Special Report No. 12

PROCEEDINGS OF A ROUND TABLE ON
RECLAIMING AND MANAGING LAKES IN ILLINOIS

October 10-11, 1980

Water Resources Center
University of Illinois at Urbana-Champaign
and
Illinois Institute of Natural Resources
Chicago, Illinois

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ABSTRACT

The purpose of the round table was to provide a basis for the exchange of information between experts and concerned citizens about problems and solutions surrounding the management and reclamation of Illinois lakes, with emphasis on man-made lakes. Speakers from governmental agencies, universities, and consulting firms gave presentations on a wide variety of topics concerning lakes and lake users, including the problems of soil erosion and eutrophication, the laws and benefits associated with lake reclamation and management, and the governmental programs which affect those activities.

Water Resources Center; Illinois Institute of Natural Resources
PROCEEDINGS OF A ROUND TABLE ON RECLAIMING AND MANAGING LAKES IN ILLINOIS
KEYWORDS: *Illinois/ *lake management/ *lake reclamation/ *proceedings/ administration/ artificial lakes/ benefits/ rehabilitation/ water management (applied)/ water policy/ water pollution effects/ water pollution treatment
ACKNOWLEDGEMENTS

Many thanks to the panelists whose presentations make up these Proceedings and to all those who participated in the round table to make it a successful forum for the exchange of ideas and viewpoints.

Thanks to the planning committee, named below, who also were active in the program as panelists or moderators, and to Linda Keasler for editing the Proceedings.

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Linda C. Keasler, Water Resources Center
W. J. Roberts, Illinois State Water Survey
Donna F. Sefton, Illinois Environmental Protection Agency
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Special thanks to Richard Buhr for his assistance at the round table and for his contribution to the Proceedings.
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iv</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>vii</td>
</tr>
<tr>
<td>Glenn E. Stout</td>
<td></td>
</tr>
<tr>
<td>LAKE PROBLEMS IN ILLINOIS</td>
<td></td>
</tr>
<tr>
<td>A Major Water Quality Problem in Illinois:</td>
<td></td>
</tr>
<tr>
<td>Soil Movement from the Watershed and Channel</td>
<td>1</td>
</tr>
<tr>
<td>Robert D. Walker</td>
<td></td>
</tr>
<tr>
<td>Major Problems of Lake Water Quality in Illinois</td>
<td>4</td>
</tr>
<tr>
<td>Michael Meyer</td>
<td></td>
</tr>
<tr>
<td>Chemical Characteristics of Lake Sediments</td>
<td>10</td>
</tr>
<tr>
<td>Michael J. Barcelona</td>
<td></td>
</tr>
<tr>
<td>Some Considerations in the Restoration and</td>
<td>21</td>
</tr>
<tr>
<td>Preservation of Lakes</td>
<td></td>
</tr>
<tr>
<td>Krishan P. Singh</td>
<td></td>
</tr>
<tr>
<td>LAKE RECLAMATION</td>
<td></td>
</tr>
<tr>
<td>An Overview of In-lake Treatment Techniques for Water Quality</td>
<td>28</td>
</tr>
<tr>
<td>Management</td>
<td></td>
</tr>
<tr>
<td>V. Kothandaraman</td>
<td></td>
</tr>
<tr>
<td>In-lake Control of Nuisance Vegetation: A Review of Eight Procedures</td>
<td>43</td>
</tr>
<tr>
<td>G. Dennis Cooke</td>
<td></td>
</tr>
<tr>
<td>Dredging in Illinois</td>
<td>56</td>
</tr>
<tr>
<td>W. J. Roberts</td>
<td></td>
</tr>
<tr>
<td>Legal Aspects of Reclaiming Lakes</td>
<td>60</td>
</tr>
<tr>
<td>David R. Boyce</td>
<td></td>
</tr>
<tr>
<td>Lake Lansing Restoration--Its Goals, Successes and Disappointments</td>
<td>64</td>
</tr>
<tr>
<td>Richard L. Sode</td>
<td></td>
</tr>
<tr>
<td>LAKE MANAGEMENT</td>
<td></td>
</tr>
<tr>
<td>Controlling Sediment by Watershed Management Techniques</td>
<td>77</td>
</tr>
<tr>
<td>Harvey Sundmaeker</td>
<td></td>
</tr>
<tr>
<td>Biological Aspects of Eutrophication</td>
<td>81</td>
</tr>
<tr>
<td>Michael Lynch</td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>LAKE MANAGEMENT (cont'd.)</td>
<td></td>
</tr>
<tr>
<td>Institutions for Lake Management</td>
<td>87</td>
</tr>
<tr>
<td>M. R. Grossman and D. L. Uchtman</td>
<td></td>
</tr>
<tr>
<td>Funding Aspects of Lake Management</td>
<td>98</td>
</tr>
<tr>
<td>Richard Burd</td>
<td></td>
</tr>
<tr>
<td>Prevention of Shoreline Erosion by Physical and Structural Methods</td>
<td>106</td>
</tr>
<tr>
<td>Dwight A. Niocum</td>
<td></td>
</tr>
<tr>
<td>Methods of Controlling Human Use of a Lake</td>
<td>110</td>
</tr>
<tr>
<td>Donald W. Ferguson</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>BENEFITS OF RECLAMATION</td>
<td></td>
</tr>
<tr>
<td>Overview of the Economic Aspects of Reclaiming a Lake</td>
<td>114</td>
</tr>
<tr>
<td>William L. Miller</td>
<td></td>
</tr>
<tr>
<td>A Case Study of the Economic Benefits of Reclaiming a Lake: Lake Paradise, Mattoon</td>
<td>121</td>
</tr>
<tr>
<td>Susan Rothrock Deo</td>
<td></td>
</tr>
<tr>
<td>Uses of Dredged Material</td>
<td>126</td>
</tr>
<tr>
<td>Thomas P. Patin</td>
<td></td>
</tr>
<tr>
<td>An Economic Analysis of the Recreational Benefits of Water Quality Improvement</td>
<td>133</td>
</tr>
<tr>
<td>Nicolaas W. Bouwees, Sr.</td>
<td></td>
</tr>
<tr>
<td>Reclamation and Recreation: The Residents' Perspective</td>
<td>153</td>
</tr>
<tr>
<td>James Abeher and Douglas Musser</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOVERNMENT PROGRAMS</td>
<td></td>
</tr>
<tr>
<td>The Clean Lakes Program</td>
<td>165</td>
</tr>
<tr>
<td>Donna F. Sefton</td>
<td></td>
</tr>
<tr>
<td>Illinois State Lake Management Program</td>
<td>180</td>
</tr>
<tr>
<td>Peter J. Paladino</td>
<td></td>
</tr>
<tr>
<td>Biomanipulation and Lake Restoration on State Waters in Illinois</td>
<td>191</td>
</tr>
<tr>
<td>Gary Erickson</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPENDIX A. Program</td>
<td>196</td>
</tr>
<tr>
<td>APPENDIX B. Panelists and Moderators</td>
<td>200</td>
</tr>
<tr>
<td>APPENDIX C. Attendees</td>
<td>203</td>
</tr>
</tbody>
</table>
INTRODUCTION
Glenn E. Stout*

On October 10 and 11, 1980 the Water Resources Center, in cooperation with the Illinois Institute of Natural Resources and the Illinois Environmental Protection Agency, held a Round Table on Reclaiming and Managing Lakes in Illinois at the Ramada Inn Convention Center in Champaign. It was an outgrowth of a February 1980 Workshop on Restoring Man-Made Illinois Lakes. (Water Resources Center Special Report 11).

Many of the topics covered at the workshop eight months earlier were updated or expanded. New ones also were added to make the round table a full two-day event with speakers from Illinois, Indiana, Mississippi, Michigan, Missouri, Ohio, and Wisconsin giving presentations. Topics included sedimentation of lakes, dredging in Illinois, the Clean Lakes Program, biological aspects of eutrophication, uses of dredged material, legal aspects of reclaiming lakes, residents' perspectives on reclamation and recreation, in-lake control of vegetation, institutions for lake management, and funding aspects of lake management.

A total of 90 people participated: 33 percent from local, state, or federal government; 32 percent from academic institutions (including the state water, natural history, and geological surveys); 17 percent from consulting or engineering firms; 11 percent from lake organizations; and 7 percent from other organizations and agencies.

ILLINOIS LAKES

Illinois has over 80,000 surface water impoundments, totaling approximately 281,500 acres. These water bodies range in size from one-quarter acre farm ponds to 26,000 acre Lake Carlyle. However, less than 3,000 of these impoundments exceed six acres in size, fewer than 500 exceed 50 acres, and only 217 are larger than 100 acres. About 96 percent of these water bodies are privately owned, yet 55 percent of the total acreage is publicly owned.

Very few Illinois lakes, about 6 percent, are natural. Glacial lakes are found only in northeastern Illinois' McHenry, Lake, and Cook counties, while natural bottomland, oxbow, and backwater lakes are found along the state's

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larger rivers. The remaining 94 percent of Illinois' impoundments are artificial—either reservoirs or man-made ponds.

Illinois lakes serve multiple purposes; they must meet the demands of water supply, flood control, recreation, agriculture, industry, and electric power generation.

THE PROBLEM

In the past, lake management has been a low priority item in Illinois, perhaps because the recent decade of ample rainfall has allowed many potential problems to remain at least partially hidden. However, factors such as urban expansion and the energy crisis are currently exposing many of these problems, and once the rainfall cycle reaches its low point, many more of these problems will undoubtedly surface. Currently, expanding municipalities are discovering that the quality and capacities of their water supply lakes are diminishing because of eutrophication and sedimentation. Meanwhile, the energy crisis has created a greater demand for local, instate water recreation facilities.

Even as the demand for high quality Illinois lakes is expanding, the lakes are developing increasingly serious problems. Eutrophication is a natural aging process by which lakes are enriched through the input of organic materials and surface runoff, leading to an increase in the growth of aquatic plants and algae, sedimentation and shallowing, and often to a deficiency in oxygen. The large number of organisms in eutrophic lakes render their waters cloudy and, in extreme cases, result in the death of most aquatic animals and large aquatic plants.

Row crop production practices have greatly accelerated eutrophication, making agricultural runoff the most serious contributing factor in the degradation of Illinois lakes. Of the 181 million tons of soil eroded annually in Illinois, about 25 percent reaches our streams and lakes to have a profound effect on water quality and quantity. Suspended sediment increases the cost of treating municipal and industrial water supplies, reduces light penetration and photosynthesis, and makes water less appealing aesthetically because of odor and taste problems. Sediment, furthermore, carries pesticides, heavy metals, and organic materials, along with phosphorus and other nutrients which cause excessive weed growth and algal blooms.

In addition, deposited sediment diminishes water storage space needed for water supplies and flood control, destroys the bottom spawning and feeding areas
of many fish species, reduces the productivity of aquatic organisms which provide food for fish and waterfowl, and creates shallow areas, which support nuisance vegetation and provide breeding places for mosquitoes. The rate of sedimentation can be dramatic. The manager of a newly established recreational lake informed us that a dredging program had to be initiated within only three years of the lake construction and filling.

The severity of problems of Illinois lakes was revealed by the 1978 Illinois Environmental Protection Agency's Assessment and Classification of Illinois Lakes. The agency's study showed that of 353 Illinois lakes, 29 percent were in "poor condition," and 68 percent exhibited a "high problem potential."

LAKE RESTORATION

The most commonly used lake restoration procedure is dredging, although many other in-lake treatment procedures are being used with various degrees of success. Procedures discussed at the round table included aeration, dilution, flushing, chemical treatment, fish population control, sediment covers, aquatic plant harvesting, and lake level drawdown for control of rooted plants.

Inland lake dredging projects have been implemented in selected areas throughout the state during the past decade, but there has been no comprehensive program. In addition, we have little data on the economics of dredging because most of the lake-dredging projects have been carried out by individual communities on a bootstrap operation. But various methods of dredging were discussed at both the February and October workshops, and it is apparent that comprehensive knowledge as to the most effective procedures is limited.

COMPREHENSIVE LAKE MANAGEMENT

Lake restoration without watershed and lake management programs can be an endless, futile process. Comprehensive lake management, however, is no easy task. Landowners in watersheds are motivated by a variety of economic and cultural perceptions that often conflict with efforts at lake management. Even lake owners themselves may have different objectives for lake utilization. Nevertheless, the effort toward comprehensive lake management must be made or the process of lake degradation will continually repeat itself. Some of the most important considerations of lake management are: (1) Lake owners must persuade landowners of the benefits of soil and sediment control. (2) Lake
owners should consider making provisions to acquire the necessary rights to land along the lake's stream or to gain the cooperation of landowners so they may implement measures to minimize streambank erosion and sediment transport. For example, a grass strip plus streambank vegetation will greatly decrease the movement of sediment from the farmlands into the stream. (3) A careful monitoring program must be set up to audit current problems and to discover potential problems before they become serious. (4) Lakeshore property development must be planned. (5) Waste disposal and sewage must be carefully controlled. (6) Lake users must reach a consensus regarding lake-use objectives.

ECONOMICS AND BENEFITS

Lake reclamation and management are expensive processes, and the benefits are not easy to quantify. Consequently, lake owners and public groups often have a difficult time convincing other owners, taxpayers, or utility users of the cost-benefits of reclamation and management programs. Several speakers addressed this problem at the lake round table in papers on the economics and the recreational benefits of reclaiming a lake. A related problem is disposal of sediment resulting from lake dredging. However, as Thomas R. Patin illustrated in his paper on "Uses of Dredged Material," dredged sediment should be considered a resource rather than a problem. Since much of the lake sediment in Illinois originated on agricultural land, returning it to the land should have many advantages. Citizens and farmers should increasingly welcome the opportunity to reuse dredged sediment, so the value of sediment could offset some of the cost of dredging, perhaps by collecting a fee for the resource. A project funded by the Illinois General Assembly is currently being conducted in Coles County by the University of Illinois College of Agriculture to determine the crop-yield potential of sediment taken from Lake Paradise.

ASSISTANCE

One agency that can play a leading role in solving these problems is the Illinois Environmental Protection Agency (IEPA). In the past, IEPA has had a rather low profile in this area, but recently they have been expanding their efforts to cope with Illinois' pending water quality problems. At the round table, some of the key factors involved in their program of assessing the quality of Illinois' lakes were described. Also, some of the important aspects
of the U.S. Environmental Protection Agency's Clean Lakes Program (Section 314) were outlined along with an announcement that, under Section 314, funds are being made available to local agencies for diagnostic-feasibility studies of lake quality and management.

A number of other agencies, including the Illinois Department of Transportation, the Illinois Institute of Natural Resources, the Illinois Department of Conservation, and the U.S. Soil Conservation Service have strong interests in working with communities or private lake owners in order to help them solve some of the problems of managing their lakes.

Additional sources of assistance and consultation are Illinois universities. The University of Illinois' Cooperative Extension Service, Water Resources Center, Department of Civil Engineering, and Department of Ecology, Ethology, and Evolution, as well as the State Water Survey and State Natural History Survey, have personnel involved in lake management or research. Many other Illinois universities have personnel who can offer similar assistance.
A MAJOR WATER QUALITY PROBLEM IN ILLINOIS:
SOIL MOVEMENT FROM THE WATERSHED AND CHANNEL

Robert D. Walker*

The topography of Illinois undergoes both wind and water erosion. However, the vast majority of our soil erosion occurs as water erosion. My presentation will deal only with soil erosion caused by water and the movement of sediment into streams and lakes.

From a soil science standpoint, soil erosion by water may occur when four conditions are met:

(1) The soil must be bare, not protected by vegetative cover either living or dead.

(2) There must be energy to detach soil particles from the soil mass. The energy may be supplied by the impact of the falling raindrop, from water moving across the soil surface, from tillage operation, or by animals or machinery moving across the soil surface.

(3) Water must be delivered to the soil surface at a rate greater than the infiltration rate.

(4) The soil must be sloping so that the surface runoff can occur.

Thus, soil erosion will occur when there is sufficient energy to detach soil particles from the soil mass and transport the detached soil particles to another point on the landscape.

Now we will look at the soil erosion process in more detail. The first step in soil erosion occurs with the falling raindrop. The accumulated energy of a rainstorm's raindrops hitting a bare soil surface is sufficient to loosen many soil particles. The raindrop itself will move soil particles with the raindrop splatter. When the rain reaches the point where runoff starts to occur, the sheet flow will carry the detached soil particles down the slope. At this point, the energy of the sheet flow is not great enough to detach soil particles. But, as rainfall continues and the sheet flow becomes greater, water will accumulate as it moves down the slope and tends to concentrate in the

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lowest area until the water flow has adequate energy to detach additional soil particles, forming rills. As the rainfall increases and the water moves further down the slope, the concentration of water can become great enough to erode gullies. At any point where the water velocity is reduced, sediment may be deposited.

Even on the upper part of the landscape we may have soil particles deposited as the water velocity is slowed by being caught in depressions in the soil or slowed with crop residue or growing plants. Soil may be moved a short distance by many rainstorms before it finds its way into a lake. Some of the smaller soil particles may be carried all the way to the ocean without ever being deposited.

When the flowing water reaches a stream, it exerts energy depending on the amount of water the stream is carrying and the rate of stream flow. Soil particles may be detached from the stream bank or stream bottom, or sediment may be deposited along the stream. If the water reaching a stream is not carrying sediment, the stream energy demand may be satisfied by eroding the stream bank or stream bottom. If the water entering the stream is carrying a heavy load or soil particles, the energy requirement of the flowing stream may be fulfilled and no additional stream bank or stream bottom erosion may occur. However, deposition may occur.

We are able to provide reasonable, accurate estimates (± 20%) of the average amount of soil erosion that may occur from a specific segment of a field using the Universal Soil Loss Equation. Due to the soil erosion and sediment process, our estimates of the amount of sediment that will reach a lake are less reliable.

We do know, however, that the sediment deposited in a lake comes from the lake's watershed. Soil conservation practices have been developed to reduce soil erosion in the watershed and thus reduce the sediment deposited in a lake. All of these practices have two factors in common: (1) they provide soil cover to absorb the energy of the falling raindrop or protect the soil from other means of soil detachment, or (2) they slow the water flow so that the water does not gain enough velocity to detach soil particles.

It has been public policy to control soil erosion since the Soil Conservation Service was created in 1933. The recent Section 208 (PL 92-500)
planning process has brought additional attention to the Illinois soil erosion problem. As a result, the state has established a policy to bring soil erosion within the established soil erosion tolerances (2-5 tons per acre per year) for all the state's agricultural land by the year 2000. Several intermediate goals have been set.

The 208 study indicates that we have excessive soil erosion on 39% or nearly 10 million acres of our cropland. The erosion rate averages from 4 to 10 tons per acre per year on 6 million acres (25%), 10 to 20 tons of 2 million acres (8%), and over 20 tons on another 2 million acres (8%) of the state's cropland. The problem has been caused by the demand for feed grains and the switch to intensive row crop production to meet this demand.

The state Soil and Water Conservation District Act was amended in 1977, requiring the Illinois Department of Agriculture to develop guidelines for the districts to follow in setting soil erosion standards for all soils in a district. The department adopted their guidelines on April 18, 1980, and the districts have two years from that date to set their erosion standards. Once the district standards are adopted, the law calls for providing landowners with adequate technical assistance and cost-sharing to control soil erosion on a voluntary basis. The program will be handled on a complaint basis. The districts will be assisted by the U.S. Soil Conservation Service, providing technical assistance; the Agricultural Stabilization and Conservation Service, providing cost-sharing money; the Cooperative Extension Service, providing education programs; and other state and local agencies.

A state-funded cost-sharing program to encourage conservation tillage was started this year. Much of the erosion on the state's gently rolling land, 25 percent, can probably be controlled with this practice. Many people believe that the agricultural community must show that they are able to control soil erosion on a voluntary basis or a regulatory program will be adopted at the end of five years.
MAJOR PROBLEMS OF LAKE WATER QUALITY IN ILLINOIS

Michael Meyer*

INTRODUCTION

It is well known that sediment pollution (suspended inorganic material and deposition of sediment) is ranked as the most serious problem of Illinois lakes (Sefton, 1978), especially those lakes in the heavily cultivated regions of the state. Urban and residential lakes near larger cities tend to show algal or aquatic weed problems which can often be associated with high levels of phosphorus from such sources as urban runoff and waste water treatment plant discharges.

This paper will present examples of central Illinois lakes and the factors that influence their water quality.

MAJOR FACTORS AFFECTING WATER QUALITY

The water quality, use impairment, and characteristics of Illinois lakes have been found to be influenced by origin, location, morphology, hydrology, watershed characteristics and meteorological conditions (Sefton, 1978; Boland et al., 1979).

Generally, artificial lakes showing the best water quality (in terms of suspended solids, algae and aquatic weed problems) are deep with long hydraulic retention times (one year or more), small watershed area to storage capacity ratios (less than 1.0), little urbanization, less row crop cultivation and soils with low fertility and erosivity.

