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**TOWARDS DEFINING  
AQUATIC ECOYSTEM HEALTH  
FOR THE GREAT LAKES**

**J.H. Hartig and M.A. Zarull**

**NWRI Contribution No. 92-60**

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## MANAGEMENT PERSPECTIVE

Since 1973, the International Joint Commission's (IJC) Great Lakes Water Quality Board (WQB) has regularly reported on the state of Great Lakes water quality. These reports included specific harbours, embayments, river mouths, and connecting channels where one or more jurisdictional standards or the general or specific objectives of the Great Lakes Water Quality Agreement were not met. Initially, these areas were designated as "Problem Areas". In 1981, these areas were renamed "Areas of Concern" and their definition was expanded to include those areas where Great Lakes Water Quality Agreement (GLWQA) objectives or jurisdictional standards, criteria, or guidelines, which were established to protect uses, were exceeded and remedial measures were necessary to restore beneficial uses. This change incorporated the concept of use impairment and placed emphasis on restoring impaired beneficial uses.

Early attempts to develop remedial action plans to restore beneficial uses in Areas of Concern showed that criteria by which these areas were designated were not consistent among jurisdictions. Differences in jurisdictional standards, as well as subjective interpretations of what constituted beneficial uses and impairment of beneficial uses contributed to these inconsistencies. Further, designation of many of these areas often relied on old or limited data. This inconsistent and subjective process of listing Areas of Concern has resulted in problems in determining how to remove them from the list (i.e., delisting).

In an attempt to develop a consistent set of criteria, the WQB sought scientific advice through a symposium of experts, sponsored by the International Association of Great Lakes Research. The WQB then had these draft criteria reviewed by the jurisdictions to check their consistency with legislation and policy. Finally, the Board entertained public review and comment of its proposed criteria. A final set of consensus criteria to both list and delist Areas of Concern in the boundary waters of the Great

Lakes was then developed. This report describes those criteria and their relationship with the use impairments described in Annex 2 of the GLWQA.

These criteria are presently under review by the governments of Canada and the United States. Their adoption implies binational consistency in designating and delisting Areas of Concern. Further, once adopted, these criteria will provide a consistent policy for managing water quality by the two countries in their nearshore areas of the Great Lakes.

## SOMMAIRE À L'INTENTION DE LA DIRECTION

Depuis 1973, la Commission mixte internationale (CMI) du Conseil de la qualité de l'eau des Grands Lacs (CQEGL) présente régulièrement des rapports portant sur l'état de la qualité de l'eau des Grands Lacs. Ces rapports portent sur des lieux spécifiques comme des ports, des baies et accidents du littoral, des embouchures de rivières et des voies interlacustres où les normes réglementaires d'un ou plusieurs gouvernements s'appliquent, là où les objectifs généraux ou particuliers de l'Accord sur la qualité de l'eau des Grands Lacs ne sont pas atteints. Au début, ces lieux étaient appelés "secteurs présentant des problèmes". En 1981, on leur a donné un nouveau nom, "secteurs préoccupants", et leur définition a été élargie de façon à inclure les zones où étaient dépassées les valeurs prescrites par les objectifs de l'Accord sur la qualité de l'eau des Grands Lacs (AQEGL) ou celles prévues par les normes, critères ou lignes directrices des divers gouvernements, qui ont été établies pour protéger des utilisations, et là où des mesures correctrices étaient nécessaires pour rétablir les utilisations bénéfiques. Ce changement était basé sur le concept de la diminution des utilisations et mettait l'accent sur la restauration des utilisations bénéfiques altérées.

Les premières tentatives visant à élaborer des plans d'actions correctrices visant à restaurer les utilisations bénéfiques dans les secteurs préoccupants ont montré que les critères selon lesquels ces secteurs étaient désignés n'étaient pas cohérents d'un gouvernement à l'autre. Ces incohérences étaient dues en partie à des différences dans les normes des divers paliers du gouvernement, ainsi que dans les interprétations subjectives de ce qu'étaient les utilisations bénéfiques et leur diminution. En outre, la désignation d'un grand nombre de ces secteurs était souvent basée sur des données anciennes ou limitées. Ce processus incohérent et subjectif utilisé par la préparation des listes des secteurs préoccupants a entraîné un certain nombre de problèmes pour ce qui est de déterminer comment des secteurs peuvent être radiés de la liste.

Dans une tentative visant à élaborer un ensemble cohérent de critères, la DJQE a cherché à obtenir l'avis de la communauté scientifique par l'entremise d'un symposium d'experts, parrainé par Association internationale de la recherche sur les Grands Lacs.

d'experts, parrainé par Association internationale de la recherche sur les Grands Lacs. Le CQEGL a ensuite soumis pour étude ces critères provisoires aux différents gouvernements pour que soit vérifiée leur cohérence avec les lois et les politiques. Enfin, le Conseil a vu à ce que ces critères proposés fassent l'objet d'un examen public, et a recueilli les commentaires. Ceci a permis l'élaboration d'un ensemble final de critères faisant l'objet d'un consensus, tant pour les secteurs préoccupants faisant partie de la liste que pour ceux qui doivent en être radiés, dans les eaux frontalières des Grands Lacs. Ce rapport décrit ces critères et leur lien avec les diminutions des utilisations décrites dans l'Annexe 2 de la LQEGL.

