ecosystem health response; and 3) beneficial use to humans. Management levers are a variety of human actions that affect the ecosystem. Ecosystem health response describes the condition of individual biotic and habitat components and the reaction to the management levers. Beneficial uses refer to those uses defined in the GLWQA that are affected by the management levers. By randomly and simultaneously moving all management levers in different directions and monitoring responses of all non-lever variables, a large set of different potential outcomes in the ecosystem can be generated. These outcomes can then be grouped into a form that can be recognized and described using a statistical clustering procedure. Groups that are considered to be significantly different from each other constitute ecosystem alternatives. A detailed description of how the model was developed and how it processes data can be found in the ecosystem objectives subcommittee's report, Colavecchia et al. (2000).

The model generated various ecosystem alternatives. These alternatives do not include social, economic, or political values because they are not part of the natural ecosystem. Rather, these values were used to determine the ecosystem alternative that was chosen.

Model Results

Of the management levers examined in the model, those that affected the availability of natural, undisturbed land caused the largest response across the greatest number of variables. Therefore, the availability of natural lands was the key driver of the ecosystem clusters. Nutrient levels were the second most important influence but did not have the impact that natural land (habitat) had on the ecosystem. In other words, phosphorus can be strictly managed, but unless natural land or habitat is protected and restored, only marginal response will be seen by many components of the ecosystem. It was determined that changes in land use that represent a return towards more natural landforms or that mitigate the impacts of urban, industrial and agricultural land use, are the most significant actions that can be taken to restore the Lake Erie ecosystem.

The ecosystem alternatives derived from the model were described based on their gain in natural land compared to the status quo conditions of the 1990s. From the modeling exercise, seven distinct ecosystem management alternatives emerged. Three alternatives represented highly degraded environmental conditions relative to 1990 conditions and were discarded as not viable alternatives for a future state of Lake Erie. The remaining four alternatives (Table 3.1) represented existing or improved environmental conditions. Alternative 3 represents moderate loss of natural landforms relative to status quo (Alternative

Table 3.1: Summary of Ecosystem Alternatives for Lake Erie

Management Lever or *effect*	Action or *effect*	Ecosystem Alternatives			
		1	2	3	4
Agricultural Land Use	Mitigation of impact	very strong	strong	strong	status quo
Industrial Land Use	Mitigation of impact	very strong	moderate	moderate	status quo
Urban Land Use	Mitigation of impact	very strong	strong	moderate	status quo
Natural Landscapes	Restoration	small gain	small gain	moderate loss	status quo
Phosphorus Concentration	Reduced concentrations in tributaries, nearshore and lake	very strong	strong	strong	status quo
Phosphorus from Land (non-point source)	Reduction in loadings	very strong	very strong	very strong	status quo
Phosphorus from STPs	Reduction in loadings	very strong	moderate	strong	status quo
Total Suspended Solids	Reduction in concentration	very strong	very strong	very strong	status quo

4), while Alternatives 1 and 2 represent small improvements in the amount of natural landscapes in the basin. Alternatives 3, 2, and 1 represent increasingly more progressive mitigation of agricultural, industrial and urban land uses. The mitigation results in very strong reductions in nutrient export from land and total suspended solids concentrations. The alternatives differ in the level of reduction of phosphorus exports from sewage treatment plants (STPs) with Alternative 2 requiring moderate reduction, Alternative 3 a strong reduction and Alternative 1 a very strong reduction.

The selection of an ecosystem alternative toward which to manage Lake Erie is not a trivial issue. There are many competing and incompatible uses of Lake Erie, and multiple agencies (federal, state and local) have jurisdiction over one or more components of the ecosystem. Societal factors that influence the choice include economics, social justice, land use, and others. To be an effective tool, the LaMP, including the desired ecological state for Lake Erie, must have the support and commitment of the various environmental managers, decision makers and the public. Without a consensus on ecological conditions to be achieved, multiple management efforts could easily be competing, ineffective, and/or counterproductive. Ultimately, the process for choosing an ecosystem alternative for management purposes becomes one of identifying which one is most closely compatible with societal values of the residents in the basin.