Six artificial impoundments in Central Illinois have been selected for discussion because they were part of the Illinois Environmental Protection Agency's (IEPA) 1979 lake sampling program, and color aerial photographs of these lakes have been provided by the Illinois Department of Transportation. Since the photographs were taken on August 16, 1979, August water quality data will be used to complement the photographs. (Lakes with a higher percentage of nonvolatile suspended solids (clay)

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appear brown while those with a lower percentage of nonvolatile suspended solids and a substantial chlorophyll a content appear green.)

Otter, Lincoln Trail, Pittsfield, Mattoon, Paradise and Taylorville are ranked (Table 1) for expected water quality based on mean depth, watershed equivalent inches, retention time, and drainage area to storage capacity ratio. Otter Lake (Macoupin County) is first with what are considered the best physical characteristics and Lake Taylorville (Christian County) is last. (Note: The selection of these lakes for presentation in no way reflects IEPA lake prioritization for the Section 314b Clean Lakes grant program.)

To assess water quality, Carlson's Trophic State Index (TSI) (see Appendix A) is applied to Secchi transparency, chlorophyll a and total phosphorus data collected in August of 1979 (Table 2). Total suspended solids (TSS) and nonvolatile suspended solids (NVSS) are included and will add to the assessment (Table 3).

The average of the August TSI values indicate that the water quality of Lincoln Trail Lake ranks first followed by Otter Lake, Pittsfield, Taylorville, Mattoon and Paradise. Examining the watershed use information (Table 2), one finds that Lincoln Trail has only 30 percent cropland and 50 percent woodland, while Otter Lake has 80 percent cropland and 10 percent woodland. This probably contributes to the better quality of Lincoln Trail in spite of its poorer physical characteristics.

Lake Taylorville ranks number four on the list because the TSI value for chlorophyll a is quite low. This is probably due to both high turbidity from suspended clay that attenuates light penetration and a short retention time that literally "flushes" the reservoir and prevents an algal culture from developing. The Secchi TSI, however, shows Taylorville with the least desirable transparency. This is probably due to the fact that in August, Taylorville had the highest total and volatile suspended solids of all the lakes; Lincoln Trail had the lowest.

Lakes Mattoon and Paradise rank fifth and sixth, respectively, in terms of trophic state index due mainly to a high chlorophyll a content. It is interesting to note that the TSI phosphorus value for Paradise is particularly high.
Table 1. Watershed and morphological information for six Illinois lakes.

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<th>LAKE</th>
<th>PHYSICAL CHARACTERISTICS</th>
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<td>Area (Acres)</td>
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<td>-------------</td>
<td>---------------</td>
</tr>
<tr>
<td>1) Otter</td>
<td>765</td>
</tr>
<tr>
<td>2) Lincoln Trail</td>
<td>146</td>
</tr>
<tr>
<td>3) Pittsfield</td>
<td>241</td>
</tr>
<tr>
<td>4) Mattoon</td>
<td>765</td>
</tr>
<tr>
<td>5) Paradise</td>
<td>176</td>
</tr>
<tr>
<td>6) Taylorville</td>
<td>1148</td>
</tr>
<tr>
<td>Lake</td>
<td>TSI</td>
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<td>-----------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td>Secchi</td>
</tr>
<tr>
<td>Otter</td>
<td>67.1</td>
</tr>
<tr>
<td>Lincoln Trail</td>
<td>57.4</td>
</tr>
<tr>
<td>Pittsfield</td>
<td>68.9</td>
</tr>
<tr>
<td>Mattoon</td>
<td>72.2</td>
</tr>
<tr>
<td>Paradise</td>
<td>74.3</td>
</tr>
<tr>
<td>Taylorville</td>
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Table 3. Total suspended solids (TSS), nonvolatile suspended solids (NVSS),
and the ratio of NVSS to TSS (percentage), August 1979.

<table>
<thead>
<tr>
<th>Lake</th>
<th>TSS (mg/l)</th>
<th>NVSS (mg/l)</th>
<th>NVSS/TSS (%)</th>
</tr>
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<tr>
<td>Otter</td>
<td>12</td>
<td>5.3</td>
<td>44</td>
</tr>
<tr>
<td>Lincoln Trail</td>
<td>6</td>
<td>2.7</td>
<td>45</td>
</tr>
<tr>
<td>Pittsfield</td>
<td>26</td>
<td>21.0</td>
<td>81</td>
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<tr>
<td>Mattoon</td>
<td>40</td>
<td>26.0</td>
<td>65</td>
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<td>Paradise</td>
<td>33</td>
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<tr>
<td>Taylorville</td>
<td>51</td>
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</tbody>
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The percentage of the total suspended solids (Table 3) that are comprised of nonvolatile suspended solids (i.e., NVSS/TSS x 100) is highest in Taylorville (84 percent) followed by Pittsfield with 81 percent. Pittsfield could have this high value due to the highly sloped woodlands near the lake that are used for hog lots and a high gross erosion rate in the watershed in general. The percentage for Mattoon and Paradise is lower, probably due to a higher algal content.

CONCLUSIONS

Based on Secchi transparency, chlorophyll a, and total phosphorus concentrations, Otter Lake has better water quality than four of the six lakes mentioned (i.e., Pittsfield, Paradise, Mattoon and Taylorville), even though it has a high percentage of land in row crops. The reason for its better water quality corresponds to its long retention time, low watershed area to lake capacity ratio, and greater mean depth. As these physical characteristics become less desirable, water quality generally declines (with the exception of Lincoln Trail which has a low percentage of row crop cultivation). This could lead to the assumption that land use is not the only problem confronting Illinois lakes. A major problem with water quality is the location of dams in areas that produce shallow mean depths, short retention times, and a poor watershed area/lake capacity ratio. These lakes will be the most difficult to protect and manage and the most expensive to restore or improve.
REFERENCES


APPENDIX A

TSI changes parameter values to a scale ranging from 0.0 to 110.0. Values above 40 are considered eutrophic. Equations used for computations are as follows:

\[
\begin{align*}
\text{TSI (chl a)} &= 9.81 \ln (\text{chl a}) + 30.6 \\
\text{TSI (Secchi)} &= 60 - 14.41 \ln (\text{Secchi}) \\
\text{TSI (TP)} &= 14.42 \ln (\text{TP}) + 4.15 \\
\text{chl a} &= \text{chlorophyll a in \mu g/l} \\
\text{Secchi} &= \text{Secchi water transparency in meters} \\
\text{TP} &= \text{total phosphorus (TP) in mg/m}^3
\end{align*}
\]
CHEMICAL CHARACTERISTICS OF LAKE SEDIMENTS

Michael J. Barcelona*†

My presentation today deals more with the benefits of good management practice than with the benefits of reclamation. Lake sediments frequently pose problems even when the storage capacity of a reservoir is not threatened by their accumulation. Speakers from many disciplines have described the symptoms we normally associate with eutrophic lake conditions: taste and odor problems, nuisance algal blooms or macrophyte growth and oxygen depletion in the deeper portions of a lake which stress fish populations.

Artificial impoundments in Illinois are nominally eutrophic from the day they are filled by virtue of their size, shallow depths and excess inputs of both suspended solids and the nutrient elements nitrogen and phosphorous. I ask you to view the sediments as solids, bathed in their interstitial waters, in communication with overlying lake waters. Dead and decaying materials sink through the lake waters and accumulate in the sediment column. Then, microorganisms within the sediment continue to remineralize organic forms of carbon, nitrogen, phosphorous and sulfur back into inorganic forms, such as CO₂, NH₃, PO₄³⁻ and SO₄²⁻.

The sediment system clearly parallels treatment processes which have been implemented to purify our industrial or municipal wastes. The products of this "treatment" process depend on many physical and biological factors. The main factor, however, is the availability of dissolved oxygen. Consequently, chemical characteristics of the sediments depend on the overlying lake conditions and vice versa. When oxygen becomes depleted, anaerobic processes proceed and the products are reduced forms of iron and manganese, methane, ammonia, phosphate, sulfides, and organosulfur compounds which can impart foul tastes and odors to lake waters.

The conditions in Illinois lakes we've heard described during this meeting favor severe oxygen depletion because inputs to the sediment "treatment" system

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†The author wishes to acknowledge the support of the Institute of Natural Resources, the Water Resources Center and the professional help of Hi-Shi Chiang, Steven Heffelfinger and Pamela C. Beavers.
are far in excess of the available oxygen necessary for aerobic processes. Stopgap measures to "seal" off the sediment, using plastic sheeting or burial of layers of inorganic solids (fly ash), may succeed for a time. However, reasonable in-lake and watershed management policies are long-term solutions to lake vitality problems. Understanding of the dynamics of lacustrine systems and their connection to sediment processes will provide a basis for effective policy. I hope to leave you today with an appreciation of the complexity of sediment processes and the physical/biological factors which affect them. I'll then present some recent data collected on Lake Paradise, which outlines carbon remineralization in the sediments, particularly as it impacts oxygen levels in overlying waters.

First of all, let's consider the source of sediment to freshwater lakes. The material ultimately delivered to the sediments comes from erosion within the lake's watershed and from biological productivity in the lake itself. Excessive dissolved and particulate nutrients which accompany the erosion products stimulate algal production, forming a cycle which ends in very rapid accumulation of sediment. Erosion from our agricultural watersheds is a problem. However, the picture could be much worse for artificial impoundments in our state. Since the bulk of our cropland is "prime," (high fertility and mostly flat, SCS classes I, I1e) annual erosion is generally less than 5 tons per acre.

This picture is brighter than the national figures (Figure 1), when we realize that approximately 74 percent of cropland in the cornbelt is in prime categories. Thus, the origin of sediment particles will be a mixture of soil and aquatic biological solids with a minor input of aerosol particles. The common property of the particles is that they are both inorganic and organic in composition and likely have some microbial component residing on their surfaces. Though these sediment particles enter the system at different points, they are entrained in the physical, chemical and biological dynamics of the lake system (Figure 2).

From a chemical perspective, the physical motions of the water couple with biological processes and the exchange of gases across the atmosphere/water interface to drive the overall system. Sedimentation occurs from the fluvial input at the head of the lake and on to the lake outlet. Algal primary production occurs in the upper layers of the lake water exposed to sunlight,
Figure 1. Sheet and Rill Erosion

<table>
<thead>
<tr>
<th>Land use</th>
<th>Tons per year (millions)</th>
<th>Tons per acre per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropland</td>
<td>1,969</td>
<td>4.8</td>
</tr>
<tr>
<td>Pastureland</td>
<td>274</td>
<td>2.4</td>
</tr>
<tr>
<td>Native pasture</td>
<td>72</td>
<td>4.1</td>
</tr>
<tr>
<td>Rangeland</td>
<td>1,392</td>
<td>3.4</td>
</tr>
<tr>
<td>Forestland</td>
<td>437</td>
<td>1.2</td>
</tr>
<tr>
<td>Total</td>
<td>4,144</td>
<td>3.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Capability class and subclass</th>
<th>Erosion (ton/acre/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>3.0</td>
</tr>
<tr>
<td>IIe</td>
<td>5.0</td>
</tr>
<tr>
<td>IIIe</td>
<td>6.9</td>
</tr>
<tr>
<td>IVe</td>
<td>8.7</td>
</tr>
<tr>
<td>VIE</td>
<td>14.9</td>
</tr>
<tr>
<td>VIIe</td>
<td>15.4</td>
</tr>
</tbody>
</table>

(SOURCE: SOIL CONSERVATION SERVICE 1977)

Figure 2. Aquatic (Sediment-Trap) Dynamics
and a certain amount of nutrient recycling and particle formation occurs in the lake waters as well. This recycling involves: the uptake of inorganic forms of carbon, nitrogen, phosphorous and silicon, the transformation to organic and skeletal forms of the elements, and finally the remineralization of the elements as higher organisms feed on the primary producers. Finally, solid particles make their way to the sediment surface as affected by various physical processes, such as: waves, currents, and inter-particle interactions depicted in Figure 3.

Once the particles accumulate as sediment, the microbial population mediates a number of chemical interactions analogous to waste treatment processes. The major pathways are dependent on the availability of an oxidizing agent or electron-acceptor such as oxygen, nitrate, ferric iron, sulfate or ultimately carbon dioxide. These processes are schematized in Figure 4. I ask you to note that the lacustrine cycling of carbon, nitrogen, phosphorous, sulfur, silica, iron and manganese are all tied to sediment processes. The principal factors which influence the stability of all sediment constituents are summarized in Figure 5. The availability of oxygen is important to the complete "combustion" or remineralization of organic matter in particular.

Figure 3

![Diagram](image1)

Figure 4

![Diagram](image2)
Figure 5

FACTORS CONTRIBUTING TO EQUILIBRIUM (OR STEADY-STATE) STABILITY OF SEDIMENT CONSTITUENTS

Constancy of physical & biological conditions.
Rate of sedimentation, origin & homogeneity of particulate matter.
Extent of interchange with overlying water, bioturbation.
Amount and type of organic matter.
Availability of dissolved oxygen.

Let us now briefly consider the effect of sediment processes on carbon cycling with reference to the oxygen demand exerted by sediments and physical factors in Lake Paradise, Mattoon, Illinois. The lake itself has been described extensively by previous speakers. Suffice it to say that it is chronologically 75 years old, endangered from both trophic and water supply capacity considerations as well as the object of intensive rehabilitation/reclamation efforts. The lake is quite typical of Illinois impoundments. The sediments are not particularly well sorted as to size and contain a relative abundance of organic carbon, nitrogen, and phosphorous. The sediment results that I'll discuss in a few moments are based on a sample taken from the deeper portion of the lake upstream from the old dam (Figure 6). Because the lake is shallow, its response to physical factors such as temperature, wind or current motion is quite rapid with a water residence time less than 60 days. Thus, sediment samples from a single area will probably not be representative of the whole lake. Sediment cores were taken during July of 1980. At this time the hypolimnia of most Illinois shallow impoundments were anoxic, reflecting well-stratified conditions in the water column. Figures 7 and 8 show temperature and oxygen profiles along the center axis of the lake. Clearly, the deeper portions of the lake, upstream from the dams, are cooler and depleted in oxygen in comparison to the surface waters. However, mixing seems to be sufficient to maintain reasonable oxygen levels in the bottom waters despite the oxygen requirements of the sediments.
Figure 6

Depth of Accumulation = $x'$
(in feet)

Gross Average Accumulation = (Y)
Rate (cm yr$^{-1}$)

Sediment Sampling Site = 

PARADISE LAKE
COLES COUNTY, ILLINOIS

SCALE OF FEET

0
500
1000
1500
2000
The physical characteristics of the sediment disclose that the 75-year net accumulation has not been uniform. In Figure 9a, the profile of sediment density with depth shows a gradual increase to a depth of ~25 cm. Below 25 cm, the density remains fairly constant at ~2 g·mL⁻¹, which is consistent with a color change noted in the sediment core. The sediment below 25 cm is principally light-brown clay, while the more recent accumulation is black silty mud. In part b of Figure 9, the physical difference in the accumulation above from that below 25 cm is even more striking. Both the water content and the percent solids show marked gradients between the two zones. The portion of the sediment shown below 25 cm is quite compact and uniform. The upper portion shows a gradual decrease in water content consistent with steady compaction and de-watering due to the weight of sediment accumulation and overlying water. It is very likely that the marked physical differences noted above result from the effects of exposure, drying and compaction during the serious drought years of 1954-1955. In this period the lake bed dried out fairly completely and sediment constituents were exposed to the oxidizing properties of the atmosphere. This physical occurrence drastically affected the profiles of most reduced chemical constituents, most notably carbon.

Figure 9
Figure 10a shows the profile of the weight loss of the whole sediment on high temperature ignition in a muffle furnace. This is a crude measure of the "combustible" constituents in the sediment which is not biased by oxide formation due to the samples' iron (30 g·kg\(^{-1}\)) or manganese (<1 g·kg\(^{-1}\)) content. From the surface to ~30 cm the "combustibles" gradually decrease as would be expected if organic matter was being utilized by the microbial "treatment" processes within the sediment. The constant value of ~2% below 30 cm demonstrates the rather complete oxidation which occurred during the drought years. Although the parallel pore (interstitial) water profile of dissolved organic carbon is incomplete, cautious conclusions may be drawn. First of all, the dissolved carbon levels are 2-10 times those in overlying lake waters which suggests that the compounds associated with this carbon are products of microbial activity and that the sediments can act as a source of dissolved organic matter to the
lake waters. Also, the concentration levels tend to decrease below 25 cm, supporting the contention that physical factors play a prominent role in the chemical characteristics of the lake sediments.

The bulk of the carbonaceous material persists in the more recent accumulation of sediment (0-25 cm), and represents the bulk oxygen demand which the bottom makes on overlying waters. A developing tool for sediment management (really oxygen management) in lakes is the Sediment Oxygen Demand (SOD) parameter. I won't go into a detailed description of the methodology, but I ask you to view the values as the amount of oxygen which would be consumed via biological respiration or chemical oxidation per gram of sediment per hour.

The SOD of Lake Paradise sediment has been fractionated into chemical and biological portions as a function of depth and the results are shown in Figure 11. It is obvious that the profile of total SOD mirrors that of the remaining carbonaceous matter shown in Figure 10a (Loss on Ignition).

Figure 11
Further, the demand exerted by both chemical and biological "treatment" processes is high in the more recently accumulated sediment (upper 10 cm). The biological demand (which by the way does not include the respiratory demands of larger organisms such as worms or benthic animals) decreases rather abruptly in the upper portion of the profile. This places the biological time scale for "treatment" in the 1-25 year period. Nonetheless, the bulk of the SOD is chemical and shows the abrupt decrease below the 25 cm level.

In closing, the process of remineralization of sedimentary organic matter is slow and the effect of rapid sediment accumulation is to overload the "treatment" system. When available oxygen is used up, the sediment microorganisms shift to other oxidants which lead to the release of nutrients like phosphate and ammonia; which, in turn, promote further primary productivity. If oxygen levels can be maintained at reasonable levels and watershed management policies implemented to slow nutrient and sediment delivery to lake systems, the environment can be expected to improve. From this point, more sophisticated in-lake rehabilitation efforts can be applied with parallel improved chances of success.
SOME CONSIDERATIONS IN THE RESTORATION AND PRESERVATION OF LAKES

Krishan P. Singh*

INTRODUCTION

Lakes occur in practically every county in Illinois and serve a multitude of purposes, such as public, industrial and agricultural water supplies; flood control; navigation; and low-flow augmentation. They serve as valuable recreational and ecological resources. We must protect and maintain our existing lakes through better watershed and lake management in order to avoid problems associated with inadequate water resources.

Many speakers in this two-day meeting here are going to impart to us invaluable knowledge they have gained from their investigation of one or more specific factors affecting lakes. Such practical knowledge and experience from actual observations, experiments, and investigations help in advancing the quest in the right direction for answers to various questions.

My experience with lakes, their construction and design, restoration and preservation, and better management covers the design and construction of large lakes in India, increasing storage by dredging and/or raising the dam for Lake Vermilion near Danville, and optimizing lake operations at Shelbyville and Carlyle Lakes for maximum benefits from recreation, flood control, water supply, and navigation. I have endeavored to put together some considerations that may be looked into when investigations are made for the restoration and preservation of lakes. With so much sentiment against creating new lakes (and rightly so because of many adverse environmental impacts), a new strategy is needed to make the lakes environmentally more acceptable and physically viable.

RESTORATION OF LAKES

Restoration of a lake implies that something is wrong and that it needs to be corrected without undue delay. Restoration includes mostly short-term measures for quick results, to be followed by long-term measures for preserving the values attributed to the lake. Some measures do overlap, but the

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21
dichotomy will be followed for purposes of this presentation. We can consider the restoration of lakes under three main headings: revitalizing storage, structural safety, and optimal lake operation. The third item has more to do with the long-term measures and is, therefore, considered under the "preservation of lakes."

**Revitalizing Storage**

Storage can be revitalized by dredging and/or raising the dam. If dredging is considered as an on-going operation for many years to come, it can be considered under "preservation" also.

**Dredging.** We can deal with four factors under dredging.

*Type of dredging equipment.* Cutter-head, mud-cat, and hydraulic dredges are generally used in dredging of lakes because they create less resuspension of sediments. The dust-pan dredges are used in rivers but these cause considerable resuspension of sediments loosened by jets of water. Increase in turbidity on account of dredging affects the primary productivity of fish. The dredging operations should be timed to minimize adverse effects on fish by avoiding critical periods of fish activity.

*Where to dredge?* Three zones of sediment deposition may be defined as an upper zone around the lake-stream junction, a middle zone with water depths up to about one-half the maximum depth, and a lower zone with higher water depths. The upper zone may be exposed partly during low flows and low lake levels, causing some compaction due to alternate drying and wetting. For small- and medium-sized lakes (with the exception of Shelbyville, Carlyle, and Rend Lakes) in Illinois, there is substantial deposition in middle and lower zones because of low travel times and low reservoir capacity-inflow ratios. Under such conditions, dredging may be desirable in all three zones.

*Disposal of dredged material.* Long-distance hauling or piping of dredged materials is costly. Economical and environmental appraisal of disposal at various sites is needed to choose the most desirable site.