Ces critères sont présentement examinés par les gouvernements du Canada et des États-Unis. Leur adoption suppose un processus cohérent pour ces deux pays concernant la désignation et la radiation de la liste des secteurs préoccupants. En outre, une fois qu'ils auront été adoptés, ces critères constitueront une base de politique cohérente pour la gestion de la qualité de l'eau par ces deux pays dans les secteurs littoraux des Grands Lacs.

## **ABSTRACT**

The Canada-U.S. Great Lakes Water Quality Agreement defines Areas of concern as geographic areas that fail to meet the general or specific objectives of the Great Lakes Water Quality Agreement where such failure has caused or is likely to cause impairment of beneficial use or the area's ability to support aquatic life. Impairment of beneficial use is defined by the Agreement as a change in the physical, chemical or biological integrity sufficient to cause any one of 14 designated use impairments. In 1987 the International Joint Commission's Water Quality Board (WQB) recommended that criteria be developed to determine when ecosystem conditions have been impacted enough to warrant designation as an Area of Concern and when conditions have improved sufficiently to be delisted. Based on scientific input and policy considerations, the WQB has adopted, in principle, a set of quantitative and qualitative listing/delisting criteria for each of the 14 use impairments. These criteria can be uniformly applied throughout the basin. Further, the WQB recommended future refinement of these criteria based on advances in science and public input.

## RÉSUMÉ

L'Accord sur la qualité de l'eau des Grands Lacs Canada-É.-U. définit les secteurs préoccupants comme des aires géographiques non conformes aux objectifs généraux ou particuliers de l'Accord sur la qualité de l'eau des Grands Lacs, quand cette non conformité est à l'origine ou peut vraisemblablement être à l'origine de la diminution d'une utilisation bénéfique ou de l'aptitude du secteur à favoriser la vie aquatique. La diminution de l'utilisation bénéfique est définie dans l'Accord comme étant un changement dans l'intégrité physique, chimique ou biologique suffisant pour être à l'origine de l'une ou l'autre des quatorze diminutions d'utilisations désignées. En 1987, la Commission mixte internationale du CQEGL a recommandé l'élaboration de critères visant à déterminer quand les conditions dans un écosystème ont été suffisamment altérées pour justifier sa désignation comme secteur préoccupant et quand les conditions se sont suffisamment améliorées pour sa radiation de la liste. Sur la base des données scientifiques et de considérations de politique, le CQEGL a adopté en principe un ensemble de critères quantitatifs et qualitatifs d'inclusion à la liste ou d'exclusion de celle-ci pour chacune des quatorze diminutions d'utilisations. Ces critères peuvent être appliqués uniformément dans tout le bassin. En outre, le CQEGL recommande, pour les années à venir, le raffinement de ces critères sur la base des progrès scientifiques et des opinions exprimées par le public.



## 1 INTRODUCTION

The concept of aquatic ecosystem health attempts to reflect the wholeness or well-being of ecosystems. Any attempts to define or assess aquatic ecosystem health will undoubtedly require factoring in more than science, including socio-economic considerations, public perceptions, and human values (Hartig et al. 1990a). Identifying the criteria or measures for defining aquatic ecosystem health will also depend on the purpose of the endeavor.

For many years the International Joint Commission (IJC) has been involved in assessing and tracking aquatic ecosystem health in the Great Lakes. The IJC was established by the 1909 Boundary Waters Treaty between Canada and the United States to cooperatively resolve disputes between the two countries, including water and air pollution, lake levels, power generation, and other issues of mutual concern. As concern for pollution increased, the IJC was given the responsibility to assist in the implementation of a Great Lakes Water Quality Agreement. This Agreement was established to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem (Canada and the United States, 1972).

In the most recent revision of the Great Lakes Water Quality Agreement (Canada and the United States, 1987), two new responsibilities were given to the IJC: 1) to recommend new or previously unrecognized polluted areas (i.e. Areas of Concern) for designation by the Governments of Canada and the United States; and 2) to review and comment on the adequacy of remedial action plans (RAPs) being developed to restore impaired beneficial uses in existing Areas of Concern at three stages (i.e. Stage 1: problem definition, Stage 2: selection of remedial actions, and Stage 3: confirmation of beneficial use restoration). Therefore, in order to fulfill the IJC's responsibilities of recommending new Areas of Concern and reviewing Stage 3 RAPs and commenting on whether or not impaired beneficial uses had been

restored, the IJC's Great Lakes Water Quality Board (the principal advisor to the Commission on matters related to the Agreement) identified the need for developing a precise set of scientifically defensible criteria and a protocol for their application to list and delist Areas of Concern (IJC 1987a). In response to this need, a special symposium on "Areas of Concern: How clean is clean?" was held as part of the 1988 International Association for Great Lakes Research Conference. This symposium recommended adopting a framework for listing/delisting Areas of Concern based on quantitative and qualitative criteria proposed to more precisely define the 14 beneficial use impairments identified in Annex 2 of the Great Lakes Water Quality Agreement (Hartig et al. 1990a). Based on this recommendation, additional scientific input, and policy considerations, the Great Lakes Water Quality Board of the IJC reached agreement on a set of listing/delisting criteria for Areas of Concern in 1988. The purpose of this paper is to present these listing/delisting criteria for Great Lakes' Areas of Concern as one attempt to define aquatic ecosystem health, and provide two examples of their application.