The Lake Erie LaMP Work Group considered several options for soliciting opinions and comments on preferred ecosystem alternatives from the governing agencies, environmental groups, industry and the general public. Opinions were solicited through informal discussions, Lake Erie Binational Public Forum input, and agency reviews. In June 2000, the LaMP Work Group reached consensus that Ecosystem Alternative 2 would represent the preferred ecosystem of the Work Group. In September 2001, the LaMP Management Committee endorsed this conclusion. Additional discussions with stakeholders, including the public, concluded with the selection of Ecosystem Alternative 2.

Ecosystem Alternative 2 is consistent with the themes of sustainable development and of multiple benefits to society of a healthy Lake Erie ecosystem. The analysis supporting Ecosystem Alternative 2 highlights the importance and urgency of improving land use activities, continued diligence in nutrient management, and the vulnerability of fish and wildlife species to human activities.

3.3 Developing a Lake Erie Vision and Ecosystem Management Objectives

The second step involved in setting a direction for the Lake Erie ecosystem was the development of a vision and ecosystem management objectives using the selected ecosystem alternative. The vision is a written description of the selected ecosystem alternative. The ecosystem management objectives describe in narrative form more details to set the stage for the actions needed to achieve the Vision.

The Lake Erie LaMP has defined the term integrity, from Karr and Dudley (1981), as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of natural habitats of the region."

3.3.1 The Lake Erie Vision

Ecosystem Alternative 2 became the Lake Erie Vision. This vision is consistent with the themes of sustainability and of the multiple benefits to society of a healthy Lake Erie ecosystem. Maintaining healthy ecosystems and restoring degraded ecosystems will foster improved economic and human health through a variety of avenues (maintaining water quality, tourism, recreation, etc.). The Lake Erie Vision is presented below:

Our Vision is a Lake Erie basin ecosystem...

Where all people, recognizing the fundamental links among the health of the ecosystem, their individual actions, and their economic and physical well-being, work to minimize the human impact in the Lake Erie basin and beyond;

Where natural resources are protected from known, preventable threats;

Where native biodiversity and the health and function of natural communities are protected and restored to the greatest extent that is feasible;

Where natural resources are managed to ensure that the integrity of existing communities is maintained or improved;

Where human-modified landscapes provide functions that approximate natural ecosystem processes;

Where land and water are managed such that water flow regimes and the associated amount of materials transported mimic natural cycles; and

Where environmental health continually improves due to virtual elimination of toxic contaminants and remedial actions at formerly degraded and/or contaminated sites.

3.3.2 Developing Ecosystem Management Objectives and Rationale

Ecosystem management objectives are targets that, when all are achieved, should result in the attainment of the Vision for the Lake Erie ecosystem.

As outlined above, the Lake Erie Vision was selected after extensive review and input. However, the vision does not prescribe the necessary management goals to realize the desired ecosystem vision. Management goals are dependent on the ecosystem management objectives, formulated to be consistent with the vision, and are based on the present state of the ecosystem components. Input from the Lake Erie community on the preferred ecosystem alternative helped define the degree of implementation that will be necessary and acceptable to be consistent with the vision.

The Lake Erie ecosystem has three very distinct basins, and within the entire watershed of the lake there are 34 third-order sub-watersheds, many of which have unique features and pressures. The impact of non-native invasive species in the Lake Erie ecosystem contributes to instability, and new species continue to enter, thereby compounding the problem. Implementation of the management strategies moves the ecosystem in the right direction, and leads to improvements in biological integrity. The process is iterative. Tracking of recovery in relation to management interventions leads to projections of reasonable and feasible endpoints for biological integrity at appropriate units of the ecosystem (i.e. watersheds and areas of influence in the lake, bays, basins).

The overall proposed ecosystem management objectives are presented as principles for management actions to achieve the Lake Erie ecosystem vision. The ecosystem management objectives are presented in relation to the main management categories influencing the status of the lake: land use; nutrients; natural resource use and disturbance; chemical and biological contaminants; and non-native invasive species. In proposing these ecosystem management objectives, it is recognized that each watershed and basin may require varying degrees of implementation. The *status quo* or "current conditions" are generally reflective of conditions found in the mid-to-late 1990s.