*Dredged material as a resource.* The dredged material can be used for improving the nearby agricultural land by filling up low-lying areas. It can be used for creating recreation areas in low lands adjacent to the lake.
A third use can be properly controlled disposal and compaction in low areas close to the lake for creating prime urban land. If favorable conditions exist, such a disposal can meet a substantial part of dredging costs by sale of the new prime urban land created.

Raising the Dam. Storage can be increased by raising the dam under favorable conditions. The following three items need to be considered if raising of the dam is contemplated:

**Dam safety.** The safety of the dam and appurtenant structures need to be ensured for increased hydraulic loads caused by raising the lake level. The increase in seismic loads needs to be considered as well as ice pressure during extremely cold winters. Adequate structural modifications must be investigated and carried out.

**Spillway and stilling basin.** Hydraulic and structural adequacy of the spillway and stilling basin must be investigated and designs modified, if necessary, to ensure the integrity of these structures.

**Economical modifications.** Innovative and imaginative thinking is needed in delineating minimal and most economical but adequate structural modifications. A thorough examination of the capability of the existing structure, the increased performance needed for raising the lake level, and various conventional and unconventional means to achieve the objectives are needed.

**Structural Safety**

An inspection program should be implemented to ensure continued safety of the structure. The following steps are an integral part of such a program:

1. Check for structural deterioration, foundation settlement, and displacement of riprap on embankment slopes.
2. Check for foundation seepage, erosion, or undercutting.
3. Check for pore-water pressures through a system of piezometers.
4. Review spillway adequacy for the new hazard classification.
5. Take measures to correct any defects revealed in the above checks.

It is interesting, and at the same time awesome, to know that structural failure can empty a medium-sized lake in 15 to 45 minutes and cause a flood
peak that may range from 1 to 1.5 times the probable maximum flood (PMF). If the failure occurs under PMF conditions, the resulting flood wave may range from 2 to 2.5 times the PMF.

PRESERVATION OF LAKES

Preservation of lakes can be accomplished by reducing sediment input to the lake, improving lake operation to reduce sediment entrapped in the lake, and reducing shoreline erosion. Various considerations relevant to the four preceding methods follow:

Reducing Sediment Input

The following five steps, taken singly or pluralily, will be helpful in delineating main sediment-contributing areas, in planning and sequencing erosion control measures, and in developing suitable sediment-retention structures.

Soil Loss Equation and Soil Loss Potential. The Universal Soil Loss Equation yields estimates of soil loss potential. The equation considers factors such as soil characteristics, soil cover, slope and length, and rainfall in making loss estimates.

Effective Soil Loss or Delivery Ratio. All soil loss obtained from use of the Universal Soil Loss Equation does not reach the lake or reservoir. When a steep slope meets a gentle slope, a major portion of the eroded soil is deposited in the upper parts of the gently sloping land. This also occurs as a result of man-made obstructions, low-lying lands, and lush vegetation in portions of a flood plain. The ratio of sediment inflow into the reservoir or lake to the potential soil loss is termed the delivery ratio. A recent study showed it to be about 0.25 to 0.30 for five lakes in Illinois.

Partial-Sediment-Contributing-Area Concept. The area contributing to flow in a stream above a gaging station increases with increase in rainfall during a storm event. This is also known as the partial-contributing-area concept. Because overland flow is needed to carry eroded soil, a rational corollary will be a partial-sediment-contributing-area concept. Methodologies are needed for defining this concept in order to identify contributing areas.

Categorize and Prioritize Areas for Erosion Control. Prioritizing areas for erosion control will depend on the relative sediment contributions and the
costs of suitable measures to reduce erosion. Let us say that only 30 to 40 percent of area contributes sediment to the lake. The costs of erosion control over this or part of this area may be shared by farmers who benefit from reduced loss of precious soil and by the authority managing the lake for the benefit from reduced sediment inflow.

Check-Weirs Upstream of the Lake. Another option that may be considered in reducing sediment input into the lake is the construction of low sediment retention or detention weirs across the stream at suitable locations upstream. These sediments may be more easily and economically removed every four to five years than those in the lake.

Better Lake Operation

Optimal rules for operating a lake need to be developed to maximize the benefits from project purposes, e.g., water supply and recreation; reduction in sediment entrapment; low-flow releases to minimize adverse impacts downstream; and minimizing stratification in the lake. The philosophy of optimal operation can be stated as follows:

1. Derive optimal filling and release procedures which may reduce sediment entrapment and lake stratification.
2. Consider economics of low-flow releases for improving water quality downstream during low-flow conditions.
3. Dynamic optimal operation should change with change in societal attitudes, perceptions, and needs.
4. Significant reduction in sediment entrapment may be achieved by passing most of the high flows through scouring sluices or bays.

Water Quality

Some considerations in maintaining and improving the water quality of the lakes follow:

Chemical Contaminant Loads and Sediment Deposition. Many chemical contaminants are adsorbed on the eroded soil particles. As these eroded soil particles commence their journey to the stream and thence to the lake, they are subject to rolling, jumping, deposition, suspension, and entrainment. Research is needed regarding the bond between the contaminants and soil particles through all the
imposed stresses and tribulations to estimate the probability of their separation at various levels of stress.

**Reduction in Chemical Loads with Sediment Reduction.** The degree of reduction in various contaminant loads compared with the reduction in the sediments needs to be investigated. Such investigations can clarify whether reduction in sediment due to improved land management practices will lead to reduction in chemical loads as well.

**Major Chemical Contributors and Relief Measures.** A survey of major chemical contributors is the first step to invoke regulatory measures for control or reduction of chemical inputs subject to such control. Reduction at the source can be achieved by proper monitoring. This can save a lot of problems created by such contaminants themselves and by their interaction with others.

**Install Multilevel Intakes.** Deep lakes stratify during summer. The upper 6 to 8 feet of water may have dissolved oxygen (DO) in the range of say 6 to 10 mg/l, but the water below say 15 feet may have its DO reduced to a small amount, say 0 to 2 mg/l. For purposes of low flow releases as well as for water supply withdrawals, better quality water is possible by installation of multilevel intakes which provide the capability to withdraw water from the upper 6 to 8 feet of water.

**Chemical Treatment and Aeration.** It may be more economical and practical to resort to chemical treatment for controlling unsightly algal growths. Another method is providing means of aeration for lake destratification as well as improvement in DO concentration.

**Dredging.** Dredging increases the turbidity of water. This temporarily reduces clarity, thus affecting primary productivity. The spawning time for the fish lasts from spring to mid-summer, dredging may not be done during this critical period of fish activity.

**Reducing Shore-Line Erosion**

Shoreline erosion not only contributes sediments to the lake but also decreases the recreation potential of the lake. Two steps for reduction of shore erosion are mentioned here, though there will no doubt be others suited to particular site conditions.
1. Remove trees and brush that lie within the variation of lake levels if these cannot survive considerably long periods of submergence. Plant new types of trees and vegetation that are more resistant and less susceptible to submergence effects.

2. Develop physical and structural plans for protection of critical areas.
AN OVERVIEW OF IN-LAKE TREATMENT TECHNIQUES
FOR WATER QUALITY MANAGEMENT

V. Kothandaraman*

INTRODUCTION

Eutrophication is a natural aging process that affects every body of water from the time of its formation. Many interacting factors contribute to the overall process of eutrophication—a term more widely known to mean the nutrient enrichment of waters. The eutrophication of a lake system consists of the gradual progression from one life stage to another based upon changes in the degree of nutrient input or productivity. The youngest stage of the life cycle is characterized by low concentrations of plant nutrients and little biological productivity. Such lakes are called oligotrophic lakes. At a later stage in the succession, the lake becomes mesotrophic, and as the life cycle continues the lake becomes eutrophic or highly productive. The final life stage before extinction is a pond, marsh, or swamp.

As a lake ages, the degree of enrichment by nutrient materials increases. In general, the lake traps a portion of the nutrients originating in the surrounding drainage basin. In addition, precipitation, dry fallout, and in certain cases groundwater inflow are contributing sources. The shore vegetation and higher aquatic plants utilize part of the inflowing nutrients, grow abundantly, and in turn trap the sediments. The lake gradually fills in, becoming shallower by the accumulation of plants and sediments on the bottom and smaller by the invasion of shore vegetation, and eventually becomes dry land. The extinction of a lake is the result of enrichment, productivity, decay, and sedimentation.

Human activities, such as altering lake drainage basins, agricultural practices, deforestation, and urban development, have hastened the nutrient addition to natural waters. When the pollutants are of a nutritional type, the enrichment of the recipient water is greatly accelerated and the rate of aging is consequently greatly increased. In this way, cultural eutrophication can significantly alter the rate of the natural process and shorten the life expectancy of the affected body of water.

Because eutrophic lakes contain an abundance of available nutrients, biological production is high and results in nuisance growths which adversely affect man's use of the water body. Plants, particularly algae, are of primary concern because they utilize dissolved inorganic nutrients from the water and thus become primary producers of new organic matter on which aquatic animal life depends. In oligotrophic lakes the phytoplankton are represented by large numbers of a few species. An overabundance of algae is generally called an algal bloom. Lackey (1949) and later Fruh (1967) arbitrarily defined an algal bloom as 500 counts/milliliter of raw water sample.

With the increased productivity associated with accelerated rates of eutrophication comes the filling of the lake basins with organic materials which subsequently exert an increased oxygen demand on the overlying waters. The increased oxygen demand may result in total depletion of oxygen in the cooler bottom waters during the summer, accompanied by an increase in the products of decomposition, e.g., carbon dioxide, ammonia, hydrogen sulfide, and methane. These developing anaerobic conditions result in replacement of benthic organisms with less desirable types.

In addition to restricting fish populations, highly eutrophic lakes are aesthetically undesirable. Algal blooms produce taste and odor problems and create unsightly surface scums which discourage water-contact recreational activities. Accumulation of algal mass and dense weed growths are most pronounced near shore. The accumulated algal masses decay resulting in extremely foul-smelling conditions.

In addition to their deleterious effects on aesthetic and recreational aspects of the lake, excessive planktonic growths affect water supply resources. They create color, taste, and odor problems in water supplies and increase the rate of clogging of filters at water treatment plants.

Within the past decade, there has been a significant resurgence in this country to protect, rehabilitate, and restore lakes and impoundments which constitute a valuable and important segment of the nation's water resource. This paper gives a brief overview of the in-lake restoration schemes generally advocated.
REMEDIAL MEASURES

Two recent publications (Dunst et al., 1974; U.S. Environmental Protection Agency, 1973) provide excellent summaries of remedial measures which have been applied in lake rehabilitation programs. The information given below has been taken mainly from these two sources.

Measures which may be effective in the restoration and enhancement of the quality of lakes can be considered under the following two major categories:

Limiting nutrient influx
  - Point source nutrient removal and control
  - Nutrient diversion
  - Control of nonpoint sources of nutrients

In-lake treatment and control measures
  - Dredging
  - Nutrient inactivation/precipitation
  - Dilution and dispersion
  - Lake bottom sealing
  - Artificial destratification and hypolimnetic aeration
  - Sediment exposure and desiccation
  - Harvesting nuisance organisms
  - Chemical control of nuisance organisms
  - Biological control of nuisance organisms

The lake restoration techniques mentioned here have been employed either alone or in combination with one or more of the other techniques in lake restoration schemes. The U.S. Environmental Protection Agency (1973) report states:

"The approach to the rehabilitation of degraded lakes is two-fold: (1) by restricting the input of undesirable materials and (2) by providing in-lake treatment for the removal or inactivation of undesirable materials. Obviously, the only means of maintaining the quality of a lake once desired conditions are achieved, is by rigidly restricting the input of undesirable materials. In some lakes reducing or eliminating the primary sources of waste loading is the only restorative measure needed to achieve the desired level of improvement. Once the source of pollution is abated, natural flushing and dilution with uncontaminated water may result in substantial improvements in the quality of the lake. However, in many lakes, particularly in hypereutrophic lakes with slow flushing rates, in-lake treatment schemes may also be required before significant improvements will be realized. In-lake treatment alone, without controlling pollutional
inflows, cannot be termed a restorative measure as only the symptoms or products of eutrophication and pollution are treated and no permanent improvements in quality are achieved. In any lake restoration program, controlling the input of undesirable materials is the initial step towards permanent lake rehabilitation; all other remedial measures are supplementary to this action."

Nonpoint sources of pollution, which are incidental to land uses throughout the drainage basin of a lake, are a significant cause of lake degradation. Efforts to limit nutrients and sediment inputs from lands within drainage basins, for lake protection as well as rehabilitation, have followed two general lines: 1) structural and land treatment measures to intercept nutrients and sediments before they reach water bodies; and 2) regulatory approaches, particularly land use controls to restrict uses with direct or indirect pollution potential. Soil conservation practices like contour farming, grassed waterways, crop residue management, feedlot waste management, etc., fall into the first category. Regulations on fertilizer application, shoreline protection statutes, etc., fall into the latter category.

**In-Lake Treatment and Control Measures**

**Dredging.** Dredging is considered a feasible method of nutrient control for preventing the recycling of nutrients from lake bottoms (U.S. Environmental Protection Agency, 1973; Pierce, 1970). As indicated earlier, highly eutrophic lakes receive large amounts of autochthonous materials resulting from massive algal growths. Much of the organic material entering the hypolimnetic zones will not degrade rapidly because of the lack of oxygen. Dredging of the accumulated organic matter has thus been proposed as a remedial technique.

Investigation of 49 lakes and ponds led Pierce (1970) to conclude that very little information is available as to whether dredging improves or damages a lake's aquatic environment. Most of the dredging reported in the literature is for maintaining navigational channels or for increasing the storage of water supply lakes. Churchill et al. (1975) reported that with limited dredging in Lake Herman, South Dakota, over a period of three years, significant amounts of nutrient were removed. Wilbur (1974) reported selective dredging in the littoral zone of two lakes in Florida where an organic muck bottom was converted to a sandy bottom which supported desirable benthic populations. The dredging
effort was undertaken primarily to reverse the loss of a productive lake bottom and thus improve the gamefish population.

Lake bottom dredging experience in Lake Tummen in Sweden (143 acres, 6 feet mean depth), where the technique was adopted with the specific purpose of arresting the eutrophic trend in the lake, is worth mentioning here. The upper 2 feet of nutrient rich sediments were dredged. The phosphorus concentration of the lake water in the year following dredging was about 0.1 mg/l compared with values as high as 1.0 mg/l in the predredging period. Dissolved oxygen concentrations remained well above critical levels compared with total depletion in earlier years. Green algae replaced blue-green algae to a large extent, although phytoplankton production was still high. A general improvement in water quality has been observed (Dunst et al., 1974).

Dredging was also employed in Crystal Lake in Minnesota. This lake has a surface area of about 400 acres and a mean depth of about 15 feet. The effort was undertaken to minimize winter fish kills and reduce algal production. It is reported that no noticeable improvement in lake water quality occurred, but further lake deterioration has been arrested (Dunst et al., 1974).

Among the several disadvantages cited for dredging, the significant ones are:

1) Dredging operations are expensive
2) The operation may release nutrients from the sediments into the overlying waters
3) The nutrient content of the sediments may remain high at considerable depth, thus making it impossible to reach a low nutrient level in sediment
4) Turbidity resulting from the process may persist for a considerable time during and following operations
5) Satisfactory disposal of the spoils may be very expensive

There are several methods available for dredging sediments from the lake bottom. These methods can be classified as either mechanical dredging or hydraulic dredging. Pierce (1970) has presented a detailed discussion on the various types of equipment and the methods employed in lake dredging operations.
**Nutrient Inactivation/Precipitation.** This technique is viewed as a method of hastening the recovery of a lake from a eutrophic condition. The purposes of this in-lake treatment are:

1) To change the form of a nutrient to make it unavailable to plants
2) To remove the nutrient from the photic zone
3) To prevent release or recycling of potentially available nutrients within the lake.

In-lake nutrient inactivation techniques have been primarily directed toward phosphorus. Inactivants which have received the most attention are aluminum, iron, and calcium salts. Of these three, aluminum appears to be the only one applicable to lakes in Illinois. Calcium is ineffective in removing phosphorus at pH values less than 9. Ferric iron is undesirable because of its tendency to be reduced to the soluble state under anaerobic conditions. Peterson et al. (1974a) reported that compounds of lanthanium, zirconium, tungsten, and titanium used in laboratory tests were capable of removing phosphorus from lake water. Other materials being used or considered as coagulants include ion exchange resins, polyelectrolytes, fly ash, powdered cement, and clay.

Horseshoe Lake (surface area 22 acres; maximum depth of 55 feet) in east-central Wisconsin was treated in May 1970 for nutrient inactivation. As reported by Peterson et al. (1973), slurried alum was applied to the top 2 feet of water at a concentration level of about 18 mg/l (200 mg/l alum). The results of the treatment were: 1) a decrease in total phosphorus in the lake water during the summer following treatment; 2) no large increase in total phosphorus in the hypolimnion during the following two summer stratifications; 3) some increase in the transparency of the water during the summer following treatment; 4) short-term decrease in color; 5) an absence of the nuisance planktonic algal blooms that had been common in previous years; 6) marked improvement in dissolved oxygen conditions, particularly during the following winters; and 7) no observations of adverse ecological consequences.

The major drawbacks cited against this method of lake renovation are:

- The relatively high cost of treatment, particularly the manpower costs
- Possible toxic effects from the introduction of an excess of a metal
- Adverse biological effects from the formation of floc (the floc could conceivably suffocate aquatic organisms, as well as interfere with the benthic ecology)
Lack of information on the effective duration of the treatment (continued inflow of nutrients and bacteriologic and benthic organism activity could influence the longevity of treatment effects).

**Dilution and Dispersion.** This technique has been attempted to alleviate excessive algal growths and associated problems by reducing nutrient levels within the lake. This is accomplished by the replacement of nutrient rich waters with nutrient deficient waters and the washout of phytoplankton. Nutrient dilution has been attempted by two procedures: 1) pumping water out of the lake and permitting increased inflow of nutrient poor groundwater; and 2) routing additional quantities of nutrient poor surface waters into the lake.

The first procedure was used in Snake Lake in Wisconsin (Peterson et al., 1974b). Nutrient levels were initially reduced significantly and duckweed blooms were eliminated. Leaching from nutrient rich sediments limited the effectiveness in this particular case.

The second procedure has been tried in several places. Two of the most successful experiments were at Green Lake in Washington, and Buffalo Pound Lake in Canada (Dunst et al., 1974). After 5 years of flushing at rates of 3.5 times per year or less, and after some initial dredging in Green Lake, the blue-green algal standing crop was suppressed and there was a shift in dominance with the elimination of *Aphanizomenon*. Submersion levels of blue-green algae were attained after 4 years in Buffalo Pound Lake.

**Lake Bottom Sealing.** In lieu of physical removal of organic rich sediments, sediment sealing may provide control at less cost. Covering of bottom sediments with sheeting material (plastic, rubber, etc.) or particulate material (sand, clay, fly ash, etc.) can prevent the exchange of nutrients from the sediments to the overlying waters either by forming a physical barrier or by increasing the capacity of surface sediments to hold nutrients.

The problem encountered when covering sediments is the ballooning of the sheeting, or rupturing of the seal due to gas production in the underlying sediments. Sand and other materials of large size tend to sink below flocculant sediments. Clay, fly ash, bentonite, and other similar materials appear to be best suited for sediment covering.
Covering of sediment to improve lake conditions has been done at Marion Millpond, Wisconsin (University of Wisconsin, 1974). The 110-acre lake was treated in 1971 by the scraping of overburden to a sand substrate, providing a sand blanket, and covering a part of the lake sediments with black plastic sheeting anchored with sand and gravel.

Fly ash in combination with lime has been used for phosphorus removal and sediment covering in Lake Charles East in northeastern Indiana (Higgins et al., 1975) as a demonstration project. Treatment of a 7-acre portion of the lake required 2,000 tons of fly ash and 24 tons of lime at an estimated cost of $22,000. To prevent phosphorus breakthrough for an extended period, a 2-inch layer of fly ash seal was found necessary.

Artificial Destratification and Hypolimnetic Aeration. Artificial destratification and hypolimnetic aeration is a process by which the lake waters are oxygenated and circulated. This is accomplished by either mechanical water pumps or by compressed air released at the lake bottom. In the case of compressed air mixing, vertical water currents are generated as the bubbles rise to the surface. The colder and denser bottom water mixes with warmer surface water, then sinks to a level of equal density and spreads horizontally. Oxygen is added to the water directly from the compressed air as well as by contact with the atmosphere. As the mixing process continues, complete circulation is achieved, and the lake approaches uniform temperature and dissolved oxygen conditions from the surface to the bottom. The whole water mass becomes inhabitable by lake biota.

In contrast to total aeration, several types of aeration devices have been designed to oxygenate the hypolimnetic waters without disrupting thermal stratification. Typically, the aerator consists of a large diameter pipe which extends from the lake bottom to a few feet above the water surface. Water inlet ports are located near the bottom of the pipe and outlet ports are located below the thermocline. The bottom water is airlifted up the vertical tube. The rising bubbles are vented to the atmosphere and the water is returned to the hypolimnion.