## **HISTORICAL PERSPECTIVE ON AREAS OF CONCERN**

Since 1973, the IJC's Great Lakes Water Quality Board has regularly reported on the state of Great Lakes water quality including specific harbors, embayments, river mouths, and connecting channels where one or more jurisdictional standards or the general or specific objectives of the Great Lakes Water Quality Agreement were not being met (IJC 1985). Initially these were designated as "problem areas". The present terminology of Areas of Concern was adopted in 1981.

In 1981, the IJC's Great Lakes Water Quality Board expanded the definition of Areas of Concern to include those areas where Great Lakes Water Quality Agreement objectives or jurisdictional standards, criteria, or guidelines, which were established to protect uses, were exceeded and remedial measures were

necessary to restore beneficial uses (IJC 1985). This change incorporated the concept of use impairment and placed emphasis on restoring impaired beneficial uses.

The number of Areas of Concern has changed with time for a variety of reasons including: the emergence of new problems or, based on more comprehensive data, the reinterpretation of the significance of previously reported problems. Over the past 15 years, the major problems identified have changed in relation to the evolution of scientific knowledge of water quality problems (i.e. from bacterial pollution to eutrophication to toxic substances contamination) and progress in implementing pollution controls.

Despite considerable progress in abating bacterial pollution and cultural eutrophication problems, 42 geographic Areas of Concern (Figure 1) were recognized by the Great Lakes Water Quality Board in 1989. Historically, the criteria by which these Areas of Concern were designated were not consistent among the jurisdictions because of differences in jurisdictional standards and subjective interpretations of what constituted beneficial uses and impairment of beneficial uses. Further, designation of many of these areas often relied on old or limited data. This inconsistent and subjective process of listing Areas of Concern has resulted in problems in determining how to remove them from the list (delisting). These problems have become further exacerbated with the formalization of the remedial action plan (RAP) process in the 1987 Protocol amending the 1978 Great Lakes Water Quality Agreement (Canada and the United States 1987). Each RAP must identify the problems, the actions to be taken to remedy them, the agencies or organizations responsible for implementing the actions, and when they will be implemented. Thus, the development of RAPs has introduced an element of accountability.

Annex 2 of the 1987 Protocol amending the 1978 Great Lakes Water Quality Agreement also defines Areas of Concern as geographic areas that fail to meet the general or specific objectives of the Agreement where such failure has caused or is likely to cause impairment of beneficial use or of the area's ability to support aquatic life. Impairment of beneficial use is defined as a change in the chemical, physical, or biological integrity of the Great Lakes sufficient to cause any of the following: restrictions on fish and wildlife consumption; tainting of fish and wildlife flavor; degradation of fish and wildlife populations; fish tumors or other deformities; bird or animal deformities or reproductive problems; degradation of benthos; restrictions on dredging activities; eutrophication or undesirable algae; restrictions on drinking water consumption, or taste or odor problems; beach closings; degradation of aesthetics; added costs to agriculture or industry; degradation of phytoplankton and zooplankton populations; or loss of fish and wildlife habitat (Canada and the United States 1987).

#### **WHERE IS AN AREA OF CONCERN?**

The Great Lakes Water Quality Board wanted to make sure that its RAP program was realistic and effective in resolving the major, localized problems in the Great Lakes. Therefore, it agreed that the geographic areas eligible for consideration under the Great Lakes Water Quality Agreement are the Boundary Waters of the Great Lakes system which are defined as the waters from main shore to main shore of the Great Lakes and connecting channels along which the international boundary between the United States and Canada passes. This includes Lake Michigan, as well as all bays, arms, and inlets, but excludes tributary waters. It was further agreed that the mouths of tributaries and inland coastal lakes at the same water level as Boundary Waters would also be geographic areas eligible for consideration. The rationale for including inland coastal lakes at the same water

level as Boundary Waters was that it could be argued that they are considered bays, arms, or inlets.

## **LISTING/DELISTING CRITERIA**

The intent of the listing/delisting criteria for Great Lakes Areas of Concern presented in Table 1 is to establish a consistent set of criteria that can be uniformly applied throughout the Great Lakes basin. These criteria should assist the IJC in making recommendations on listing and delisting Great Lakes Areas of Concern. For example, if a geographic area of the Boundary Waters, a mouth of a tributary, or an inland coastal lake at the same water level as Boundary Waters has a health advisory on fish that is unique or different from the whole lake, it would qualify for Area of Concern designation. An exception to this would be that if a health advisory on fish (in a geographic area of the Boundary Waters, a mouth of a tributary, or an inland coastal lake at the same water level) is no different from the health advisory on the whole lake (e.g. lipid-weight, contaminant concentrations in fish from the localized area are not higher than mean, lakewide, lipid-weight, contaminant concentrations) and this area is not contributing to a whole lake problem, then it would not qualify for Area of Concern designation. Such whole lake problems will be addressed by Canada and the United States within lakewide management plans which are also identified in Annex 2 of the Agreement (Canada and the United States 1987).