3.3.3 Ecosystem Management Objectives and Rationale

Land Use

Strategic Objective:

Land-based activities enhance native biodiversity and ecosystem integrity.

Tactical Objective:

Land use activities result in gains in the quantity and quality of natural habitat in order to support the maximum amount of native biodiversity and community integrity that can be achieved and be sustained for the benefit of future generations.

Rationale:

Ecosystem alternative analysis identified land use practices as the dominant management category affecting the Lake Erie ecosystem. Poor land use management has resulted in increased water runoff containing sediments, nutrients, and chemicals to Lake Erie, and reduced areas of natural landscapes and habitats. Key elements within the land use management category are gains in quality natural lands and environmentally sound management practices for rural, urban and industrial landscapes.

Best management practices (BMPs) can mitigate many deleterious land uses and their impacts to the extent that natural habitat (ecosystem) quality and quantity can improve. It is expected that there will be increasing demands and pressures for land conversion in the Lake Erie basin. Proactive planning for these pressures needs to include the protection of critical habitat corridors that connect and link habitats between the lake, the wetlands and the upland habitat. Specific targets need to be established, which include securing, protecting and restoring natural lands. A watershed approach is critical to developing local solutions and to maximize gains with partners.

Nutrients

Strategic Objective:

Nutrient levels are consistent with ecosystem goals (watershed and basinwide).

Tactical Objective:

Nutrient inputs from both point and non-point sources are managed to ensure that ambient concentrations are within bounds of sustainable watershed management and consistent with the Lake Erie Vision.

Rationale:

Current nutrient inputs are resulting in reduced use of beaches, changes in aquatic community structure, and increased algal blooms. It is important that all sources that contribute to the watershed nutrient load and ultimately to the basin load, be managed to limit local and regional impacts. Best management practices and point source controls need to be implemented with consideration of the ecological requirements for the maintenance or recovery of healthy aquatic communities in the watershed, the hydrologic cycle and water usage. In addition to phosphorus, other nutrients and their various forms, such as nitrates, also need to be included in assessments of watershed and basinwide impacts.

Natural Resource Use and Disturbance

Strategic Objective:

Ecologically wise and sustainable use of natural resources

Tactical Objective:

Natural resource use (e.g. commercial and sport fishing, hunting, trapping, logging, water withdrawal) and disturbance by human presence or activity be managed to ensure that the integrity of existing healthy ecological communities be maintained and/or improved, and provide benefits to consumers.

Rationale:

Commercial and sport fishing, hunting, trapping, logging, water withdrawal and disturbance by human presence or activity may have negative impacts on target species, habitats and more broadly on other components of the ecosystem if not properly managed. Natural resource use (exploitation and disturbance) should be managed in such a manner as to encourage the recovery of degraded communities. The harvest of valued fish, timber resources, extraction of aggregate deposits, the removal of water, and the utilization of other features of the working landscape should be done in a manner that is sustainable and which affords the greatest opportunity to preserve and enhance the biological integrity of the Lake Erie ecosystem. Integrity is a general term for the recurring structure and composition of a community over time, due to internal regulation.

Sustainable management of natural resources can realize valued harvests for present and future generations and still maintain essential habitat function. Resource extraction is recognized as valued economic activity but should be done in a manner to prevent or mitigate to the greatest extent possible the negative environmental impacts.

Photo: U.S. EPA Great Lakes National Program Office

Chemical and Biological Contaminants

Strategic Objective:

Virtual elimination of toxic chemicals and biological contaminants.

Tactical Objective:

Toxic chemical and biological contaminant concentrations within the basin must be virtually eliminated.