The advantages of artificial destratification in eutrophic lakes are:
- With increased oxygen levels in the hypolimnion, there is a reduction in the anaerobic release of nutrients from the bottom sediments
- Oxidation of reduced organic and inorganic materials occurs in the water (this is particularly advantageous when the lakes serve as a raw water source, because taste, odor, and color problems caused by iron, manganese, and/or hydrogen sulfide are eliminated or at least minimized)

- The range of benthic populations is extended to the profundal region which was once anaerobic (an increase in the number of fish and a shift to more favorable species can result from the greater availability of food organisms)

- Favorable changes in algal populations occur with a decrease in undesirable blue-green species (this is a result of the lowering of water temperature of the algae between the euphotic and aphotic zones; however, there is no reduction in the productivity of the lake)

- Evaporation rates are reduced in summer with the reduction in surface water temperatures

- Artificial destratification often results in increased water clarity

- Winter fish kills may be prevented by maintaining sufficient oxygen levels under ice.

The disadvantages of artificial destratification include:

- Increased heat budget in the lake

- Aeration may temporarily increase water turbidity due to the resuspension of bottom sediments

- In most investigations artificial destratification resulted in a reduction in blue-green algae, but in other instances there had been no observable effect on blue-green algae

- The artificial destratification may induce foaming

- The oxygen demand of resuspended anaerobic mud may result in a decrease in oxygen concentrations, temporarily at least, that may kill fish.

Destratification in combination with copper sulfate treatment was tried in Lake Catherine, which is a part of the Fox Chain of Lakes in the northeastern part of Illinois. These lakes have a long history of nuisance algal blooms, fish kills, and other classic symptoms of hyper-eutrophication. The aeration system installed in Lake Catherine proved to be very successful, resulting in improved lake clarity, decreased algal abundance, a shift in algal species makeup
toward the more desirable greens and diatoms, and a significant decrease in the release of products of anaerobic decomposition (Kothandaraman et al., 1980).

Hypolimnetic aeration was applied continuously to Hemlock Lake in Michigan from June 14 to September 7, 1970 (Fast et al., 1973). Hemlock Lake is a eutrophic lake with a surface area of 6 acres and a maximum depth of 61 feet. Before artificial aeration, hypolimnion oxygen concentrations were typically zero below thermocline. Phytoplankton populations usually limited the Secchi disk transparencies. After initiating aeration, there was an initial increase in phytoplankton cell numbers. However, the standing crop decreased subsequently from 30,000 cells/ml to less than 500 cells/ml. Concomitantly, Secchi disk measurements increased to over 30 feet, the deepest ever recorded for the lake. Following aeration, zooplankton inhabited the deeper lake waters and their numbers increased until predation stress by fish caused zooplankton numbers to decline. The total number of zoobenthos increased although the biomass remained the same.

Sediment Exposure and Desiccation. Water level manipulation has been employed as a mechanism for enhancing the quality of certain lakes and reservoirs. The exposure of lake bottom mud to the atmosphere reduces sediment oxygen demand and increases the oxidation state of the mud surface. This procedure may retard the movement of nutrients from the sediments to the overlying water when flooded once again. Sediment exposure can also curb sediment nutrient release by physically stabilizing the upper flocculant zone of the sediments. Lake drawdown has been investigated as a control measure for submerged rooted aquatic vegetation, and as a mechanism for lake deepening through sediment consolidation.

Harvesting Nuisance Organisms. Harvesting of nuisance organisms is limited to macrophytes and some undesirable fish. Technical difficulties have precluded in-lake harvesting of algal cells. The technique has been advocated as a practical means of accelerating the nutrient outflow from lake systems. However, this technique alone is deemed inadequate for lowering nutrient supplies in lake receiving cultural enrichment (Neel et al., 1973). Removal of weeds and fish may hasten nutrient depletion after elimination of extraneous nutrient influx.

Mechanical control deals with harvesting and removal of aquatic plants from the water. Mechanical removal of plants allows immediate use of the
harvested area and the plants removed from the water are not available to
deplete dissolved oxygen resources and release nutrients for new plant growth.
According to a survey of mechanical harvesting used in 32 locations in the
upper Midwest, information on the acreage harvested, including the costs, was
not reliable. The high initial investment in machinery was the most serious
obstacle to implementing a management program. Costs for weed control by
mechanical harvesting were reported to vary from about $15 to $75 per acre.

Chemical Control of Nuisance Organisms. Nuisance algal blooms, dense
growth of macrophytes, and unbalanced fish populations often restrict various
recreational and domestic uses of surface waters. Chemical treatment has been
most widely used as a treatment method. Chemical treatment has the greatest
utility and justification in highly eutrophic lakes in which the nutrient supply
cannot be effectively controlled or in which nutrient input control measures
are envisaged sometime in the future. Based on the intent, chemical controls
can be divided into three categories: 1) algicides, 2) herbicides, and
3) piscicides.

Copper sulfate is probably the most widely used chemical for control of
blue-green algae, taste and odor producing algae, and some filter clogging
algae. Over 10,000 tons of copper sulfate are used for this purpose each year
in this country at concentrations ranging from less than 0.5 mg/l to more than
10.0 mg/l (Fitzgerald, 1971). The amounts of oxygen, organic matter, and
alkalinity in the water determine the dosages required for effective plankton
control (Fitzgerald, 1971; Mackenthun, 1969). For waters with alkalinity
greater than 40 mg/l copper sulfate at a rate of 1 mg/l for the upper 2 feet
of water regardless of actual depth has been widely used (Mackenthun, 1969). On
an acreage basis, the concentration would amount to 5.4 lbs/surface acre. For
lakes with alkalinity less than 40 mg/l, a concentration of 0.3 mg/l of copper
sulfate amounting to 0.9 lbs/acre has been suggested. The difference is mainly
due to the fact that the effectiveness of copper sulfate is reduced in high
alkalinity waters because of the formation of an insoluble precipitate of
copper basic carbonate. Chelated copper sulfate (cutrine), which does not
precipitate as readily as copper sulfate, has been employed successfully in
controlling noxious algal blooms (Dunst et al., 1974).
Copper sulfate has a low mammalian toxicity, is inexpensive, and is effective in controlling a wide range of plankton algae. However, instances of fish kills have been reported soon after copper sulfate applications. These were generally traced to improper application and excessive dosage rates. The toxic effect of copper sulfate on plants is caused by the inactivation of enzymes and precipitation of proteins by the divalent ion Cu$^{2+}$.

Copper sulfate may be applied in a variety of ways: bag dragging, dry feeding behind power boats, liquid spray, or airplane application of either dry or wet material. Application by blowing the chemical rather than by slurry has also been employed (Mackenthun, 1969). The advantage of the blower-type machine is the ability to treat a large surface area rapidly with a light dosing of material. Use of blower-type machines is dependent upon the wind for distribution of the chemical. However, there is always some loss of copper sulfate dust that is carried by wind to the shore of the lake. Helicopters have also been used in chemical distribution. The East Bay Water Company, Oakland, California, found that a more efficient treatment could be attained with a helicopter (Mackenthun, 1969).

Chemical algal control measures should be undertaken before the maximum development of algal blooms. Mackenthun (1969) suggests that it is a good practice to subdivide the total area into sections and control the nuisance in one section followed by treatment of other sections at intervals of 7 to 10 days. This procedure will ensure that sufficient dissolved oxygen is present to satisfy the demands of the decomposing algae.

The frequency of copper sulfate application varies from a single annual application to monthly applications during spring and summer. The continuous feed of copper sulfate to the inlet of a reservoir has also been reported (Muchmore, 1973).

The toxicity of copper sulfate toward humans presents no problem at the concentration levels normally used in lakes and reservoirs. Of concern, in long-term treatment of water supplies with copper sulfate, is the potential of accumulating harmful amounts of copper in the bottom sediments (Muchmore, 1973). The copper added as copper sulfate will end up in bottom sediments. Muchmore reports that a study of a group of Wisconsin lakes where copper in bottom muds of reservoirs that had been routinely treated with copper sulfate was considerably lower in concentration than the 9,000 ppm (dry basis) they
found necessary to affect bottom dwelling organisms. No difference in the
diversity of benthal populations could be attributed to the presence of copper.

Other algicides of some use are the rosin amines, triazine derivatives,
mixture of copper sulfate and silver nitrate, quarternary ammonium compounds,
organic acids, aldehydes, ketones, etc. Prows and McIlhenny (1973, 1974)
reported after examining more than 10,000 compounds that p-chlorophenyl-2-
thienyl iodonium chloride is an effective chemical for algal control. Based
on laboratory tests and limited field evaluations, the authors concluded that the
compound is safe to applicators, fish, and other higher aquatic plants and
animals; it has a fairly rapid degradation pattern under open atmospheric con-
ditions with a half-life of 1 to 2 days; and it exhibits a high degree of
specificity to nuisance algae, particularly Anabaena, Microcystis, Aphanizomenon,
and Oscillatoria. It must be pointed out that none of these algicides has
been used as extensively as copper sulfate.

Biological Control of Nuisance Organisms. This approach encompasses the
introduction or promotion of organisms that are inimical to the target organisms.
Dense growths of aquatic macrophytes were found to inhibit the growth of phyto-
plankton, both by direct competition for nutrients and by shading. One of the
natural ways in which algal populations are kept under control is through pre-
dation by zooplankton and fish species. Effective grazing by Daphnia and related
zooplankton on phytoplankton populations in a mesotrophic lake has been reported;
(U.S. Environmental Protection Agency, 1973). Dunst et al. (1974) reported that
suitable plankton feeding fish species are Tilapia mossambica, and its allies,
Hypophthalmichthys molitrix and Mugil cephalus.

Dunst et al. (1974) reported about the only deliberate in-lake treatment
to control blue-green algae by the use of virus. Blue-green algal scums were
apparently dissolved as a result of spraying cyanophages on the surface of a
lake in the U.S.S.R. Evaluation of biological controls has been limited, with
much of the testing conducted in laboratory and experimental ponds. In general,
biological control measures have met with only very limited success.
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IN-LAKE CONTROL OF NUISANCE VEGETATION:  
A REVIEW OF EIGHT PROCEDURES

G. Dennis Cooke*

INTRODUCTION

Eutrophication is a process which brings about excessive biological production and decreased lake or reservoir volume. Lakes which have become eutrophic often exhibit a group of undesirable symptoms, including decreased transparency due to silt and suspended organic matter, dissolved oxygen depletions and fish winterkill, nuisance rooted plants, increased abundance of rough fish, and taste-odor problems. Use of the lake for recreation may decline; industrial costs may increase as extensive pre-treatment becomes necessary; property values may change; and lake users may become increasingly frustrated as palliative measures to alleviate symptoms, such as herbicide use, become increasingly costly and fail to achieve anything other than short-term relief from the problem.

Section 314 of Public Law 92-500 (1972) provided for the administrative and technical requirements to develop a national program to improve the quality of public lakes and reservoirs of the United States. These requirements were retained in the 1977 Clean Water Act (P.L. 95-217). Section 314 requires the states to survey the trophic state of their publically owned lakes and reservoirs and to report the results to the USEPA. The states then describe the pollutant loading problems of their lakes, develop plans to control pollution sources, and implement watershed management and in-lake control and restoration procedures. Generally, funding for up to 70 percent of the cost is available from the Environmental Protection Agency (EPA). Additional details of the program are available (USEPA, 1980a), or may be obtained from the USEPA Region V Office, Chicago, Illinois, 60604.

An opportunity is thus available to obtain funds to protect and restore public bodies of water. The research and technology developed by the EPA (USEPA, 1980b), however, is available to everyone and can therefore be used

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to implement long-term protection and restoration of private lakes as well, although not with an expenditure of public funds.

WHAT IS LAKE RESTORATION?

In general, no projects are funded unless the project involves diversions of silt and nutrient income from the lake. In-lake methods normally will be futile unless causes are first attacked.

Even if substantial diversion can be accomplished, lake recovery may be greatly delayed by internal recycling of plant nutrients from sediments, by shallowness, and by long water retention time. In these cases, in-lake procedures may greatly accelerate the rate of lake recovery.

Several techniques for restoring lakes are known, and each can provide long-term relief from symptoms, following diversion, if properly selected and applied. In general, excessive shallowness and/or rooted plants can be treated by dredging, harvesting, sediment covers, or lake level drawdown. Lakes with excessive algae may benefit from nutrient inactivation, dilution/flushing, or aeration. In some cases, biological controls may be employed and even be beneficial where sufficient diversion is not possible.

Some lake treatments, while providing temporary relief, cannot be classified as lake restoration. Herbicides and algicides may be very acceptable for "spot" uses, but their use will not be supported by Clean Lakes funds since they are temporary measures and may cause more problems than they solve. Also, some commercial lake treatment firms employ "secret" methods wherein the materials and procedures to be used will not be explained. These latter treatments of lakes are to be completely avoided.

Lakes must be restored within the context of what is possible. Lakes which are naturally shallow and slowly flushing and which lie in fertile soils will probably always have rooted plants and algae. Not all lakes can be, or ever were, clear, blue, and deep. Most lakes, however, can be restored to usefulness in which the condition of the water reflects the desired activities of its users.

Finally, it is possible to prevent eutrophication of real estate lakes by planning the development before the lake is built. Septic tank systems rarely work for long periods since they require regular maintenance. The
usual case is for such waste disposal systems to eventually become perched water tables with leach field effluent draining to the soil surface and thence to the lake. Buffer zones of vegetation, terracing of lawns, pre-treatment of storm wastes, and other land management techniques will protect a newly formed lake and greatly retard the development of eutrophic conditions.

Lake restoration is thus a combination of land management to divert pollutants and to protect the lake, and the manipulation of the lake itself to provide long-term relief from the symptoms of eutrophication. There are no short-cuts to lake improvement. It may take as much energy to protect and restore it as was expended during its period of degradation.

IN-LAKE RESTORATION METHODS

Land management to divert pollutants and decrease income of materials to lakes and reservoirs is discussed elsewhere in this symposium. In this paper, steps to accelerate lake recovery following land management are briefly discussed. At present, there are seven techniques for which adequate research information exists. Sediment removal, harvesting, sediment covers, and lake level drawdown have been used to control rooted plants, and aeration/circulation, dilution/flushing, and nutrient inactivation may control excessive algae. Biological control of nuisance vegetation is still under extensive investigation and is generally not an established procedure.

Readers wishing more details about methods, costs, and effectiveness of the following procedures are urged to examine the literature cited in the text or to consult an expert in the area. Additional details of lake and land management are provided in a new publication (USEPA, 1980b). The section on in-lake restoration of that report, prepared by me, forms the basis of the following discussion.

Sediment Removal

Dredging, or sediment removal, is one of the most expensive and often the most disruptive of the in-lake techniques. The lake owners or manager therefore must be prepared to consider several questions before proceeding. Some of these questions require extensive on-site research. Detailed reviews of this technique have been published by S. A. Peterson (1979, 1980).
First, the sources of silt must be ascertained and proper land management to control them enacted. Sediment removal will be an expensive exercise in futility if silt income remains high after the operation is completed.

Sediment removal may be used to open channels to boaters, and to control algae and rooted plants. Control of algae production may occur if the sediments are a significant source of nutrients to the water column and/or if removal will expose a layer of sediments with low potential for nutrient release. Thus, a budget of substances (usually phosphorus) must be developed in order to ascertain the significance of nutrient release from these sediments. There is no point in sediment removal for algae control if they are not a significant nutrient source. Sediment cores also should be obtained to determine whether dredging can proceed down to a layer with low nutrient release potential. Control of rooted plants may occur if dredging deepens the lake to the point where plants are light limited. The Wisconsin Department of Natural Resources uses this formula:

\[ \text{Maximum depth of growth} = 0.83 + (1.22 \times \text{average summer water clarity, or Secchi disk, in meters}) \]

Sediment removal is generally a very positive step to take to improve lake quality. There are several negative environmental impacts which could occur, however. Resuspension of nutrients and soils may stimulate an algal bloom and oxygen consumption. Toxic substances stored in lake sediments may be released to the water column. Problems at the disposal site, particularly dike failure and insufficient capacity, often occur and discharge from the site may require treatment.

Costs of sediment removal vary widely with geographic area. S. A. Peterson (1979) estimates that costs in the Great Lakes area will be $1.34 per cubic meter ($1.02 per cubic yard). Effectiveness will depend upon many factors, including the extent to which sediments were a source of nutrients, the depth to which removal occurred, and the rate at which new silt enters the lake.

**Harvesting**

Aquatic plant harvesting, a procedure in which rooted and floating vegetation is cut and removed from the lake, is seldom regarded as a lake restoration technique unless the amount of nutrients removed per year exceeds the
net annual income. However, harvesting is at least as effective as herbicide use and is no more expensive. Harvesting has the advantages of being target specific and at the control of the lake owners or managers. Toxic materials are not introduced to the lake; no license is needed for operation; the lake can remain open for use during harvesting; and treated plants are not left to decompose, use oxygen, and release nutrients which may trigger an algal bloom. Some lake associations have used the cut plants for compost and mulch, and the possibility of generating methane is now under investigation. Additional information about harvesting is available in Burton et al. (1979), Breck et al. (1979), and Carpenter and Adams (1977).

Regrowth of rooted plants in the season after harvesting is apparently delayed if several cuts in one season are made, and if cuts are close to the sediments. Up to five or more acres can be harvested per day, giving users immediate access to the water.

The adverse effects of harvesting appear to be slight, although algal blooms have been known to occur. Costs range from $70-$100 per acre ($173-$250 per hectare), including labor, equipment, depreciation, and disposal. American-made harvesting equipment has appreciated in price in some instances. Costs can be lowered by designing an efficient harvesting plan and by buying a machine of a size appropriate for the area to be harvested.

**Sediment Covering**

Several materials, including fly ash, polyethylene sheeting, and fiberglass screens, have been employed to control nutrient release from lake sediments or to stop growth of rooted plants. This in-lake procedure has been reviewed by Cooke (1980a).

Fly ash is the fine particulate matter collected by electrostatic precipitators via the smokestacks of coal-fired power plants. It was originally believed that the adsorptive properties of fly ash as well as its cement-like consistency when added to water would make it a good agent for control of phosphorus release from lake sediments and control of rooted plant growth. However, field trials of the material have not been successful, apparently due to the high pH, loss of dissolved oxygen, and release of heavy metals. At this time, fly ash for lake restoration is not recommended.
Sheeting materials to control rooted plant growth can be very effective, although costly. Impermeable materials, such as polyethylene, have been found to be difficult to handle and must be perforated to allow escape of gases. A far better material, evaluated by Mayer (1978) and Perkins et al. (1980), is fiberglass screen. The screen is easily applied by skin or scuba divers, effective until silted over, and may be moved from one place to another. Costs are $8,700 per acre ($22,000 per hectare) or $140 for rolls measuring 7 x 100 feet.

Sediment covering is an effective and ecologically safe method for controlling rooted plants. Costs, however, are very high, and the material is recommended for selected areas such as docks, beaches, and boating areas rather than the entire shallow zone of the lake. One installation will be effective until siltation on top of it provides substrate for more plants. Periodic removal and cleaning are recommended.

Lake Level Drawdown

Lake level drawdown is used to control susceptible rooted plants by exposing them to conditions of dry cold or heat. At the same time, it creates ideal conditions for application of sediment covers, or for repair of dams, docks, and shoreline structures. A review of the technique has been published (Cooke, 1980b) in which 63 plants are reviewed for their responses to winter or summer drawdown.

This technique is species-specific. Only Chara vulgaris, Eichhornia crassipes (water hyacinth), and Nuphar spp. (water lily) have been shown to always decrease in abundance. Most, but not all, species of pond weed (Potamogeton spp.), Najas flexilis (naiad), and Alternanthera philoxeroides (alligatorweed) always seem to increase in abundance after drawdown. Thus, proper identification of plant species in the lake is important to successful control of plants by drawdown. Resistant species may spread rapidly after a drawdown. Failure to achieve control may also be due to a failure to achieve sufficient dewatering of the sediments.

Changes in lake level have been shown to improve sport fishing. Predation on small fish is said to intensify in the smaller lake volume, and spawning of small fish can be prevented by a summer drawdown.
This method of plant control is highly recommended, particularly where additional lake improvement steps such as repair of shoreline structures, sediment removal, or emplacement of sediment covers can take place. Lake managers must be certain to begin the refill process in time to avoid droughts.

**Aeration/Circulation**

Aeration is a procedure to introduce oxygen to the deep, stagnant, oxygen-free water of a thermally stratified lake, without disrupting the stratification. The procedure will free water of taste and odor and may also bring about a decline in nutrient concentration in deep water. There is little evidence that aeration will bring about control of algae, but it will provide an opportunity to establish a cold-water fishery. Algal grazers may escape predation in the upper lighted waters by migrating into the aerated waters during the day and then return to graze on algae at night. It is not known whether this will bring about control of algae. Aeration is also effective in preventing fish winterkill.

Artificial circulation is achieved by introducing air to the lake bottom at rates sufficient to overcome thermal stratification. In about half the reported cases, some control of algal biomass was achieved. In several instances, the species composition of the algal community has shifted from nuisance blue-green algae to more acceptable forms such as green algae. Taste and odor may be removed and new fish habitats created.