Once a new Area of Concern has been identified and listed, a RAP would be developed following the guidelines of the Great Lakes Water Quality Board and the 1987 Protocol amending the Great Lakes Water Quality Agreement. More information on the RAP program can be found in Hartig and Thomas (1988), Hartig and Vallentyne (1989), and Hartig et al. (1990b).

The Water Quality Board felt that it was critically important to obtain agreement on problem definition to avoid postponement or forestalling of remediation (Hartig et al. 1990a). Therefore, when a geographic area is being considered for listing as an Area of Concern, the Parties and jurisdictions must reach agreement, in writing, on the definition of the problem (i.e. use impairments) based on the criteria in Table 1. The use impairments identified would be those addressed in a RAP. Should additional impaired uses be discovered during the development of the RAP, the Parties and jurisdictions will revise, in writing, the definition of the problem.

These listing/delisting criteria for Great Lakes Areas of Concern are intended to provide a "set of rules" that are consistent with the Great Lakes Water Quality Agreement and can be uniformly applied throughout the Great Lakes basin. Further, these criteria are intended to help make sure that the RAP program is properly focused and pragmatic and that it gets maximum benefit out of limited resources.

## EXAMPLES OF CRITERIA APPLICATION

The first example is application of the listing criteria. For several years there has been considerable public concern for potential use impairments in Presque Isle Bay in Erie, Pennsylvania. Presque Isle Bay is located on the southern shore of Lake Erie 125 km southwest of Buffalo, New York. Public concern focused on reports of skin and lip tumors on brown bullheads (Ictalurus nebulosus) and elevated levels of toxic substances in fish and sediments (Howison 1989). Despite public concern, no action was taken by the Commonwealth of Pennsylvania or the Government of the United States to designate Presque Isle Bay as an Area of Concern, or to satisfactorily alleviate the public's concerns.

At this point the Presque Isle Bay issue was referred to the IJC and its Great Lakes Water Quality Board. The Water Quality Board compiled the available data and information on use impairments and concluded that there were restrictions on dredging activities due to polynuclear aromatic hydrocarbon and heavy metal contamination and that there was violation of Pennsylvania's water quality standard for protection of total body contact recreation (swimming). The Great Lakes Water Quality Board felt that there were insufficient data to confirm tumors in fish or exceedence of toxic substance guidelines for protection of human consumption of fish. Therefore, based on restrictions on dredging activities and exceedence of fecal coliform bacteria standards the Great Lakes Water Quality Board recommended to the IJC that Presque Isle Bay be designated an Area of Concern (IJC 1989). Subsequently, the IJC recommended to the Government of the United States and the Commonwealth of Pennsylvania that Presque Isle Bay be designated an Area of Concern (IJC 1990). Pennsylvania has responded by initiating an investigation to collect sufficient data relative to each of the 14 use impairments identified in Table 1. Following compilation and interpretation of those data, Pennsylvania will make a determination on Area of Concern designation for Presque Isle Bay.

Another example is application of the delisting criteria to the Deer Lake-Carp River/Creek Area of Concern located in Michigan's Upper Peninsula. Deer Lake is a 367 ha hypereutrophic impoundment located 32 km upstream of the mouth of the Carp River where it enters Lake Superior. Carp Creek, an inflow to Deer Lake, historically received mercury discharges from a metalurgical industry. Mercury has been found at high concentrations in fish (5 mg/kg), sediments (2-16 mg/kg), and fish-eating birds (50 mg/kg) (IJC 1989). Further, a fish consumption advisory has been in effect for all fish in Deer Lake and all resident fish in the Carp River downstream to Lake Superior.

Regarding this Area of Concern, Michigan informed the Great Lakes Water Quality Board that a consent decree had been implemented to control the

industrial discharge of mercury to the system, stabilize the lake level, remove mercury-contaminated fish, and restock the system with new fish. Therefore, Michigan petitioned the Great Lakes Water Quality Board to remove Deer Lake-Carp River/Creek from the Areas of Concern list. The Great Lakes Water Quality Board, in turn, reviewed the Deer Lake-Carp River/Creek RAP and the supplemental data and information provided, and concluded that a health advisory on fish is still in effect at the mouth of Carp River as it enters Lake Superior. In addition, nesting bald eagles on the shore of Deer Lake have not produced viable young for over 10 years, undoubtedly due to mercury contamination (Michigan Department of Natural Resources 1987). Therefore, impaired beneficial uses had not been fully restored (consistent with the delisting criteria) in Deer Lake-Carp River/Creek and the Great Lakes Water Quality Board recommended that it not be removed from the Areas of Concern list. Monitoring to track the system response is continuing.

## CONCLUDING REMARKS

The IJC's Great Lakes Water Quality Board adopted, in principle, these listing/delisting criteria to establish a set of rules which were consistent with the Great Lakes Water Quality Agreement and could be uniformly applied throughout the basin. These criteria are intended to assist the Great Lakes Water Quality Board in making recommendations on new Areas of Concern and in reviewing Stage 3 RAPs, which confirm restoration of impaired beneficial uses.

These criteria have been developed following the requirements of Annex 2 in the Protocol amending the 1978 Great Lakes Water Quality Agreement. They are also a consequence of the state of the Great Lakes ecosystem. These criteria provide a framework for assessing the health of aquatic ecosystems (which are extensively used and depended upon by humans) which is applicable elsewhere



in the world. Since these criteria are dependent upon the ecosystem to which they are being applied and human interaction with it, they will likely require modification for application elsewhere. Other countries have utilized one or more of these indicators to assess the state of aquatic ecosystem health or use impairments to manage water bodies; however, nowhere else, to our knowledge, has this extensive or diverse an array of measures been employed.