Rationale:

Biological contaminants are defined here as pathogens, toxins released by cyanobacteria (such as microcystin from *Microcystis*) or bacteria. Toxic chemicals and biological contaminants degrade watersheds, not only impacting local fauna, but potentially having lakewide impacts. Locally contaminated areas may affect populations of fish and wildlife in the open waters of the lake if those locations are used for feeding, spawning or nursery habitat. The amount of toxic contaminants in the Lake Erie ecosystem is the result of the combined inputs from point and non-point sources within the basin, upstream loadings transported via the Detroit River, and long-range atmospheric transport from regional and global sources. Effective management of local point and non-point sources and adopting pollution prevention practices can improve, and have improved, watershed and basin ecosystem quality. However, broad based actions such as those promoted in the Great Lakes Binational Toxics Strategy, the Stockholm Convention on Persistent Organic Pollutants (POPs), and the United Nations Agenda 21 that address global atmospheric pollutant transport, are also required to fully reach this objective since these programs address regional and global atmospheric pollutant transport.

Non-native Invasive Species

Strategic Objective:

Prevent further invasions of non-native invasive species. Control existing invasive non-native species where possible.

Tactical Objective:

Non-native invasive species should be prevented from colonizing the Lake Erie ecosystem. Existing non-native invasive species should be controlled and reduced where feasible and consistent with other objectives.

Rationale:

Successful invaders may prey upon native species or compete with them for limited resources, altering the structure of the local and lakewide ecosystems. The presence of non-native invasive species is the result of intentional or unintentional introductions, or range expansion and colonization. The LaMP has identified invasive non-native species as one of the key problems impairing the Lake Erie ecosystem. The impact of non-native invasive species needs to be minimized where feasible by preventing access, and by controlling or managing them once they have entered the ecosystem.

3.4 Linking the Vision and Ecosystem Management Objectives to Beneficial Use Impairments

Restoring impaired beneficial uses to the Lake Erie watershed is a driving force behind the development of the Lake Erie LaMP. Therefore, as the LaMP developed its vision and ecosystem management objectives the relationship between these and the identified beneficial use impairments (BUIs) were defined (Colavecchia et al. 2000).

The underlying causes of the BUIs, as identified by the Beneficial Use Impairment Assessment process, are complicated. Their restoration will frequently be linked to more than one ecosystem management objective. Successful achievement of the Lake Erie LaMP vision and ecosystem management objectives will realize the restoration of beneficial use impairments. These relationships are summarized in Table 3.2.

Table 3.2: Linking Ecosystem Management Objectives to Lake Erie's Beneficial Use Impairments (Colavecchia *et al.* 2000)

Ecosystem Management Objective	Beneficial Use Impairment
Land Use	Degraded Fish and Wildlife Populations Restrictions on Fish and Wildlife Consumption Bird or Animal Deformities or Reproductive Problems Restrictions on Dredging Degradation of Benthos Eutrophication or Undesirable Algae Beach Closings Loss of Fish and Wildlife Habitat
Nutrients	Degraded Fish and Wildlife Populations Degradation of Benthos Eutrophication or Undesirable Algae Degradation of Aesthetics Degradation of Phytoplankton and Zooplankton Populations
Chemical and Biological Contaminants	Restrictions on Fish and Wildlife Consumption Bird or Animal Deformities or Reproductive Problems Fish Tumors and Other Deformities Degraded Fish and Wildlife Populations Restrictions on Dredging Activities (quality) Beach Closings Degradation of Benthos
Natural Resource Use and Disturbance	Degraded Fish and Wildlife Populations Loss of Fish and Wildlife Habitat
Non-native Invasive Species	Degraded Fish and Wildlife Populations Degradation of Benthos Degradation of Aesthetics Loss of Fish and Wildlife Habitat Eutrophication or Undesirable Algae Degradation of Phytoplankton and Zooplankton Populations

3.5 Developing Lake Erie Indicators

Ecosystem indicators and corresponding monitoring programs allow us to evaluate progress in achieving the ecosystem management objectives and the Lake Erie LaMP vision. There are many challenges associated with establishing a suite of indicators for Lake Erie because of its many unique characteristics (e.g., three distinct basins, high biodiversity, heavily populated and developed land base, vulnerability to non-native species invasions).

An Indicators Task Group was appointed by the Lake Erie LaMP Work Group and tasked with developing a suite of indicators that will allow progress toward achieving the ecosystem management objectives to be tracked. The approach being taken is to: (a) compile a list of potential indicators representative of a variety of ecosystem components; (b) complete a review of the proposed indicators; (c) get scientific consensus for the use of these indicators, and (d) present a recommended suite of indicators to the Lake Erie LaMP.