Neither aeration nor artificial circulation have been shown to consistently improve lakes with algae problems. Both procedures are effective in improving taste and odor, and in expanding fish habitat or preventing fish kills due to low oxygen. Further details of these techniques are found in Lorenzen and Fast (1977) and Pastorok et al. (1980).

**Dilution/Flushing**

Dilution is a lake improvement technique in which water of low nutrient content is added to the lake at a rate sufficient to lower the concentration of a nutrient to limiting levels. It has been shown to be very effective in the few reported trials. Flushing involves the addition of water at a rate which approaches the algal growth rate (water replacement every 2-3 weeks).
Welch (1979, 1980) has reviewed the two techniques. Either could prove to be successful means of controlling algae, but lake managers are frequently constrained by the unavailability of low nutrient water, or water in sufficient volume to flush the lake.

**Phosphorus Precipitation/Inactivation**

These procedures are used to control nuisance algae by lowering the concentration of phosphorus in the water column to limiting levels. Phosphorus precipitation is achieved by adding aluminum salts, principally aluminum sulfate or sodium aluminate, to the water column at a dose sufficient to remove phosphorus as a precipitate or sorbed to the visible "floc" of aluminum hydroxide which is formed when these salts are added to water with alkalinity. Phosphorus inactivation, which is the recommended technique, is an addition of aluminum sulfate or sodium aluminate to a lake in an attempt to obtain long-term control of phosphorus release from lake sediments. Neither treatment can be effective unless significant amounts of external nutrient input to the lake have been stopped. At present phosphorus precipitation and inactivation are used only for control of algae.

The amount of aluminum salt added to the water is the principal difference between the two techniques. With phosphorus precipitation, just enough aluminum is added to the lake surface to remove the phosphorus in the water column. While this procedure runs few risks of any side effects, no control of the recycling of phosphorus from lake sediments is achieved and long-term control of algae usually does not occur. Phosphorus inactivation is achieved by adding as much aluminum salt to the lake sediments as possible, short of developing toxicity problems for lake biota. Long-term (5-6 years or more) control of phosphorus recycling and algal biomass is usually obtained.

The dose of aluminum sulfate which can be added to a lake for phosphorus inactivation is dependent on lake alkalinity, and thus varies from lake to lake. Dissolved aluminum, which can be toxic to fish when its concentration reaches about 50 μg Al/1, will not appear until pH falls to 6.0. Thus, for lakes with moderate to high alkalinity, a dose sufficient to control phosphorus release can be achieved by adding aluminum sulfate until pH 6.0 is reached. For soft water lakes, a mixture of sodium aluminate and aluminum sulfate can be
added. The pH will not fall; toxic levels of aluminum will not be reached, and phosphorus cycling will be controlled.

There have been at least 28 full-scale lake treatments with aluminum salts. In those few for which published monitoring data are available, there has been no evidence of toxicity to fish or benthos, and in the two cases with long-term monitoring, lake trophic state was immediately improved and has remained so for 5 or 6 years after treatment.

Costs of this type of lake treatment are high, due largely to labor which is about 1-2 man days per hectare. Equipment and chemicals cost $400-500 per hectare.

This method has been reviewed in detail by Cooke and Kennedy (1980) and Kennedy and Cooke (1980), with regard to dose, application methods, case histories, and costs. Both publications offer simplified procedures for dose calculations.

**Biological Controls**

Nuisance vegetation in lakes has been attacked by various physical and chemical means. Few of them offer any lasting control, and some offer nothing but high expense and perpetual re-treatment. Can we manipulate the food webs of a lake by adding a species or by enhancing the populations of species already there in such a way as to reduce vegetation to acceptable levels without machinery or chemicals? With few exceptions, there are no operational biological controls for problems of excessive vegetation, perhaps reflecting our truly meager knowledge of the biology of lakes and reservoirs and our even more meager support of research in aquatic biology.

Plant pathogens, exotic insects and fish, and manipulation of planktonic food webs are all under careful study. With few exceptions, such as insect control of alligatorweed, the introduction of exotic organisms to control nuisance plants is being viewed with great caution by aquatic scientists. A step-by-step approach should be taken since some exotics, such as the common carp which was introduced to our waters as a food organism, may cause as much damage as benefit. Reviews of progress are found in Schuytema (1977) and Cooke (1980c).
The white amur (*Ctenopharyngodon idella* Val.), or grass carp, is an exotic fish which may be of benefit to lakes with problems of rooted plants. Preliminary tests in Iowa and Arkansas suggest that plants will be removed by the fish without harmful side effects. Yet, there are many unanswered questions about this fish. It is a notorious spreader of fish diseases in Europe, and a serious tapeworm pest to European game fish has been found in grass carp in this country (Riley, 1978). Forester and Lawrence (1978), in contrast to the report of Bailey (1978), have found that grass carp interfere with populations of bluegill and red-eared sunfish. Additional work must be done on the question of whether the grass carp will recycle nutrients at a rate sufficient to stimulate algal blooms.

At this time, research with grass carp has not progressed to the point where its widespread and indiscriminate use is justified. We have lived with nuisance plants for years and we can afford to do so until the research has been done.

Shapiro et al. (1975) called the alteration of food webs "biomanipulation," a lake improvement technique in which populations of grazers of algae are increased by decreasing the predation on them by small fish. Shapiro has good evidence to suggest that higher water clarity will result if large-bodied zooplankton are relieved of intense predation and allowed to graze on algae. This result may be brought about by removal of small fish through winterkill, use of fish poisons, or introduction of fish predators. Also, aeration of deep waters could provide a habitat where these algal grazers could escape the intense visual predation of daylight, and then return to the upper waters to graze on algae at night. Biomanipulation or other biological controls may be the only answer to some lake problems, particularly where diversion is not possible.

**SUMMARY**

Improvement of lakes is possible if the sources of plant nutrients and of silt are controlled. Following this step, both rooted plants and nuisance algae may be limited by restricting light, preventing their growth by physical barriers or cutting, and by controlling the recycling of nutrients from
storage in lake sediments. Many of the techniques briefly reviewed here have thorough literature reviews available which discuss costs, effectiveness, side effects, and procedures. These reviews are cited in the references section.

Lake restoration does not include the treatment of symptoms alone. Thus, herbicidal chemicals, while briefly effective, are not lake restoration agents and may be responsible for more problems than they solve. Lake restoration includes land management to control sources of the problem and in-lake manipulations to give long-term control of plant growth. An adequate lake management plan may require resources and time, but it will also give lasting control of eutrophication.

REFERENCES


DREDGING IN ILLINOIS

W. J. Roberts*

The Midwest is not alone in having serious and expensive water problems. The availability of relatively abundant fresh water has been taken for granted, and periodic shortages caused by droughts have not always taught their lessons. Today we are faced with many public water supplies that are apparently adequate only because of fortuitous runoff. Any appreciable lack of runoff will place them in severe difficulty.

Loss of storage is one of the greatest problems facing most Illinois water supply lakes. High rates of sedimentation have greatly shortened the useful lives of many such impoundments. Cities are finding that the accumulated deferred maintenance of reservoirs is more than they can afford. However, a few cities have tried to rehabilitate their lakes by removing sediment, and their efforts are worth examining.

The U. S. Army Engineers have done practically all the important dredging operations in Illinois. Their work has been confined to Lake Michigan, the Illinois River, and surrounding rivers. During the early 1950's the city of Macomb attempted to remove sediment from its Spring Lake by installing a cutterhead dredge and pumping the sediment over the spillway. The project was active for only a short time before the State Sanitary Board stopped the operation. The project would probably have had a short life anyway, because the cost of operating the large inefficient dredge was five times greater than the city had anticipated.

Dredging has been used for specific projects such as opening navigation channels in the Chain-of-Lakes in northern Illinois or for cleaning out the sediment that collected in the Caterpillar Company lake near Peoria.

The availability of small portable dredges in the past fifteen years has made it possible to remove sediment hydraulically from small lakes. There are several varieties, but two main types, the cutterhead and the horizontal auger, have been used successfully in Illinois. The cutterhead has a hydraulically operated auger which rotates in an arc as it digs into the lake bottom. Lake water is pumped to dilute the sediment and carry it by pipeline to a spoil area.

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The second type of dredge, such as the Mud Cat, has a horizontally rotating auger which moves along a narrow path and directs soft sediments to its midpoint where a suction line provides a flow of lake water to transport the solution by pipeline to the disposal area.

The cutterhead dredge maintains its position in a reservoir by means of an onboard swing winch. This is a hydraulically operated drum around which cable is coiled. Lateral movement of the cutterhead is controlled by the swing winch working on a 5/8-inch steel cable anchored to opposite shores. Two anchor spuds at the stern of the dredge alternate as foci around which the cutterhead rotates 90° horizontally. When the cutterhead reaches the end of its arc to the left, the right spud is depressed into the bottom sediment and the left one is raised. As the cutterhead makes a 90° arc around the right spud, the dredge moves forward a distance equal to one-half the space between the spuds. In this manner the dredge movement is controlled.

The auger-type dredge clears a path through the sediment 8 feet wide and has a maximum cut depth of 18 inches. The dredge movement, both forward and reverse, is controlled by a guide cable attached at opposite shore points ahead and behind the dredge. The average cutting speed is 8 to 12 feet per minute. After each traverse across the lake the cable is moved laterally 8 feet.

DREDGING EXPERIENCES

Carlinville, in western Illinois, is a city that has had some experience with removing silt from its municipal reservoir by means of a cutterhead dredge. Lake Carlinville had good operational records which were valuable in project planning. The lake was built in 1937 and originally had a surface area of 220 acres and a capacity at spillway crest elevation of 562 million gallons. The area of the watershed is 26 square miles. A sedimentation survey made on the lake in 1949 showed that the storage capacity had decreased by 110 million gallons while daily pumpage had steadily increased. The demand for more water from an impoundment that was decreasing in capacity prompted the city to purchase a small portable cutterhead dredge. A spoil area adjacent to the lake was compartmentalized into three basins so that the slurry discharged from the dredge moved in a circuitous path that permitted maximum deposition of silt before the water released from the last basin was returned to the lake.
Carlinville spent $89,000 which covered purchase of the dredge, pipe, and preparation of the spoil area. The city had planned to operate the dredge with water department employees but unforeseen circumstances caused the city to suspend operations and dispose of the dredge after only three summers of operation.

It should be mentioned that even though the spoil area had not been tile drained, it was farmed successfully as soon as dredging was terminated. After leveling, the area produced 45 bushels per acre of winter wheat without addition of fertilizers, so rich in nutrients was the silt.

The dredge was operated an average of 41 days per year and moved approximately 125,000 cubic yards of silt. This increased the lake storage by 22 million gallons. Although the cost of dredging averaged 66 cents per yard, the loss suffered on the sale of the equipment put the final cost per yard close to $1.80.

The most successful dredging project on small lakes in Illinois was accomplished at Oakland, Coles County. Here a horizontal auger-type dredge, known commercially as a Mud Cat, was used for a four-year period. The lake at Oakland covers 26 acres, but it has a watershed of 14.3 square miles. It was inevitable that such a large drainage area feeding a small impoundment would result in rapid build up of sediment in the lake. During 32 years of its life the lake lost 56.2 acre-feet of storage, approximately one-half its volume.

The city leased a 15-acre plot of rolling uncultivated land near the upper end of the lake and installed tile drains and drop-inlet spillways. A total of 95,198 cubic yards of sediment was removed from the lake during the four years of operation at an overall cost of 76 cents per yard. It should be noted that the lake sediment converted the rolling spoil area into a flat field that is now being farmed.

Two small residential lakes should be included in this report since they demonstrate both good points and weakness of dredging as a permanent solution to lake sedimentation.

A small residential lake near Mahomet was constructed in 1956, and it had suffered a loss of storage of 3.4 percent per year due to its seven-square-mile watershed supplying runoff to a 32-acre impoundment. The lot owners association purchased a Mud Cat dredge and used it during five summers. About 100,000 cubic yards of sediment continues to enter the lake at the same high rate, and in another 15 years the dredging will have to be repeated.
In contrast, another small six-acre residential lake south of Champaign found itself filled with sediment. It has a watershed of 0.8 square mile. Since there was no water available for transporting the sediment, a dredge could not be used. The area was drained and 22,300 cubic yards of dry lake bed were removed by trucks. In addition, a one-acre sedimentation pond was constructed above the lake and a bypass channel constructed around the lake. While the lake was empty, owners of shore property sculptured their borders so that when the lake was refilled it had a stable attractive shoreline. This little lake should experience a long useful life since all flood flows will be routed around the lake, and the upstream pond will collect most of the sediment.

There are other dredging projects being carried out in the state, and the ones used in this report happened to have fairly good records. Dredging represents one way of rehabilitating a lake. A study of alternative measures should be made before resorting to a dredging program. However, many towns have waited too long for action and, like Flora, no longer have a lake to enjoy.
LEGAL ASPECTS OF RECLAIMING LAKES

David R. Boyce*

There are three regulatory agencies from which one may need approval for lake restoration by dredging. They are the Illinois Department of Transportation (IDOT) Division of Water Resources, the Illinois Environmental Protection Agency (IEPA), and the U.S. Army Corps of Engineers. In addition to the three regulatory agencies, input and comments are generally provided by other state and federal agencies, including the Illinois Department of Conservation and the U.S. Fish and Wildlife Service. I will describe the permit authority and procedure of IDOT's Division of Water Resources in some detail and indicate briefly the permit requirements of the Corps of Engineers and the IEPA, including the interrelationship of the permit functions.

The regulatory authority of IDOT's Division of Water Resources originates in the 1911 Rivers, Lakes, and Streams Act, as amended (Ill. Rev. Stat., Chap. 19, Sec. 52, et seq.). The department's regulatory program is based on three fundamental principles: 1) the protection of the public waters of the state against wrongful encroachment or violation of the public interest; 2) prevention of flood damage or increase in flood damage potential due to construction in or near the state's rivers, lakes, and streams; and 3) the preservation of the natural conditions of the state's rivers, lakes, and streams. For the sake of brevity, I will confine my remarks to the application of these principles to lake restoration through dredging.

Lake dredging, per se, requires a permit from IDOT only if dredging from a public body of water is proposed. The Rivers, Lakes, and Streams Act defines public waters as, "All open public streams and lakes capable of being navigated by watercraft in whole or in part, for commercial uses and purposes, and all lakes, rivers, and streams which in their natural condition were capable of being improved and made navigable, or that are connected with or discharge their waters into navigable lakes or rivers, within, or upon the borders of the State of Illinois, together with all bayous, sloughs, backwaters, and submerged lands that are open to the main channel or body of water and directly accessible thereto." Rather than attempt, at this time, to further define

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which streams are public (some are obvious—like the Mississippi and Illinois Rivers), I will discuss only lakes as public waters. Of course, we would all recognize Lake Michigan as a public body of water. Also included are the lakes in the Fox Chain-O-Lakes and several backwater lakes along the Illinois and Mississippi Rivers.

A permit may also be required for disposition of the dredged material, depending on where it is to be placed. While dredging in a private lake (e.g., Lake Decatur) does not require a permit from IDOT, disposing of the dredged material may. Indeed, it is the disposal of the dredged material which generally represents the greater problem, from a regulatory point of view, than the actual dredging. An IDOT permit for disposal is required if the material is to be disposed of in a river, lake, or stream, or in the floodway of a river or stream draining ten or more square miles in a rural area or one or more square miles in an urban area. The floodway is defined as that portion of the floodplain required to store and convey flood water with no significant increase in flood damages when determined by hydraulic analysis using the 100-year-frequency flood discharge.

Upon receipt of an application for permit for dredging and/or dredged material disposal, IDOT issues a public notice to interested state and federal agencies, local officials and adjacent property owners. The proposal is reviewed to assure that the activities outlined in it will not encroach on the public interest (for example, by making land); will not result in unacceptable adverse effects on the natural conditions of the state's rivers, lakes, and streams; and will not result in significant, uncompensated flood damage or flood damage potential to other property. For information regarding potential adverse effects on natural conditions, IDOT relies primarily on input and advice from the Department of Conservation. An example of a natural condition impact to be avoided would be the destruction of critical habitat of an endangered species. IDOT has developed various guidelines and criteria to avoid potential increased flooding damage by limiting increases in water surface profile elevations and velocity and decreases in natural valley storage. Increases in water surface profile elevation for the same flood event will, of course, inundate more area and potentially increase flood damage on adjacent
and upstream property. On the other hand, increased velocities and loss of valley storage can result in higher peak flood discharges for the same volume of runoff, thereby potentially increasing flood damages downstream of the proposed dredged material disposal site.

Approval for dredging and dredged material disposal may also be required from the Corps of Engineers and the IEPA. Permits are required from the Corps under Section 10 of the Rivers and Harbors Act of 1899 for dredging from "navigable waters of the United States" and under Section 404 of P.L. 92-500 (Clean Water Act) for deposit of dredge or fill material below the ordinary high water line or within designated wetlands. The prime interests of the Corps' regulatory program are protection of navigation and water quality, although comments are solicited regarding the effects of the proposed project on, "conservation, economics, aesthetics, environmental concerns, fish and wildlife values, flood damage prevention, welfare of the general public, historic values, recreation, land use, water supply, water quality, navigation, energy needs, safety, and flood production."

Generally, whenever a proposed construction activity would require a Corps or an IDOT permit, a certification of water quality standards (or waiver) will be required from the IEPA under the provisions of Section 401 of P.L. 92-500. In addition to certification or waiver, permits may be required from the IEPA under state law for dredge spoil disposal. If the material to be disposed of is found to contain substances with a pollution potential, either a Chapter 3 (wastewater treatment permit) or a Chapter 7 (hazardous waste landfill) permit may be required.

Although each of the three regulatory agencies operate under separate statutory authority and have primary interests in different aspects of dredging and dredged material disposition, there is a certain amount of overlap in data needs and processing requirements. In order to avoid unnecessary burden to the applicant, the three agencies coordinate their regulatory functions to the extent possible. For example, efforts are currently underway to develop an application-for-permit form to be used jointly by the three agencies. Future plans call for consideration of joint public notice issuance and other coordinated efforts.
In conclusion, it is important to remember that when contemplating lake restoration through dredging, three regulatory agencies at the state and federal level may be involved: the Illinois Department of Transportation, the Illinois Environmental Protection Agency, and the U.S. Army Corps of Engineers. The principle items reviewed by the agencies are environmental considerations, water quality considerations, and impact on flooding potential. Each of the three agencies are more than willing to discuss potential projects with respect to their particular concerns.
LAKE LANSING RESTORATION--ITS GOALS, SUCCESSES AND DISAPPOINTMENTS

Richard L. Sode*

Lake Lansing is a 450-acre public access lake and the only major water recreational facility within a 30-mile radius of the Greater Lansing Area. It has a drainage area of about 1,765 acres for a drainage basin/surface area ratio of 4:1.

Although Lake Lansing currently provides major recreational benefits for a large part of the Greater Lansing urban population, which is about 500,000 people, its potential through restoration is many times the present use. It is currently used by the Lansing Sailing Club, the Michigan State University Sailing Club, and by a significant number of boaters and fishermen. The Ingham County Parks Commission presently has two public parks on the lake: an older swimming park on the north side with 280 feet of frontage, and the newly developed 30-acre, all purpose park, with 1300 feet of frontage on the west side. This area was developed at a cost of $2,000,000. In addition, the county is finalizing plans to develop a 250-acre park with natureways and cross-country skiing on the northeast side of the lake.

Lake Lansing is an intermediate sized eutrophic lake. It is generally shallow with an average depth of about five feet (1.7 meters). Only about 10 percent of the lake is deeper than 10 feet, extending to a maximum depth of about 30 feet. Two deep-water areas in the lake are characterized by depleted oxygen in the hypolimnion during both summer and winter. Substantial concentrations of carbon dioxide are produced in the hypolimnion, reflecting the relatively large quantity of organic matter which is produced and degraded annually. In addition, dissolved oxygen is generally less than saturation, even in surface waters. The water quality in the lake is considered excellent and is estimated to be ten times as good as it was prior to the construction of sanitary sewers around the lake in the early 1960's.

As far back as 1963, Jackson described the lake as rapidly aging and containing a prolific abundance of floating, emergent and submergent vegetation.

*Project Director Ingham County Department of Public Works, and Drain Commissioner, Lansing, Michigan
The lake as it currently exists is weed clogged from about the middle of June until late fall. This weed problem creates serious limitations for all water-related recreational uses of the lake particularly sailing, boating, skiing, and fishing. In addition, excessive weed growths are believed to shelter small forage fish from predators who are unable to keep them in check, creating many stunted panfish.

PROJECT DESCRIPTION

The original program as proposed called for the removal of 2 million cubic yards of bottom sediments. Due to changes in the locations of spoil disposal areas and the associated costs of development and filling, it has become necessary to reduce the volume of dredging. The project, as currently envisioned, would remove 1,610,000 cubic yards which is approximately 80 percent of the original volume. The plans for the reduced project call for leaving a few priority areas undredged for spawning and feeding purposes as well as a cost-saving measure.