The significance or "power" of these criteria is that the institutional structure of the Great Lakes Water Quality Board (representing the United States and Canadian Governments and the eight states and two provinces) reached agreement on these decision-making criteria. The Great Lakes Water Quality Board also recognized that these criteria could be improved and immediately upon adoption of the criteria, published them in the IJC's newsletter (Focus) in an effort to obtain widespread scientific and public comment. Based on this input, the listing/delisting criteria will be revised under the auspices of the IJC. The IJC recognizes that there is need for periodic refinement of these listing/delisting criteria in order that they remain scientifically defensible, sensitive to public concerns, and pragmatic. Such decision-making criteria are essential in documenting progress toward and achievement of the Great Lakes Water Quality Agreement's goal to restore and maintain the chemical, physical, and biological integrity of the Great Lakes Basin Ecosystem.



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FIGURE 1. FORTY-TWO AREAS OF CONCERN IDENTIFIED IN THE GREAT LAKES BASIN

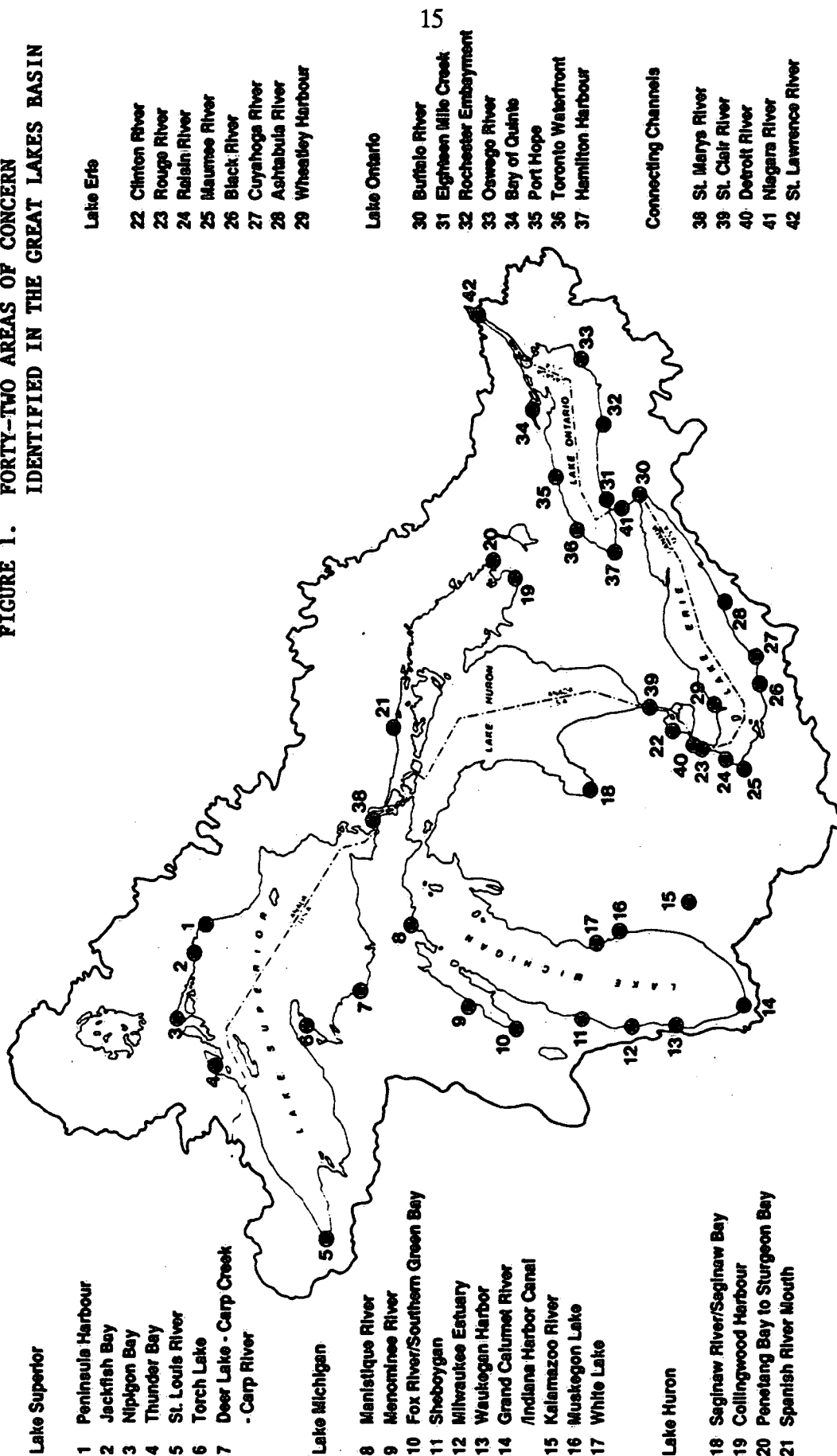






TABLE 1  
LISTING/DELISTING CRITERIA FOR GREAT LAKES AREAS OF CONCERN

USE IMPAIRMENT	LISTING CRITERIA	DELISTING CRITERIA	REFERENCE
RESTRICTIONS ON FISH AND WILDLIFE CONSUMPTION	When contaminant levels in fish or wildlife populations exceed current standards, objectives or guidelines and 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 (i.e. lipid-weight, contaminant concentrations in fish and wildlife will exceed lakewide or regional levels).	When contaminant levels in fish and wildlife populations do not exceed current standards, objectives or guidelines and no public health advisories are in effect for human consumption of fish or wildlife.	Adapted from Mack 1988
TAINTING OF FISH AND WILDLIFE FLAVOR	When effluent limits necessary to achieve ambient water quality standards for the anthropogenic substance(s) causing tainting are being exceeded and survey results have identified tainting of fish or wildlife flavor.	When effluent limits necessary to achieve ambient water quality standards for the anthropogenic substance(s) causing tainting are being met and a survey has confirmed no tainting of fish or wildlife flavor.	See American Public Health Association 1980 for survey results
DEGRADED FISH AND WILDLIFE POPULATIONS	When fish and wildlife personnel have identified degraded fish or wildlife populations due to a cause within the watershed as part of fish and wildlife management programs.	When environmental conditions support healthy, self-sustaining communities of desired fish and wildlife at predetermined levels of abundance that would be expected from the amount and quality of suitable physical, chemical and biological habitat present. For example, the Green Bay RAP has identified quantifiable objectives for desired population densities (e.g. seven adult walleye/acre, 500 nesting pairs of Forster's terns, etc.) to allow a determination to be made. An effort must be made to ensure that such ecosystem objectives for Areas of Concern are consistent with ecosystem objectives being established for the Great Lakes (e.g. lake trout productivity in Lake Superior >0.38 kg/hectare/yr) and consistent with fish community goals being established under the auspices of the Great Lakes Fishery Commission.	Adapted from Manny and Pacific, 1988; Wisconsin DNR 1987; Canada and the United States, 1987