3.5.1 Purpose and Criteria for Selection

Ecosystem indicators have been identified by SOLEC (Bertram and Stadler-Salt, 1998) as measurable features that provide managerially and scientifically useful evidence of environmental and ecosystem quality, or reliable evidence of trends in quality. For Lake Erie, this definition of indicators must be broadened in order to link them to the Lake Erie Ecosystem Management Objectives. Therefore, the Lake Erie LaMP definition of an indicator is:

A measurable feature that identifies the current state of the ecosystem relative to the desired state of the ecosystem, as described by the Lake Erie Vision and Ecosystem Management Objectives.

The purpose of the Lake Erie LaMP indicator suite is to: (1) assess overall ecosystem management integrity; (2) evaluate components contributing to change at component level and basin level; (3) evaluate important components for reporting and long-term trends; and (4) provide predictive capacity (i.e., allow us to anticipate problems and adopt a proactive approach).

Numerous indicators have already been developed or are being developed to address different purposes in the Great Lakes basin and beyond. In order to ensure that the selected indicators meet the purposes of the Lake Erie LaMP, a set of selection criteria was developed. Each potential indicator will be evaluated using the selection criteria.

3.5.2 Developing Recommended Indicators

The Indicators Task Group began accumulating potential indicators using a questionnaire that was distributed to the scientific and management community in June 2004. The questionnaire requested information on indicators that were currently in use or in development, with the intent that, wherever possible, the LaMP indicator suite would build upon work that has already been done.

An indicator matrix was developed as a means of organizing and understanding the application of the proposed indicators (Table 3.3). The matrix structure is based on the five habitat zones developed by the Lake Erie Millennium Network: terrestrial, streams, coastal wetlands, nearshore, and offshore. For each indicator category, indicators will

Table 3.3: The Lake Erie Indicators Matrix

Indicator Category	Habitat Zone				
	Terrestrial	Streams	Coastal Wetlands	Nearshore	Offshore
PRESSURE INDICATORS					
Management Objectives:					
Natural Lands					
Nutrients					
Chemical Contamination					
Biological Contamination					
Non-Native Invasive Species					
Resource Use and Disturbance					
Processes:					
Flow Disruption					
Energy Disruption					
Economic Disruption					
STATE INDICATORS					
Plant Cover					
Food Web Base					
Lower Food Web (benthic invertebrates)					
Lower Food Web (plankton)					
Middle Food Web (fish)					
Upper Food Web (fish)					
Upper Food Web (amphibians/reptiles/ birds)					

be developed within each habitat zone. The matrix is divided into two general indicator categories utilized by SOLEC: pressure and state (Bertram and Stadler-Salt, 1998). The Pressure Indicator category is further sub-divided into Management Objectives indicators (used to measure progress toward the Lake Erie ecosystem management objectives) and Processes indicators (used to measure impacts to important ecosystem and economic processes). The State Indicators will be used to measure the current state of the various components of the Lake Erie ecosystem.

The six management objectives indicator categories – natural lands, nutrients, chemical contamination, biological contamination, resource use and disturbance and non-native invasive species – correspond directly to the LaMP ecosystem management objectives and will be used to report on the LaMP's progress in achieving the Lake Erie Vision.

The processes and state indicators provide a further level of detail that will allow the LaMP to go beyond reporting progress on achieving the vision, and will allow an evaluation of ecosystem components that are contributing to change, an evaluation of important components for reporting and long-term trends, and will provide predictive capacity.

3.5.3 Review of the Candidate Indicators

Each of the cells within the Lake Erie indicators matrix has been populated with candidate indicators that had been proposed by respondents of the questionnaire or during discussions of the Indicators Task Group. This "comprehensive matrix" includes all possible indicators, whether they are already in use elsewhere, currently in development or still need to be developed.

The next step is to refine the list of candidate indicators based on their feasibility specifically for use by the Lake Erie LaMP.

3.6 References

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Photo: Grand River Conservation Authority