Removal of the bottom sediment is being accomplished with a hydraulic dredge. This method consists of pumping the dredged materials through a pipeline to the spoils disposal sites. The excess water is allowed to return to the lake after the sediment has settled. It is anticipated that 60 percent or more of the water removed during the dredging process will be directly returned to the lake. A supplemental water supply from a well is in place so that the lake level can be maintained within two feet of the established legal level.

After the spoils have been dewatered and settled, the areas will be graded and seeded so that they can be used for recreational purposes.

In addition to the sediment removal, the shoreline will also be improved. Many sections of the shoreline are now sandy; however, most of these areas are too shallow for optimum use. Other portions of the shoreline are soft and mucky and restrict access to the lake. The planned improvements consist of redistributing sand from the shallow sandy areas to those without sand. Cleaning and grading of the shoreline is also planned, except for those sections which are viable fish and game habitats.

Various aspects of the project have been approved by the Michigan Department of Natural Resources, the U.S. Fish and Wildlife Service, the
U.S. Army Corps of Engineers, and the Michigan Environmental Review Board. All required documents have been submitted to the U.S. Environmental Protection Agency. The Michigan Department of Natural Resources issued the state permit for the dredging operation on May 5, 1978; and Michigan State University conducted the archaeological survey of the spoils disposal sites. Aquifer performance testing was also conducted.

GOALS AND OBJECTIVES

The primary goal of the project is to restore the recreational potential of Lake Lansing. Recreation potential is generally defined as a site's capacity to provide active and/or passive recreational opportunities after appropriate development. Restoration will include the reduction of excessive aquatic vegetation and the removal of sediments which have significantly decreased the lake's average depth and apparently act as a substantial nutrient reservoir. Another goal of the proposed project is to evaluate hydraulic dredging as a lake restoration technique so that the knowledge gained can be transmitted to other concerned parties and agencies interested in determining the impact of similar projects.

The following objectives must be attained to achieve the project goals:

1. To develop and implement the most environmentally sound and economically feasible restoration program for Lake Lansing based upon modern restoration techniques.

2. To design and implement a program of study to document the suitability of various subsystem approaches within the selected restoration plan.

3. To design and implement a study to document the results of the selected restoration program. (A proposal to develop a study of this nature has been presented to the EPA by Dr. C.D. McNabb, Jr., of Michigan State University, and this grant has been approved as well as other grants related to the Lake Lansing Project.)

PROJECT COST AND FUNDING

The project is, in part, funded as a Research and Demonstration Project through Section 314 of PL 92-500, as amended. Provisions of this law allow a maximum grant of 50 percent of qualified project costs. Therefore, of the original project cost of 2.6 million dollars, 1.3 million dollars had to be
generated from other sources to match the USEPA grant. To date, funds have been committed by Ingham County, Meridian Charter Township, the Cities of East Lansing and Lansing, and a special assessment district including benefiting properties surrounding Lake Lansing, as well as a State Cash Grant of $135,000 (Appendixes I and II).

UNANTICIPATED PROBLEMS

Hydrogeological

Significant problems which have arisen but were not originally contemplated from the hydrogeological point of view are:

1. Hydrogeologic budget and need for supplemental water supply at originally proposed dredging schedule.

2. DNR requirement that arsenic and mercury be added to the parameters tested for in the groundwater sampling.

3. Relocation of all spoil sites from primarily wetland areas to all upland sites—THIS WAS THE MOST SIGNIFICANT PROBLEM.

4. Frequency of groundwater quality sampling was increased from twice a year to weekly for the first three months of spoil site use and monthly thereafter as a result of DNR directive.

5. Legal action associated a township, a homeowners association, and individual property owners.

6. Failure of a dike and its associated ramifications.

Legal

The catalog of legal problems that have arisen, but which could not be anticipated, were the major construction delay, as well as over 500 thousand dollars in unexpected costs. The major legal problem is one which is more human than perhaps legal. There were, and are, some individuals in the vicinity of Lake Lansing who, for whatever reason, are antagonistic to the project. Additionally, several statutes of the State of Michigan gave those individuals or entities a wedge to urge an interpretation of a statute or statutes which had not been resolved by prior case decision. Specifically, I make reference to the portions of Act 185 in controversy with
Bath Township, the Michigan environmental statutes, as well as the state of the law in regard to the jurisdictional split between the Tax Tribunal and the Circuit Court. Many of these questions have not been resolved by appellate decisions. In addition, the legal interpretation of responsibility between federal agencies has caused more than one project delay. Consequently, higher project cost was encountered.

**Engineering**

1. DNR requirements for an Environmental Impact Statement versus an Environmental Assessment (9/29/76).

2. Subsequent loss of planned "wetland" spoil areas and resultant investigation to search for approvable "upland" spoil sites.

3. Subsequent reduction in dredging scope (2.1 million cubic yards to 1.6 million cubic yards) due to increased costs to construct and pump to upland spoil sites. Reduction in scope occurred after receiving bids but prior to contract award and necessitated the three underwater islands previously mentioned.

4. Requirement of lake level augmentation well(s) to maintain the legal lake level within a 2-foot drawdown variance as required by the DNR permit dated 5/5/78.

5. Reduction in lake level variance (planned on 4-foot drawdown) may cause the beach cleaning and sanding operations to take considerably longer to complete due to the extra two feet of lake water. Planned construction methods and techniques may not be as appropriate as per planned 4-foot drawdown.

6. Design and construction of a lowhead dam and mitigative ponds prior to the anticipated use of a spoil site.

7. Design and construction of a toe drain on the east side of another spoil site to intercept groundwater and surface drainage affecting a private drive, which was questionable as to need, but cheaper to construct than fight over in Court.

**PROJECT COST**

It was difficult enough to put together multiple municipal participation including a special assessment district of local property owners
as well as state and federal agencies during the height of the anti-tax movement, yet like most projects during this period of high inflation and the maze of unexpected problems, we, too, find ourselves once again in an extremely painful position of coming up with the funds of what was a 2.5 million dollar project and now has soared to 3.8 million dollars--a major problem we are presently attempting to resolve.

Surface Water Monitoring

Snell Environmental Group, Inc., is obtaining and analyzing the surface waters collected at the discharge location of each spoil site, the inlet of the lake, within 50 feet of the dredge, and at a large location from within the lake. The water samples are being tested for the following parameters: total phosphorus, ortho phosphorus, inorganic nitrogen, kjeldahl nitrogen, chlorophyll a, alkalinity, temperature, dissolved oxygen, pH and turbidity.

Ground Water Monitoring

Keck Consulting Services, Inc., is obtaining and analyzing the ground waters collected at observation wells around each of the spoil sites. Samples are collected weekly at each site for the first three months and monthly thereafter. The collected samples are being tested for the following parameters: BOD, total kjeldahl nitrogen, total phosphorus, dissolved oxygen, hardness (CaCO₃), total solids, iron, calcium, nitrate (nitrogen), pH, mercury and arsenic. Mercury and arsenic are being tested weekly for the project duration. In addition to chemical monitoring, groundwater levels are being monitored to determine the effect of spoil sites on the local groundwater levels.

Pre-and Post-dredging Monitoring

Michigan State University (MSU) under the direction of Dr. Carl McNabb, has the responsibility to establish a nitrogen and phosphorus budget on the lake. Surface water samples have been collected at lake inlet locations prior to dredging and sample collection is planned to re-commence after the dredging project is completed. MSU has also conducted a predredging arsenic study and plan to follow up with a postdredging study on arsenic.
## APPENDIX I. LAKE LANSING EXPENDITURE RESPONSIBILITIES

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## APPENDIX I. LAKE LANSING EXPENDITURE RESPONSIBILITIES (cont.)

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## APPENDIX II. LAKE LANSING PROPOSED BUDGET (cont'd.)

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APPENDIX III. PROPOSED NEW BUDGET

Existing Budget

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New Budget

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- EPA $811,180.50 increase share

Local Funding Needs

- $2,067,138.00 new match
- $1,362,000.00 (funds available see below)
- $705,138.00 short fall
- $165,000.00 (interest earned and projected)
- $540,138.00 match needs for increased budget

Funds Available

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$1,362,000

Funding Sources:

1. EPA
2. Contractor Insurance
3. DNR
4. Local Units
5. Other Grants
CONTROLLING SEDIMENT BY WATERSHED MANAGEMENT TECHNIQUES

Harvey Sundmacker*

Sediment damage to lakes in Illinois is a result, in most cases, of soil loss from cropland. Often times, eroding cropland is being farmed to continuous corn and soybeans and is tilled close to drainage systems resulting in high delivery rates of sediment. Since cropland is usually the land use contributing most of the sedimentation problem, I will discuss the conservation practices most often applied to eroding cropland.

Conservation tillage has been proven to be a satisfactory method of tillage that provides excellent erosion control. To understand how conservation tillage controls erosion, it is necessary to have an understanding of the erosion process. It begins as the raindrop impacts on the soil surface. The explosive energy of the raindrop detaches soil particles, making them subject to transport by runoff water. Interception of the raindrop before it strikes the soil surface is one of the key factors in controlling soil erosion. Crop residues on the soil surface intercept the raindrop before it hits the soil surface, dissipating much of the raindrop impact energy.

The time that crop residues remain on the soil surface is extremely important for conservation tillage to be effective in controlling soil erosion. Some people feel that chisel plowing in the fall is conservation tillage. It is a start, but the real key is how much residue remains on the soil surface after planting. Most chisel plowed fields effectively control erosion from November 1 through April 15 (time of spring tillage operations). This period of time accounts for only 13 percent of the annual rainfall erosion index or erosive rains. From April 15 until crop canopy intercepts the falling raindrop (approximately July 1) 35 percent of our erosive rainfall occurs. Since residues overwinter and crop canopy after mid-year reduce the energy of the falling raindrop, our most critical period for soil erosion is after the start of spring tillage until crop canopy has developed. If we can protect our soil from erosion during this critical period we can control soil erosion in most cases.

*Soil Conservation Service, U.S. Department of Agriculture, Champaign, Illinois
In order for conservation tillage to be effective, crop residues have to be on the surface after planting. Amounts of residues remaining on the surface after planting will depend on the previous crop grown, variety of crop, type of tillage equipment, and depth and speed of tillage operations. We need to be concerned about the small amount of residues left after soybeans have been chisel plowed and even some corn fields which have been heavily disked and chiseled with wide twisted shanks.

Some farmers, who realize the importance and loss of soybean residue with the chisel plow, are no longer tilling in the fall. All residues are left on the surface over winter and the seedbed prepared next spring with a field cultivator. By eliminating the chisel plow, more residue is left on the surface for erosion control the following spring.

There are two dominant conservation tillage systems used in Illinois, the chisel plow and no-till system. Of these, the chisel plow is the most widely used. Crop residues are incorporated into the soil surface and left over winter. Secondary tillage operations in the spring leave residues on the surface and the soil in a "loose" condition with less compaction than with conventional tillage. During periods of heavy rainfall, the soil is able to absorb more rain water before runoff and erosion occur.

The no-till system provides for optimum erosion control. It has been popular in southern Illinois for several years and is gaining in popularity in the central and northern areas of the state. Seedbed preparation is done with a no-till planter which tills a narrow band of soil with a coulter where the seed is placed. Crop residues are left undisturbed between the rows providing protection from the raindrop impact.

Chemicals are applied on the surface for weed and insect control. Fertilizer is applied either in dry or liquid form at time of planting. In some cases, nitrogen is applied for corn in the form of anhydrous ammonia after the crop is up. The system requires a higher level of management than with other tillage methods. Additional attention is required for herbicide selection, planter adjustment, plant population, insect control, and selection of fields with suitable soils.

Contour farming is highly effective in erosion control but is being used less as equipment size continues to increase. Contouring is most effec-
tive on slopes of 2.1 to 7.0 percent, resulting in a 50 percent reduction in soil loss. The effectiveness of contouring decreases as slope gradient increases above 7 percent.

Terraces have received renewed attention in recent years. Of particular interest to landowners has been the parallel tile outlet terrace. Where field topography permits and with minor cutting and filling within the channel, terraces are constructed parallel to each other eliminating unnecessary point rows common to gradient terraces constructed in earlier years. With tile outlet terraces, runoff is temporarily stored behind the terrace ridge and slowly released through an inlet pipe attached to an underground field tile. In most cases, storage areas are located where grass waterways normally exist. Once the terraces are installed, grass waterways are eliminated and become part of the cultivated area.

Terraces reduce erosion most on long slopes by breaking the slope length into shorter segments. Runoff is diverted by the terrace ridge to a non-erodible outlet as it moves down the slope preventing a buildup in volume and thus reducing the ability of water to erode. When used in combination with conservation tillage and contouring, terraces will reduce soil loss to tolerable levels on the majority of cropland in Illinois.

Grass waterways are important and play a vital part in resource management systems. Their main purpose is to convey excess water runoff across a field to a safe outlet. Often times, waterways are constructed in watersheds with severe erosion problems only to be filled with sediment in a short period of time. In severe erosion situations, resource management systems should be installed first to solve the erosion problem. Sedimentation damages and maintenance cost to grass waterways, drainage ditches, reservoirs, etc., are thus reduced.

Grade stabilization structures are often needed to stabilize grass waterways and other water disposal systems. They are used where the concentration and flow velocity of water might cause channels to erode to cause the formation of gulley heads along natural channels. The type of structure installed is largely dependent upon size of watershed and amount of overfall at the site.

Construction sites in developing areas with rolling topography are often high sediment producing areas. Where large areas are stripped of all vege-
vegetation in preparation for construction, erosion can result in severe off-site sediment damages.

Sediment basins are often used to reduce these off-site damages. Reservoir-type structures are constructed that temporarily hold runoff, allowing sediment to settle out. After the area has been developed and the sediment producing area stabilized, the sediment basins are removed, vegetated, and become part of the regular landscape.

Streambanks are also potential sediment-producing areas. Stabilizing measures vary depending upon site conditions. Vegetation is most often used on favorable sites. In some cases, it is necessary to provide temporary protection until permanent vegetation is established.

Rock riprap is used on sites unfavorable for good vegetative cover. Examples are channels that experience fluctuating water levels for extended periods of time, sharp changes in direction of flow, and areas with excessive velocity.

Streambank erosion can be greatly reduced through proper maintenance. Removal of fallen trees, log jams and other debris that cause current turbulence and deflection will prevent scouring, undercutting and sloughing of channel banks. Removal of trees and brush that adversely affect the growth of desirable bank vegetation will help maintain a vigorous vegetative cover.

The role of the USDA Soil Conservation Service is to provide technical assistance to landusers to bring about the conservation, development and wise use of land, water and related resources. SCS technical assistance is available through local Soil and Water Conservation Districts. The working relationship was established through a Memorandum of Understanding between the USDA and Soil and Water Conservation Districts and a supplemental Memorandum of Understanding between the USDA, Soil Conservation Service, and Soil and Water Conservation Districts. These memorandums list mutual objectives and items that each party will do in carrying out effective working relationships.
BIOLOGICAL ASPECTS OF EUTROPHICATION

Michael Lynch*

Attempts to reduce the growth of nuisance blue-green algae can generally be grouped into two major categories: 1) those which reduce the influx of nutrients to lakes, and 2) those which resort to the eradication of algal blooms by chemical or mechanical means. The first approach is a logical beginning, but it is not always effective. Long residence times of lakes or internal recycling mechanisms of nutrients may prevent any response to reduced nutrient loading for many years. Furthermore, the technology is expensive and cannot be applied to nonpoint sources.

The second approach is simply cosmetic. It treats the symptoms of enrichment but generally is not preventive. Many of the available techniques are energetically and economically demanding, and many may have long-term deleterious effects which we have not yet discovered.

However, rather than dwell on the limitations of existing lake management technology, I will present an alternative approach which avoids many of the previously mentioned objections. First, let me say that I am not questioning the importance of nutrients in lakes. An examination of the relation between mean summer phosphorus and chlorophyll for a variety of North American lakes shows an excellent correlation between the two when plotted on a logarithmic plot (Jones and Bachmann, 1976). This apparent close relationship has been repeatedly interpreted to mean that the greenness of lakes is irrevocably connected to phosphorus. However, a reexamination of these data plotted on an arithmetic scale reveals the extent to which the logarithmic plot conceals the variation in the phosphorus-to-chlorophyll relationship (Shapiro, 1978); for any concentration of phosphorus, the range of variation in chlorophyll concentration between lakes is about an order of magnitude. Furthermore, when individual data points (rather than means) from different lakes are examined, the relationship disappears entirely (Smith and Shapiro, 1980).

The simple point is that the phosphorus-chlorophyll relationship is not cast in stone. At best, phosphorus sets the upper limit of "greenness" that can be obtained in any lake. Once this is realized, then one can begin to

*Assistant Professor of Ecology, Ethology, and Evolution, University of Illinois at Urbana-Champaign
ask some interesting questions about the eutrophication process. In particular, why do some lakes with high phosphorus concentrations nonetheless have very low standing crops of algae?

There are several potential explanations for this. I will simply focus on one answer which now seems to be of overwhelming, general significance, i.e., that the numbers and species of fish in a lake determine its sensitivity to nutrient enrichment. The simple point that I wish to make is that any concern we have about the eutrophication process should focus as much on the fish community and its resultant biotic interactions as on nutrient availability.

If one goes to any of the traditional limnology textbooks, the historical neglect of fish by limnologists is immediately apparent. Since fish were never caught in limnological sampling gear, the general assumption was that they must be of minor significance with respect to the overall metabolism of lakes at best. As a result of much recent work, however, this stance has been radically altered.

One of the first indications that fish might have an important influence on the response of lakes to nutrients came from the revelation of Kitchell et al. (1975) that 74% of the phosphorus in Lake Wingra, Wisconsin was in the form of fish. An initial reaction to this startling observation might be that it would be wise to encourage the growth of fish in lakes since they would contain nutrients which would otherwise be available to the algae. But this ignores the fact that lake processes are dynamic ones. Our concern should be as much with the flux rates of phosphorus between pools as with the actual pool sizes.

Indeed, the recycling of nutrients by fish is a primary mechanism by which fish encourage the growth of algae in lakes (Lamarra, 1975). Nutrients in the form of benthic organisms (those which dwell in the sediments) are unavailable to the algae; in this sense, the sediments act as a sink for nutrients. By feeding on the sediments and excreting nutrients into the water, benthic feeding fish provide an additional supply of nutrients which would otherwise be unavailable to the algae. Even if all external sources of nutrients were eliminated from a lake, the internal loading of nutrients resulting from a dense population of benthic feeding fish could be sufficient to support considerable algal growth.
Not all fish will influence the total concentration of phosphorus in lakes in this manner, since many of them simply feed on organisms which reside in the water column. However, because of their selective feeding habits planktivorous fish aggravate the eutrophication process in other ways. By selectively removing the large herbivorous zooplankton from lakes, these fish cause dramatic changes in both the total abundance and the composition of the phytoplankton community. This results from a reduction in the intensity of grazing on the phytoplankton.

There is much evidence for these effects both on an experimental and a descriptive basis, on scales ranging from small 1 M diameter enclosures to entire lakes. Some good experimental support for the encouragement of algal blooms by fish comes from Pleasant Pond, Minnesota, where different densities of bluegill sunfish were enclosed in large polyethylene bags (Lynch and Shapiro, 1981). Enclosures without fish contained populations of large herbivores which maintained the algae at very low levels; Secchi disk transparency was in excess of 2 M. Enclosures with fish developed dense blooms of blue-green algae as a result of the removal of large herbivorous zooplankton. A great deal of phosphorus remained unutilized in dissolved form in the control enclosures; most of it in the fish enclosures was converted into algae. Similar results were obtained by dividing the pond and stocking one side with planktivorous fish.

This is not a regional phenomenon. Very similar experiments have been performed in Czechoslovakian (Losos and Hetesa, 1973) and Swedish (Andersson et al., 1978) lakes with both benthophagous and planktivorous fish. The results are unequivocal: the presence of these types of fish results in about an order of magnitude increase in the density of algae.

The results are not limited to ponds either. Nature has performed numerous experiments in much larger lakes which clearly demonstrate the role of herbivorous zooplankton in the eutrophication process. Winterkill lakes, i.e., those which lose their fish populations as a consequence of anoxic conditions under ice cover, often show a dramatic increase in transparency the following spring. Schindler and Comita (1972) have shown most clearly for Severson Lake, Minnesota that this is the result of the recovery of the population of large Daphnia.
Lake Washington, without doubt this country's finest example of lake restoration by nutrient diversion, is now performing an experiment of its own. In the late 1960's municipal waste from the city of Seattle was diverted from the lake. The lake responded almost immediately. By the early 1970's Secchi disk transparency had nearly tripled to 5 M. In terms of phosphorus concentration, the lake is now approaching a steady state. Yet in 1975, despite the fact that the nutrients changed very little, the transparency nearly doubled again, on some occasions reaching 13 meters (Edmondson, 1981). Accompanying this change was the appearance for the first time in more than 30 years of a population of large Daphnia. Although the mechanism responsible for the sudden increase in Daphnia is not known, they have now been present for five years, and the transparency of Lake Washington is greater than at any time in recorded history.