FISH TUMORS OR OTHER DEFORMITIES	One would expect a zero liver tumor incidence rate in fishes from clean locations. However, due to uncertainty in fish movement, other possible causes and experience with field data, a site will be listed as an Area of Concern when the incidence of neoplastic or pre-neoplastic liver tumors exceeds 2% in bullheads or 3.5% in suckers. A similar approach should be developed for other deformities.	When the incidence rate of neoplastic and pre-neoplastic liver tumors in bottom-feeding fishes does not exceed 2% in bullheads and 3.5% in suckers. A similar approach should be developed for other deformities.	Mac and Smith, 1988
BIRD OR ANIMAL DEFORMITIES OR REPRODUCTIVE PROBLEMS	Use of incidence rates of cross-bill syndrome and reproductive failure in populations of colonial birds has not received as much attention as chemical objectives. The incidence rates of cross-bill syndrome and congenital malformations in sentinel wildlife species can be statistically compared between unimpacted control populations and impacted control populations in Areas of Concern e.g. (Green Bay and Saginaw Bay). A site will be listed as an Area of Concern when incidence rates of cross-bill syndrome, reproductive failure, etc. are significantly (95% probability level) higher than incidence rates at control sites. Further a site will be listed when bald eagle reproduction is less than one eaglet per active nest.	When there is no significant difference between incidence rates of cross-bill syndrome, reproductive failure, etc. in colonial birds from the Area of Concern and those in control populations. Further, bald eagle reproduction will be at least one eaglet per active nest.	Adapted from Kubiak 1988; Miller 1988; Wiemeyer et al. 1984
DEGRADATION OF BENTHOS	When the benthic macroinvertebrate community structure significantly diverges from unimpacted control sites of comparable physical and chemical characteristics. Benthic invertebrate community structure and composition are good integrators of ecosystem status. Three examples of utility include: 1) developing an endpoint using species diversity; 2) quantifying divergence from an expected community, given quantifiable physical and chemical habitat descriptors; and 3) developing an ecosystem objective using benthic community structure. Further, benthic invertebrates are effective for bioassessment of sediment-associated contaminants. It is recommended that both field and laboratory bioassay data and historical information be used to define endpoints for toxicity and bioavailability of sediment-associated contaminants. A site will be listed when toxicity or bioavailability of sediment-associated contaminants is significantly (95% probability level) higher than controls.	When the benthic macroinvertebrate community structure does not significantly diverge from unimpacted control sites of comparable physical and chemical characteristics. Further, a site will be delisted when toxicity and bioavailability of sediment-associated contaminants in the Area of Concern are not significantly (95% probability level) higher than controls.	Adapted from Reynoldson 1988; Henry 1988; IJC 1988