Lake Tahoe, perhaps this nation's finest oligotrophic lake, appears now to be in a very precarious position as a result of the disappearance in 1970 of all of its herbivorous cladocerans, including the large Daphnia. These appear to have fallen victim to Mysis relicta, an invertebrate which was stocked into the lake by the California and Nevada Fish and Game Departments as a forage for the salmon population (Goldman et al., 1979). Without the modifying influence of these grazers, the transparency of Lake Tahoe will be maximally sensitive to any increase in nutrient loading.

The simple point here is that by applying our ecological understanding of lakes we can do a great deal to alleviate the undesirable consequences of enrichment. Biological approaches to lake restoration are less demanding of energy and finances, are less cosmetic, are bolstered by a rather substantial theoretical framework, and are less likely to produce long-term environmentally damaging effects than are many existing methods. Biological control seems particularly appropriate for Illinois lakes, many of which suffer from nonpoint-source inputs of nutrients.

The most obvious approach is to encourage the growth of populations of large Daphnia. By no means do we yet have a completely accurate means of predicting the events which control their populations, but predation by planktivorous fish seems to be of overwhelming importance. One logical means of increasing the density of large grazers, short of decimating the entire fish fauna, is to restructure the fish community by heavy stocking with larger, predatory fish.
Whatever the means utilized to promote the growth of the large herbivores, once they are present they are likely to have multiple effects which will ultimately result in an amelioration of the deleterious consequences of eutrophication. Their grazing alone will result in a reduction in total algal biomass. Other indirect consequences of their presence are also likely to encourage a qualitative shift in the algal community from the nuisance blue-greens to more edible (and hence removable) types of algae. These include: increased light intensity, which has the most damaging effects on the blue-greens (Senft, 1978), and increased concentrations of carbon dioxide and ammonia resulting from zooplankton excretion. High concentrations of CO₂ favor the growth of edible green algae (Shapiro, 1973), whereas ammonia inhibits nitrogen fixation by blue-greens which would otherwise be an advantage for them (Healy, 1973). Ultimately, grazing by large zooplankton might even result in a total decrease in the phosphorus concentration of lakes. The larger fecal pellets of large zooplankton are likely to sink out of the water column more rapidly resulting in a net flux to the sediments. Furthermore, if total primary production declines as a result of intense grazing, then less total organic matter will be deposited on the sediments and anoxia will develop more slowly in the hypolimnion; consequently, less phosphorus should be recycled during fall overturn.

The use of predatory fish to restructure the fish community is particularly attractive for several reasons. First, predators will reduce the populations of both planktivorous and benthic feeding fish. Consequently, the size structure of these populations would most likely shift from numerous, stunted planktivorous individuals to fewer and larger omnivores. Second, the total excretion of nutrients by fish would probably be reduced as well since many benthoophagous fish will be removed and the remaining larger fish would have a lower metabolic rate than an equivalent biomass of smaller fish. Third, the induced changes in the fish community should actually enhance the recreational value of the lake since fishermen generally prefer larger fish. And this, in turn, would act as a mechanism for permanently removing nutrients from the lake.
REFERENCES


INSTITUTIONS FOR LAKE MANAGEMENT

M. R. Grossman & D. L. Uchtmann*

Many of the contributions to this round table have focused on the technology for lake management: methods for preserving the quality and quantity of water in lakes, and means for restoring the health and beauty of those lakes when preventative management techniques have been ignored or have not succeeded. The implementation of both preventative measures and restoration techniques, however, can be carried out only through some institution—for example, a unit of government, a special district with appropriate powers, or a private association.

This paper explores the potential of several of these institutions for successful lake management and reclamation. It focuses on small, private lakes, particularly those that comprise part of the commonly owned areas of residential subdivisions.

Two types of institutions may be relevant in managing these small private lakes. Most significant are associations composed of residents, usually landowners, who control the lake and the immediately adjacent property. Also relevant are special districts authorized by statute, created voluntarily by interested citizens, and granted power to implement plans for watershed management.

HOMEOWNERS ASSOCIATIONS

Homeowners associations are organizations composed of the owners of lots, usually in residential subdivisions, who have agreed to abide by certain restrictions on the use of their property and to maintain the commonly owned areas in the subdivision. These associations are consensual. Their power, and therefore their effectiveness, comes entirely from contractual provisions or from restrictive covenants that run with the land. The associations are not created by statute, nor do they have statutory management powers.

The consensual nature of the power of homeowners associations means that the associations encounter few restrictions, as long as their actions remain within the bounds of their authority. That authority, however, extends only to members of the association—those who have consented to be governed by the

*Assistant Professor and Associate Professor, respectively, of Agricultural Law, Department of Agricultural Economics, University of Illinois at Urbana-Champaign
rules of the association. Others, even nearby landowners, cannot be bound. In addition, a few constitutional limitations may prevent judicial enforcement of restrictive covenants. These usually involve racial or religious restrictions on lot ownership, and are not directly relevant to lake management.

Because homeowners associations can be created with extensive and specially designed powers, including the authority to levy assessments against their members, they can be effective institutions for the management of small private lakes.

Homeowners associations are normally created at the time that a developer plans a new subdivision. When the developer files the plat for the subdivision in the county recorder's office, the plat is typically accompanied by a list of restrictive covenants governing the lots in the subdivision. When filed with the flat, these covenants run with the land and will bind the initial and subsequent purchasers of the lots and homes in the subdivision. Subdivision covenants typically include building restrictions that govern the type, size, and location of the dwelling to be built on each lot, landscape restrictions, off-street parking requirements, as well as other limitations on the use of the land.

If a homeowners association is to be formed, one of the covenants will typically require that each lot owner become a member of the association and comply with the bylaws and regulations of the association. The association itself is usually governed by a board of directors, elected by the membership and invested with powers through the association bylaws. The bylaws themselves may provide for annual dues, the levying of special assessments, and the adoption of rules and regulations concerning both the use of individual lots and the management of the common areas, including the lake.

The system just described ensures that each new resident of the subdivision will become a member of the homeowners association when he purchases a lot. Thus, he is bound by the bylaws and regulations of the association, as well as by the covenants recorded with the plat. Moreover, Illinois case law indicates that although normally individual landowners will sue to enforce a covenant, the homeowners association itself has the authority to enforce the restrictive covenants that govern each lot. This authority may increase the effectiveness of the covenants. Because the association is a rather impersonal organization,
its enforcement of the covenants avoids the sometimes awkward necessity for one neighbor to sue another for enforcement.

Through careful planning, the combination of covenants, bylaws, regulations, assessment capability, and enforcement authority can invest the homeowners association with considerable power in the area of lake management and restoration. An effective association will have the organizational and financial ability to initiate such projects as shoreline protection, fish stocking, and when necessary, lake dredging and reclamation.

If the homeowners association is to function effectively throughout its existence, in both its lake management and its other responsibilities, the developer must ensure that the association will have the authority it requires to carry out these functions. In organizing the association, therefore, the developer should provide for three important attributes: enforceability, flexibility, and visibility.

Because the association has the legal authority to enforce restrictive covenants on behalf of the landowners, its very existence provides the potential for effective enforcement. Restrictive covenants are intended to protect the living conditions and property values of all the lot owners in a subdivision. If they are not enforced vigorously, they fail to fulfill their purpose. Indeed, the lack of enforcement may eventually result in the waiver or lapse of restrictive covenants.4

To avoid a situation in which the lack of vigorous enforcement of restrictive covenants during one period of time will result in a decision that those covenants have been waived through nonenforcement, some developers include a nonwaiver clause among the restrictive covenants. Such a clause can provide that the failure of the association or a landowner to enforce any of the restrictive covenants, conditions, reservations, liens, or charges to which a lot is subject shall not be a waiver of the right to enforce that provision or any other provision in the future. Until litigation over the waiver or nonwaiver of a covenant actually ensues, one cannot predict the efficacy of such a nonwaiver clause in a particular situation. A nonwaiver clause may carry substantial weight in litigation, however, and may therefore be a helpful addition to the other covenants imposed when a subdivision is platted.

Flexibility is necessary to allow the homeowners association to tailor its programs to the changing needs of the subdivision and the commonly owned lake.
That flexibility can be obtained through a careful allocation of powers and responsibilities between the rather inflexible restrictive covenants and the more readily amended bylaws of the association. Those elements of subdivision control and management that the developer expects to remain unchanged through the life of the subdivision could be included among the covenants, which run with the land and bind successive owners. Those elements for which changes may be desirable could be included more effectively in the association bylaws, where amendments are possible and relatively simple to make. For example, the covenants might require the lot owners to pay dues and assessments levied by the homeowners association; the bylaws might set the level of those dues and assessments, which may be expected to vary as the requirements of the subdivision change. This method will ensure that funds will be available to finance a high-cost project, such as lake reclamation. The bylaws might also prescribe other duties of the lot owner that should remain flexible to take advantage of improving technology. One example is the method of shoreline protection.

Another element of flexibility that may be desirable is a provision that covenants, or any particular covenant, may be rescinded after a prescribed number of years, if a large percentage of the lot owners vote in favor of rescission. In this way, a covenant that is no longer necessary or effective in protecting the residents can be eliminated, but only if the vast majority of the owners agree to the rescission.

One important attribute of an effective homeowners association is visibility. By its very nature, such an association will experience continual changes in its membership and its board of directors. New residents, in particular, should be aware of the existence of the association, the obligation of membership, and the powers of enforcement of the association. In that way, no one will be surprised when the association enforces a covenant or regulation, or seeks funds for a project that is essential to the well-being or property value of all the members of the association.

As the foregoing discussion has indicated, homeowners associations can be effective institutions for management of privately owned lakes. These associations, however, can be formed and invested with the necessary authority most readily at the inception of the subdivision development. Once a private lake development has been built, the task of forming a truly effective association is
much more difficult. Although it is theoretically possible to establish new covenants that bind current and subsequent owners and that require membership in a powerful homeowners association, it may be infeasible to persuade all of the residents of a lake development to agree to the covenants. Those who refuse to agree will not be bound, and covenants that do not bind all the owners in the development cannot be entirely effective. Thus, the ideal homeowners association for lake management is one formed at the inception of the development, and invested at the time of formation with the powers necessary to plan and finance lake management and reclamation programs as the need arises.

OTHER INSTITUTIONS

Because the members of a homeowners association have the most compelling interest in ensuring the continued viability of their privately owned lake, the homeowners association may be the most effective institution for managing such a lake. These associations, however, can regulate only the landowners who are members. Some lake problems, particularly those involving sedimentation, may result from activities within an entire watershed, rather than only within a subdivision boundary. To solve these problems, therefore, concerned lake owners will seek an institution with broadly based powers.

Lake owners who are evaluating the availability of institutions for watershed management will find that numerous institutions have authority relating to water in Illinois. These include institutions that are already functioning and others whose organization is authorized by statute. For example, both the federal and the state Environmental Protection Agencies have water-related authority. On the state level, the Department of Transportation (in particular, its Division of Water Resources), the Department of Agriculture (in particular, its Division of Natural Resources), and the Department of Conservation have authority to affect water resources. Moreover, local governments—counties, municipalities, and townships—also exert influence in this sphere.

In addition to federal, state, and local government organizations, a number of other institutions have power to exercise control over the water resources of the state. Although these institutions vary in the extent and direction of their authority, each has some water-related function. Among them are conservation districts, drainage districts, forest preserve districts, park districts, river conservancy districts, municipal and rural sanitary districts, soil and water conservation districts, surface water protection districts, water authorities, and water service districts. The methods for organizing these districts
and the extent of their powers after organization are prescribed by statute.

Although all of these institutions perform water-related functions, relatively few would prove effective in efforts directed towards maintaining the viability of a small private lake. Assuming that the area of soil and water conservation is most crucial in controlling sedimentation and pollution, only three of these special districts demonstrate potential. These are conservation districts, soil and water conservation districts, and river conservancy districts. Merely having some authorized function relating to soil and water conservation, however, will be insufficient to decrease sedimentation and pollution effectively. Direct power to regulate the use of the land is therefore necessary. Of the three types of special districts with soil conservation functions, only the soil and water conservation district has the authority to adopt and enforce land-use regulations with soil conservation considerations.⁵

Lake owners who might hope to rely on the land-use regulation authority of soil conservation districts to reduce sedimentation and pollution of their lakes are not faced with the necessity of forming these districts. Illinois passed its Soil and Water Conservation Districts Act in 1937,⁶ and districts have been operating in most areas of the state for several decades.

The Soil and Water Conservation Districts Act gives the directors of any district the authority to propose land-use regulations "in the interest of conserving soil, soil resources, water and water resources and preventing and controlling soil erosion and erosion, floodwater and sediment damages."⁷ The regulations may require the observance of particular methods of cultivation and the implementation of specific engineering operations to control erosion.⁸ Thus, the mechanism is in place for the adoption of regulations that could reduce sedimentation and pollution substantially.

Despite this provision, however, lake owners may face a formidable obstacle to the enactment of effective land-use regulations. Although the directors have authority to develop and propose land-use regulations, they cannot enact those regulations into law without submitting them to the land-owners of the district in a referendum. Three-fourths of the owners of land who vote in the referendum must approve the regulations before they can be enacted. Lake owners could reasonably expect land owners within the district, especially farmers, to resist the enactment of regulations requiring cultivation measures intended primarily to protect the waters of a privately owned lake within the district.
Lake owners would therefore face difficulty in using this regulatory provision to provide watershed protection for their lake. This difficulty may be explained in part by the origins of soil and water conservation districts, which have traditionally been aligned with agricultural producers. Those districts were a response to the agriculture problems of the depression and the severe wind and water erosion of the ensuing years. Legislation creating the federal Soil Conservation Service, with its new program to encourage soil conservation and improvements on private land, required responsible state and local cooperation. In part, soil conservation districts provided this cooperation, and in so doing formed the link between the individual farmer and the federal Soil Conservation Service. The districts worked with the farmer in an effort to ensure voluntary adoption of measures to reduce the on-farm effects of erosion.

Now, however, when society is concerned with the off-farm effects, such as sedimentation of waters, as well as the on-farm effects of erosion, the role of soil conservation districts is undergoing a transition. As effective, already-functioning organizations concerned with erosion, the districts are the logical entities to help control the increasing off-farm problems created by erosion. Their orientation must therefore change; they cannot focus solely on the problems and concerns of the farmer, but must balance the continuing needs of the farmer with the public demand for control of erosion and pollution.

A catalyst for this changing orientation is the relatively new federal requirement of statewide planning for the control of nonpoint-source water pollution. Section 208 of the Federal Water Pollution Control Act Amendments of 1972 focuses on area wide waste treatment management. Although the federal Environmental Protection Agency originally interpreted this section to apply only to areas with particularly complex water pollution problems, a 1977 federal appellate court decision made it clear that Section 208 planning must be done in all areas, and that each state is responsible for its own planning.

Congress has recently provided financial incentives for state Section 208 planning. The "Culver amendment" to Section 208, enacted in 1977, implements a cost-sharing program to assist landowners and operators in installing best management practices for nonpoint-source pollution control. The program authorizes the secretary of agriculture, acting through the Soil Conservation Service and other agencies he designates, to enter into five-to-ten-year contracts with farmers to provide cost-sharing and technical assistance
for installing and maintaining best management practices. This federal financial assistance is available, however, only in states where Section 208 plans have been developed, certified by the governor, and approved by the federal Environmental Protection Agency. Moreover, a state plan can be approved by the federal agency only when its components demonstrate that the plan will work. Thus, the availability of federal financial assistance will encourage the implementation of an effective state 208 plan.

As a prelude to the required statewide control of nonpoint-source pollution, the Illinois legislature amended the Soil and Water Conservation Districts Act. The amended Act required the state department of agriculture to adopt guidelines for erosion and sediment control. On April 18, 1980, the department adopted those guidelines, which are designed to reduce soil erosion to the established soil loss tolerance of 2-5 tons per acre per year by the year 2000 (earlier on gently sloping lands).

The amended Illinois statute also provides that within two years of the adoption of the state guidelines, each soil and water conservation district is to adopt its own soil erosion and sediment control program. Each district program must be consistent with the state guidelines, but may impose more stringent controls, if technically feasible and economically reasonable. In some watershed areas, district standards that comply with the statewide minimum guidelines will result in significant improvement, with correspondingly reduced sedimentation. In other areas, more stringent standards will be required to reduce current soil losses.

No district may adopt standards without giving notice to the public and conducting a public hearing. This required hearing will provide the opportunity for all interested citizens--owners of property around private lakes and users of water from publicly owned lakes, as well as farmers--to contribute their views as to the stringency of the standards in each district. The process, to be completed in each district by April 1982, will no doubt result in a compromise between the interests of farm owners and operators and the interests of those who live around the privately owned lakes in each district. Thus, the opportunity exists now for lake property owners to participate in setting the standards that will determine the level of erosion and lake sedimentation for the next several decades.
At present, the system for controlling erosion in Illinois is voluntary, with cost-sharing programs designed as the incentive for widespread participation by farmers. If this voluntary program fails to make significant reductions in soil erosion, however, the federal Environmental Protection Agency will require other strategies to ensure that 208 planning really accomplishes its goals. Thus, Section 208, as implemented by soil and water conservation districts, promises an eventual reduction in the rate of soil erosion and, therefore, of lake sedimentation.

CONCLUSION

Strong homeowners associations are probably the best institution for managing private lakes. They can raise money through assessments and annual dues, conduct reclamation activities, and even impose restrictions (such as requiring adequate shoreline protection) that will help preserve the quality of private lakes.

The powers of homeowners associations, however, do not extend beyond the reach of the individual members. Accordingly, other institutions with powers derived from legislative enactment become important for watershed management.

The soil and water conservation district is probably the most important legislatively created institution with the powers necessary to reduce lake sedimentation. The responsibilities of soil and water conservation districts are currently evolving as a result of the 208 planning process. With the participation of the public, these districts are developing sediment-control guidelines that will require soil losses to be limited to an amount that does not affect the long-term productivity of the land. Enforcement of these guidelines through a complaint system also seems to be evolving, although a system of incentives to landowners is the primary focus of the current implementation strategy.

Critics suggest that a voluntary system of erosion control can never work. Only time will tell us if these critics are correct. It must be remembered, however, that the legislation prescribing the 208 planning process requires the implementation of a nonpoint-source pollution control program that works. If the voluntary approach does not produce results, other approaches must be developed to ensure adequate control, lest Illinois lose the significant federal dollars that are tied to the implementation of an effective erosion control program.
FOOTNOTES

1. E.g., Shelley v. Kraemer, 334 U.S. 1 (1948) (state court enforcement of restrictive covenants designed to exclude persons of a designated race or color violates the fourteenth amendment of the U.S. Constitution).

2. Alternatively, such covenants may be stated expressly in the deeds to the lots. In this situation, too, the restrictions bind the original and subsequent owners.


5. Both the conservation district and the river conservancy district have power to acquire, construct, or maintain facilities to accomplish soil conservation measures. In addition, the conservation district can conduct research and develop comprehensive plans in which soil conservation is an object. Nonetheless, soil conservation is not the main goal of either type of district. See Ill. Rev. Stat., ch. 42, §§ 383-410.1 (River Conservancy Districts); ch. 96 1/2, §§ 7101-7128 (Conservation District Act) (1979).


7. Id., § 128.

8. Id.


10. Nonpoint-source water pollution is generated by diffused land-use activities and is conveyed to waterways through natural processes like storm runoff or groundwater seepage. Usually nonpoint-source pollution can be controlled only by changes in land management practices. Point-source pollution, in contrast, can usually be controlled by an "end of pipe" technology that treats the waste before it is discharged into the lake or stream.
18. Id.
FUNDING ASPECTS OF LAKE MANAGEMENT

Richard Burd*

INTRODUCTION

Now that you have heard the other speakers tell you the "how and why" of lake reclamation and management, you are probably expecting me to tell you where the bag of money is to carry out these projects. I have bad news for you, because there just is no such bag of money. Generally, the money that is available is only what the custodian of your lake already has or can extract from the people who benefit from the use of the lake. As for running off and getting a grant from the state or federal government, that just doesn't work in most cases--but we'll talk more about that later.

Today, I wish to focus my remarks on publically owned lakes, that is, a lake owned by a governmental body. Privately owned lakes will have an even greater problem obtaining money. An individual lake owner or group of property owners, such as a lake association, is generally limited to the usual financial resources available to private businesses.

PUBLIC OWNERSHIP

In almost all cases, a publically owned lake is controlled by one of the following governmental entities: a city or village, county, township, water commission, public water district, water authority, surface water protection district, river conservancy district, soil and water conservation district, sanitary district or conservation district. In many of those instances, the lake's main function is to serve as a water supply for the people living in the area.

SOURCES OF REVENUE

The sources of revenue available to these governmental entities can be grouped into four basic categories: (1) user charges, (2) bonds, (3) taxes, and (4) state/federal aid. Keep in mind that there are considerable differences as to which financial resources are available to what government.

*Office of Local Management Services, Illinois Department of Commerce and Community Affairs, Springfield
For example, a city has a far greater number of revenue sources available to it (such as sales tax, federal revenue-sharing payments, property taxes, etc.) than does a water commission, which has only water charges available to it.