Table 1 - continued

## LISTING/DELISTING CRITERIA FOR GREAT LAKES AREAS OF CONCERN

USE IMPAIRMENT	LISTING CRITERIA	DELISTING CRITERIA	REFERENCE
RESTRICTIONS ON DREDGING ACTIVITIES	When contaminants in sediment exceed standards, guidelines or objectives, and there are restrictions on the disposal of dredged materials. For example, the Ontario Ministry of the Environment has set guidelines which address the disposal of sediments in open water. If the contaminant concentrations exceed the guidelines, the material is considered unsuitable for open-water disposal. The Great Lakes states have individual policies based on a case-by-case consideration of contaminant levels and deep-water placements. U.S. EPA's criteria for sediment classification are used to help make a determination.	When contaminants in sediment do not exceed standards, guidelines or objectives, and there are no restrictions on the disposal of dredged materials.	Adapted from IJC 1988
EUTROPHICATION OR UNDESIRABLE ALGAE	When there are persistent water quality problems (e.g. dissolved oxygen depletion of bottom waters, nuisance algal accumulation on bathing beaches, nuisance algal blooms, decreased water clarity, etc.) attributed to accelerated or cultural eutrophication or the area is contributing to the lack of achievement of the Great Lakes phosphorus target loads identified in Annex 3 of the GLMCA.	When there are no persistent water quality problems (e.g. dissolved oxygen depletion of bottom waters, nuisance algal accumulation on bathing beaches, nuisance algal blooms, decreased water clarity, etc.) attributed to accelerated or cultural eutrophication and the Area of Concern is not contributing to the lack of achievement of the Great Lakes phosphorus target loads identified in Annex 3 of the GLMCA.	Adapted from Canada and the United States, 1987
RESTRICTIONS ON DRINKING WATER CONSUMPTION OR TASTE AND ODOUR PROBLEMS	The primary concern is public health and potable water supply. Thus, any waters (intended for human consumption) that contained disease-causing organisms or hazardous concentrations of toxic chemicals or radioactive substances in excess of standards, objectives or guidelines will be listed as an Area of Concern. Numerical water quality objectives and standards have been established to protect human health (e.g. ten of the 44 GLMCA objectives have human health considerations; if required objectives are not available, priority must be given to establishment of drinking water objectives). Further, a site will be listed as an Area of Concern when taste and odour problems are present (e.g. taste and odour problems due to blue-green algae or phenolic compounds).	Any waters intended for human consumption should be free of disease-causing organisms or hazardous concentrations of toxic chemicals or radioactive substances. Numerical water quality objectives, standards and guidelines will be met (e.g. ten of the 44 GLMCA objectives have human health considerations; if required objectives are not available, priority must be given to establishment of drinking water objectives). Taste and odour problems will also be absent (e.g. taste and odour problems due to blue-green algae or phenolic compounds).	Adapted from Canada and the United States, 1987
BEACH CLOSINGS	When there are persistent beach closings due to contamination from bacteria, fungi or viruses that may produce enteric disorders or eye, ear, nose, throat and skin infections or other human diseases and infections. For example, the Province of Ontario has established the following criteria: 1) when the geometric mean of a series of fecal coliform bacteria measurements exceeds 100 colonies per 100 ml; and 2) when the geometric mean of a series of total coliform measurements exceeds 1,000 colonies per 100 ml.	When there are no persistent beach closings and waters for body contact recreation activities are substantially free from bacteria, fungi or viruses that may produce enteric disorders or eye, ear, nose and throat infections. For example, the Province of Ontario has established the following criteria: 1) when the geometric mean of a series of fecal coliform bacteria measurements does not exceed 100 colonies per 100 ml; and 2) the geometric mean of a series of total coliform measurements does not exceed 1,000 colonies per 100 ml.	Adapted from Canada and the United States, 1987; Ontario Ministry of Environment 1984
DEGRADATION OF AESTHETICS	When debris, oil, scum or any substance produces a persistent objectionable deposit, unnatural color or turbidity, or unnatural odour.	When the waters are devoid of debris, oil, scum or any substance which would produce a persistent objectionable deposit, unnatural color or turbidity or unnatural odour.	Adapted from the Ontario Ministry of Environment 1984
ADDED COSTS TO AGRICULTURE OR INDUSTRY	When there are additional costs required to treat the water prior to use for agricultural purposes (i.e. including, but not limited to, livestock watering, irrigation and crop-spraying) or industrial purposes (i.e. intended for commercial or industrial applications and non-contact food processing).	When there are no additional costs required to treat the water prior to use for agricultural purposes (i.e. including, but not limited to, livestock watering, irrigation and crop-spraying) and industrial purposes (i.e. intended for commercial or industrial applications and non-contact food processing).	Adapted from Michigan DNR 1977
DEGRADATION OF PHYTOPLANKTON AND ZOOPLANKTON POPULATIONS	When phytoplankton or zooplankton community structure significantly diverges from unimpacted control sites of comparable physicochemical characteristics. Phytoplankton and zooplankton populations should also be used to assess the effects of contaminants. Greater emphasis must be placed on ecological toxicology, including use of bioassays and field data. A site will be listed as an Area of Concern when phytoplankton or zooplankton bioassays (e.g. <i>Caricodaphnia</i> ; algal fractionation bioassays) confirm toxicity (significant at the 95% probability level).	When phytoplankton and zooplankton community structure does not significantly diverge from unimpacted control sites of comparable physicochemical characteristics. Further, a site will be delisted as an Area of Concern when bioassays confirm no significant phytoplankton and zooplankton toxicity (at the 95% probability level).	Adapted from IJC 1987b

Table 1 - continued

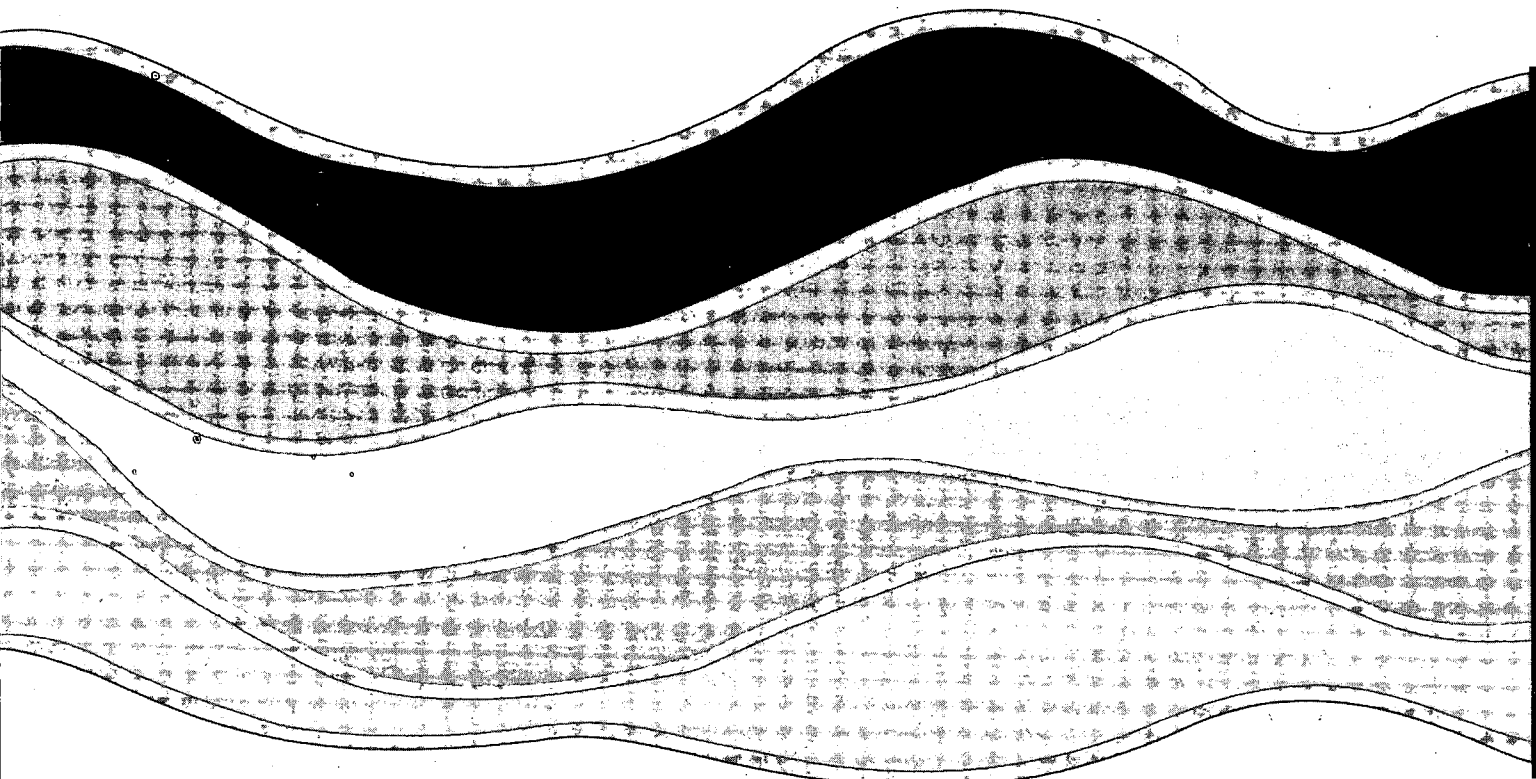
## LISTING/DELISTING CRITERIA FOR GREAT LAKES AREAS OF CONCERN

USE IMPAIRMENT	LISTING CRITERIA	DELISTING CRITERIA	REFERENCE
LOSS OF FISH AND WILDLIFE HABITAT	When fish and wildlife personnel have identified loss of fish and wildlife habitat due to water quality contamination as part of fish and wildlife management program.	Once loss of fish and wildlife habitat has been established (due to water quality degradation), the jurisdictions should identify species-specific fish and wildlife goals for the Area of Concern. The amount and quality of physical, chemical and biological habitat required to meet the goals can then be determined and compared against existing conditions. Once the amount and quality of physical, chemical and biological habitat has been achieved (consistent with fish and wildlife management goals), the use would no longer be impaired. Species-specific goals for self-sustaining fish and wildlife populations are desired so that: 1) essential habitats are created and protected by law from future development, physical degradation or contamination; 2) fish and wildlife can migrate freely in and through Areas of Concern to utilize essential habitats; 3) management of fish and wildlife populations in Areas of Concern is compatible with management plans developed by fish and wildlife authorities; and 4) fish and wildlife populations in Areas of Concern are self-sustaining (i.e. having stable population structure and surviving without periodic stocking by humans) and normally productive (i.e. productive at a level expected from that amount of habitat present under unimpaired natural conditions, based on historic information on sport, commercial, non-game and endangered species in Areas of Concern, as set forth in RAPs).	Adapted from Manny and Pacific, 1988

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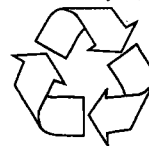
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