Let's take a closer look at these revenue sources.

**User Charges**

If the lake is used as a source of water for the area's water system, then the logical and sound way to provide money for lake maintenance is through user charges from the sale of water. A water utility (although it may be operated by a local government) should be considered as a business and should be self-supporting. Whatever money is needed to operate the system, retire outstanding bonds, and provide an adequate level of maintenance to the lake should come from the sale of the water. All too often the local government officials who are responsible for managing the lake are reluctant to keep the water rates at a level high enough to provide the necessary revenue to adequately maintain the lake. There are a few short-term benefits to artificially low water rates—however, the local government officials must also accept responsibility for the future condition of the lake. Although it may be politically unpopular, water charges must be periodically reviewed to ensure that they are adequate to meet the lake's maintenance and other expenses.

In addition, if the lake is used for recreation purposes, serious thought should be given to implementing a system of user charges to ensure that any expenses incurred to provide and maintain the recreation facilities are paid for by the people benefiting from the use of those facilities. User charges you may wish to consider are boat launching fees, park entrance fees, beach admittance fees, marina fees, etc. Certainly don't overlook the possibility of licensing any concessions that may be operating at your lake. The concept of user charges, or requiring those people that benefit from the use of a service to pick up the tab, is rapidly gaining increased interest by local governments across the country.
Bonds

Often, expensive lake projects which will provide benefits for a number of years into the future are financed through the sale of bonds. Generally for lake projects, there are two basic types of bonds: revenue bonds and general obligation bonds.

Revenue Bonds. Revenue bonds are retired only from the money generated from the sale of water. As a result, they tend to carry a higher interest rate than general obligation bonds because of the greater risk to the bond holders. However, there are several advantages to revenue bonds: (1) they are not included within the statutory debt limit of governmental body, and (2) revenue bonds can usually be issued by the government without a referendum.

There is no limit on the amount of revenue bonds which can be sold. However, investors will not purchase such bonds unless the project is financially feasible. Therefore, in order to interest investors, the projected net earning (after operation expenses) must substantially exceed the principal and interest requirements.

General Obligation Bonds. General obligation bonds are backed by the full faith and credit of the issuing governmental body. In other words, the bonds create a lien on all of the taxable property within the community. The annual principal and interest payments are met through a property tax. Because the bond holders are assured of repayment regardless of the financial success of the project, the bonds tend to have lower interest rates than revenue bonds.

Sometimes a government will issue general obligation bonds to obtain a low interest rate, then abate the annual property tax and pay off the bonds completely through revenues earned from the system.

General obligation bonds have some disadvantages: (1) before they can be issued, the citizens of the community must give their approval in a referendum, and (2) the bonds are included in the government's statutory debt limit.

Taxes

The next category of revenue that is usually available to the local governments mentioned earlier is property taxes. As you know, property
taxes are probably the least tolerated of all local revenues. A sure way for a local government official to become unpopular is to propose an increase in an already existing property tax or to propose a new property tax. However, if your water project is not just a personal pet project, but rather a project that has long-term important benefits to the entire community, then an additional property tax may be the answer to finance it.

Some property taxes simply require a decision by the governing body to impose the tax. Other taxes require the approval of the citizens in a referendum. The Department of Commerce and Community Affairs publishes a booklet entitled, The Tax Rate and Levy Manual, which lists all of the various property taxes available to all governments. The booklet also indicates which taxes require a referendum, what the maximum tax rate is, and where the reference to the tax can be found in state law.

I'm sure there are a number of people who will quickly say that the local taxes are already too high, and that if a referendum is required for an additional tax, it would never be approved by the voters. This may be true. However, if your project is important to the future of the area the lake serves, then you should consider undertaking a strong campaign to educate the people about the importance of your project. In addition, you should critically analyze the existing budgets of your local governments with the purpose of establishing new spending priorities.

Although this may sound like a naive approach to having your project funded, I want to emphasize to you that it may be less naive than to believe you will obtain a federal grant to fund your project.

**Grants**

For every community that you can point to that has received a federal grant, I can point to at least 20 that have been turned down. Many of those communities that have received a grant had their grant application pending several years before they were awarded the grant. During that period of time the project's cost skyrocketed because of the rate of inflation. In some cases the community was not in any better position for having waited for the grant than if it had gone ahead with the project when it was first proposed and financed it completely with local revenue.
What is available in grants?

**Farmers Home Administration.** The Farmers Home Administration (FmHA), an agency of the U.S. Department of Agriculture, administers a grant which in certain circumstances can provide up to 75 percent of the cost of a project which improves a rural community's water system. The community must be willing to shoulder a large portion of the project by accepting an FmHA loan. The loan interest rate is set at five percent and can be paid back over a period as long as 40 years. After receiving the loan application, FmHA will determine if the community is eligible for a grant by considering the community's outstanding bonded debt and the estimated water rates in relation to the area's median family income.

Even if a community meets the eligibility test, it may not receive a grant. Grant awards are made on a competitive basis and the demand for grant money far outstrips the amount of money available. Also, it appears that Congress will reduce the amount of money in this program.

**Contact:** Gerald Townsend, Farmers Home Administration, 2106 West Springfield Avenue, Champaign, Illinois 61820; telephone (217) 398-5235.

**Community Development Block Grant Program.** The U.S. Department of Housing and Urban Development (HUD) administers a program called the Community Development Block Grant Program which under certain conditions could provide 100 percent of a water project. Although obtaining a grant for a water project is technically possible, in actuality, only a few communities would in fact be able to secure a grant for a water project under the program. The program will only fund projects which directly benefit low and moderate income families and improve the housing conditions of the area. As a result, it would be difficult to secure a grant for a water project under the program—however, it has been done.

**Urban Development Action Grant (UDAG).** HUD also administers a relatively new program known as the Urban Development Action Grant. The UDAG program was designed to encourage the private sector to invest in the community and create jobs. As a result, it is possible to obtain a grant
for lake rehabilitation if the project is necessary to attract new or additional capital investment into the community from the private sector. An example of private investment may be the construction of a new factory. If the grant application is to be successful, the project would have at least seven dollars of private investment to every one dollar of federal money. If the private investment is in a neighborhood project, the ratio of private dollars to federal dollars should be at least five to one to be competitive.

For further information on both HUD programs *contact:* Don Falls, Department of Commerce and Community Affairs, 222 South College, Springfield, Illinois 62706; telephone (217) 782-7564.

**Illinois Department of Transportation Division of Water Resources.** The Illinois Department of Transportation Division of Water Resources may also be a possible source of outside funding under certain circumstances. However, keep in mind the Division of Water Resources can be of financial assistance only when the purpose of the project is flood control and is cost effective. Any other benefits that your project may provide such as public water supply or recreation can not be funded by the Division of Water Resources and the cost for these benefits must be met from some other source. Under an acceptable project, the local government is responsible to meet the costs of the land, easements, and the necessary rights of way. The state could pick up the cost of engineering, inspection and construction.

*Contact:* Don Vonnahme, Division of Water Resources, Illinois Department of Transportation, 2200 South Dirksen Parkway, Springfield, Illinois 62704; telephone (217) 782-0690.

**U.S. Department of Agriculture Soil Conservation Service.** The Soil Conservation Service administers two programs which may be important to your program. They are the Small Watershed Project (PL. 566) and the Resource Conservation and Development programs. If your area is not already working under these programs, you may have a difficult time utilizing them for your project. A great deal of time and study is necessary before projects can be approved under these programs.
Contact: Warren Fitzgerald, Soil Conservation Service, 301 North Randolph, Champaign, Illinois 61820; telephone (217) 398-5265.

U.S. Army Corps of Engineers. The Corps of Engineers administers a number of flood control programs which have some spin-off benefits for recreation and water supply.

Contact: Richard Carlson, 219 South Dearborn, Chicago, Illinois 60604; telephone (312) 353-6513. Art Klinger,man, Clock Tower Building, Rock Island, Illinois 61201; telephone (309) 788-6361. Louisville District, P.O. Box 59, Louisville, Kentucky 40201; telephone (502) 582-5601. St. Louis District, 210 North 12th Street, St. Louis, Missouri 63101; telephone (314) 268-2821.

As I have already indicated, the Department of Commerce and Community Affairs can provide you with information about the grant programs administered by the U.S. Department of Housing and Urban Development. We will be pleased to discuss with you eligibility, funding levels, program requirements, application procedures, filing dates, environmental assessment requirements, and the chances of getting your project funded. In addition, the department can provide information on local sources of revenue, budgeting, utility accounting procedures, and establishing water rates.
<table>
<thead>
<tr>
<th>NAME</th>
<th>PURPOSE &amp; POWERS</th>
<th>FORMATION</th>
<th>GOVERNING BODY</th>
<th>PROPERTY TAX AUTHORIZATION</th>
<th>GENERAL OBLIGATION BOND AUTHORIZATION</th>
<th>REVENUE BOND AUTHORIZATION</th>
<th>NUMBER IN EXISTENCE IN 1975</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cities &amp; Villages</td>
<td>May operate a water supply and waterworks system.</td>
<td>Referendum</td>
<td>Varies in size. Elected.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Counties</td>
<td>May operate a works system.</td>
<td>Political subdivisions of state.</td>
<td>Varies in size. Elected.</td>
<td>Yes</td>
<td>Yes</td>
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<td>Townships</td>
<td>May operate a waterworks system.</td>
<td>Political subdivisions of state.</td>
<td>4 Trustees and 1 Supervisor. No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>Water Commissions</td>
<td>To operate a water supply and waterworks system.</td>
<td>By vote of boards of member municipalities. Boundaries coterminous with member municipalities.</td>
<td>Appointed board of varying size. Appointed by member municipalities and county board or circuit court judge.</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<td>Public Water Districts</td>
<td>To obtain and distribute water, and to provide for waterworks and sewage properties.</td>
<td>Contiguous area with not more than 50,000 residents, by referendum.</td>
<td>Appointed board of 7 members.</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
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<td>Water Authorities</td>
<td>To regulate use of water and wells.</td>
<td>Contiguous territory, by referendum.</td>
<td>Appointed, number of members varies.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Surface Water Protection Districts</td>
<td>To provide for the collection, conveyance &amp; disposal of surface water.</td>
<td>Contiguous territory in one or two counties by referendum or by unanimous consent of all landowners.</td>
<td>Appointed board of 5 members for 3-year terms.</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
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</tr>
<tr>
<td>River Conservancy Districts</td>
<td>To provide for river and flood control, irrigation, conservation recreation &amp; water supply.</td>
<td>Area need not be contiguous, by referendum.</td>
<td>Appointed board, number of members varies (at least 5): 3-year terms.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Soil &amp; Water Conservation Districts</td>
<td>To develop plans for the control &amp; conservation of soil and water resources.</td>
<td>25 or more landowners, by petition, approval of the Illinois Dept. of Agriculture, 6 election.</td>
<td>5-member elected board.</td>
<td>No</td>
<td>No</td>
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<td>Conservation Districts</td>
<td>To acquire &amp; manage wildlands.</td>
<td>Contiguous territory, boundaries coterminous with boundaries of 1 to 5 counties, by referendum.</td>
<td>5-member appointed board.</td>
<td>Yes</td>
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<td>Urban Sanitary Districts - Act of 1937</td>
<td>To provide drainage &amp; sewage disposal. May acquire &amp; operate a waterworks system.</td>
<td>Contiguous territory containing all or parts of one or more municipalities &amp; area within 6 miles of a municipality, by referendum.</td>
<td>3-to-5-member appointed board. 3-year terms.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Rural Sanitary Districts - Act of 1936</td>
<td>To provide drainage &amp; sewage disposal. May acquire &amp; operate a waterworks system.</td>
<td>Contiguous territory in a single county &amp; outside any municipality, by referendum.</td>
<td>5-member appointed board. By referendum. 3-year terms.</td>
<td>Yes</td>
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<td>Yes</td>
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PREVENTION OF SHORELINE EROSION BY PHYSICAL AND STRUCTURAL METHODS

Dwight A. Niccum*

Lake Sara, Effingham, Illinois, we believe to be the only lake in the Midwest to be owned and operated by a municipal body known as a water authority.

Why? The city of Effingham had a serious water shortage problem in the early 1950's, as did many other communities. The usual source of supply, the Little Wabash River, ran dry several times each year. Community leaders tried several approaches—such as wells, dredging, formation of a river conservancy district—but without success. Finally, these community leaders worked to secure legislation which would permit a water authority to be formed in Illinois. In 1955 the water authority was approved by the voters, and by 1957 Lake Sara came into being.

One thing different about Lake Sara is that no state or federal funds were involved. The water authority entered into a contract with the city of Effingham, giving them exclusive right to use of water from the lake for a stipulated monthly fee covering forty years. Because of this contract, the water authority borrowed $1,200,000 to be repaid from revenue received from the contract with the city. The city, in turn, increased their water rate sufficiently to pay the monthly fee due the water authority. The city has no control over the lake, only the right to use water when needed. So, this lake is different in that neither the city, state, or federal governments supplied any funds directly nor have any control.

A second difference is that the city uses no water directly from Lake Sara. The lake is a reserve supply tapped only when normal supply dries up. This is usually late in the fall, and as a result, our lake has a constant water level, which aids greatly in shoreline protection, which is the subject of this discussion.

The court appointed the three trustees of the water authority with the full responsibility of building the lake and managing all the completely unfamiliar problems. However, we were lucky enough to do some things right. First, and most importantly, we employed a planning and engineering firm to prepare a

*Former trustee of the Water Authority, Effingham, Illinois
comprehensive plan, and we set up very strict zoning requirements. By doing this, we were able to enforce rules and regulations which made it possible to protect the shoreline and to prevent practices which would result in silting.

Our lake is 58 feet deep at the dam and has a projected life of 600 years, according to the engineers. We are told by Mr. Roberts, of the Water Survey Surface Water Section, that our silting has been very minimal. We have 735 acres flooded but own 2,200 acres which provide us with very good control of the area surrounding the lake. A small creek and a 12-square-mile watershed provide ample water to maintain a constant level. Capacity of the lake is 4½ billion gallons.

In zoning, we provided one-third of the shoreline for public use, one-third for residential use, and the remainder for commercial camping, swimming, marina, motel, and club use. All residential lots were set up in half-acre lots to prevent problems from septic facilities.

Perhaps another thing we did right was that when the interstate routes were built, we funded the cost of a tunnel for water lines. As a result, city filtered water is now piped to lake residents some 2½ miles outside the city. Several residential communities have sprung up along the water line.

What about shoreline protection? A great majority of the property owners have been installing steel, concrete, and wood protection. The water authority has made a practice of lowering the lake every year or so in late fall to permit and encourage property owners to build shoreline protection of various kinds. (When we speak of property owners, we really mean lessees, as no property is sold outright. Long-term leases are issued, and by this method, control of the lake is under the enforceable zoning regulations.)

The various types of shoreline protection used but not shown include: vertical concrete walls of varying heights, depending on the slope of the bank; horizontal creosoted wood timbers riveted together to form a retaining wall structure; a sloping concrete floor which meets a vertical wall above the lake level; and in one area, a breaker wall of oil drums and planking several feet away from the shore to cut down wave action.

Another innovative structure is a wall formed of 48-inch galvanized window wells strung together by aluminum wire and filled with poured concrete
(Figure 1). An equally creative but somewhat more expensive idea consists of an all-steel-sheeting dock and a steel piling wall (Figure 2).

Figure 1. Wall of window wells filled with poured concrete.

Figure 2. Steel dock and steel piling wall.
One of the better solutions to shoreline erosion is shown in Figures 3 and 4. It is a sloping concrete wall, extending from three feet above normal lake level into a trench 36 inches deep in the floor of the lake. There is heavy wire fencing reinforcing the concrete. This wall is especially effective in preventing ice damage.

Figure 3. Sloping concrete wall.
METHODS OF CONTROLLING HUMAN USE OF A LAKE

Donald W. Ferguson*

I don't expect to be able to bring forth every possible method of controlling human use of a lake which is available, but I will suggest two methods which we have used on two separate lakes with some degree of success. The city of Bloomington has as its water supply two man-made lakes which were built about thirty years apart and are handled in two different methods. The fact that the lakes are primarily water supply and secondarily recreational facilities has a good deal of bearing on the methods of guiding their use by humans.

Let us take each lake and the method used for control individually beginning with Lake Bloomington. This lake is about twelve miles north of the city of Bloomington and was built in 1929-30 for water supply. The purification plant is located adjacent to the lake and was put into operation in early 1930. Some of us remember the depression of the mid 1930's and its effect on city finances at the time. I suspect that the depression and the pressure of citizens to enjoy the new lake were the two major factors which influenced the administration at the time to subdivide shoreline lots around a portion of the lake.

Land was not sold but leased to individuals for a period of ninety-nine years at an original price of up to $300 with an annual maintenance charge from $1 to $25 per year. The leases were pretty well thought out and put together. They set forth the responsibilities of the lessee concerning shoreline maintenance, cleanliness and maintenance of the lots, and guidelines for septic tank and tile drain fields for the lots. Subsequent leases all expire on January 1, 2032, which is ninety-nine years from the first lease signed. We no longer lease additional areas to individuals, because we believe a good bit of the shoreline should be open to use by the general public. The water area and shoreline are not actually leased to the leaseholder. All leases cease at a contour line which is five feet, vertically, above the spillway overflow elevation and the use of the water area is given to the leaseholder by the rules. Rules covering the area of the lake which can be used by the leaseholder

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110
for swimming, boat storage, dock space, etc., were adopted and are periodically reviewed and updated. There are several organizations which have negotiated special leases. These include the Boy Scouts of America, Girl Scouts of America, East Bay Camp (a church affiliated group) and the marina which is authorized to lease boats, sell gas, bait, snacks, etc. They also rent, on a weekly basis, a couple of cottages which they have constructed.

So we have some control over the leaseholders who have leases adjacent to the lake by means of their leases which have cancellation processes included if the terms of the lease are not complied with. We have not cancelled any leases but have used the threat in several instances to get leaseholders to comply with some facet of their lease requirements.

The city provides garbage collection on a weekly basis at a nominal charge which eliminates the leaseholder's urge to throw his garbage in the lake and clutter the shoreline with the resulting debris.

The area around the lake is zoned entirely for residential use, except the marina, and both county and city permits are required when additions or alterations to existing structures are contemplated. The County Health Department regulates all septic tank and tile field installations or maintenance.

The purification plant is at the lake and through the years potable water has been made available to the several subdivisions around the lake, eliminating the potential problems of wells and septic systems being in close proximity.

All boats which use the lake are required to be licensed not only by the State but also by the city of Bloomington. A special security officer is employed and lives on the lake shore. He inspects all boats and motors prior to issuing a city license for the boat. He is furnished a boat for patrolling the water surface and is required to patrol the public property around the lake. His duties require him to check all safety features—lights, life jackets, etc.—both at the time of licensing and any time he is patrolling the water. Boats shall be of the proper size to handle the motor which is attached. The motor horsepower is limited to 40 at the present, and through the years this limit has
been changed from 12 to 40, depending on the city council thinking at any given time.

Any informal control exists in the competition between fishermen who want small motors only, and the water skiing enthusiast who would like unlimited horsepower. A happy medium is usually the result of this competition.

The lake is divided into several zones which carry speed control in accordance with the nature of the zone. Controls are based on depth of water, proximity to shoreline and cottages, distance from the spillway, etc.

Finally, the leaseholders at Lake Bloomington have formed an association with whom we work very closely in all phases of control and lake development. They meet monthly and are of great help to the security officer in his patrolling operation and to the administration in continuing development of the public areas around the lake. No camping or public swimming is allowed at Lake Bloomington.

The other lake which was built by the city to supplement its water supply, Lake Evergreen, was full for the first time in January, 1972. Construction occurred from 1968 through 1971. When the lake is full it has about 700 acres of water area while Lake Bloomington has about 600 acres of water area. After construction of Lake Evergreen was complete, the administration made several important and long-lasting decisions concerning the lake and the 1,400 acres of city-owned land surrounding it. They determined that no individual lots would be leased at the new lake and that no motors other than trolling motors would be allowed on the lake. They directed the regional planning staff to create a development plan for the lands surrounding the lake. Negotiations began with McLean County officials with the results to be the leasing of the public areas to the county.

The final lease calls for the county to develop the lands in accordance with the planning commission's development plan over a ten-year period. The county is to patrol and control the lands in accordance with rules and regulations set forth by the city council. The city retained the right to patrol the water and do what many be required to maintain a quality of water in the lake which would minimize the treatment process when necessary to use water from the lake for the city's water supply.

A swimming area was developed adjacent to the lake, and public camp grounds have been developed. A fine park area has been developed with nature trails,
wildlife areas, etc. Complete cooperation between city and county officials as it affects the leased lands occurs at all levels. The county patrols the grounds and the activities thereon with little difficulty. The officials of both agencies cooperate wholly with the Bass Club and the McLean County Sailing Club to the extent that fish stocking has occurred and sailing regattas occur periodically throughout the summer months.

The enforcement of the rules for the lake and its environs is similar to that at Lake Bloomington even though it is a lease arrangement with the County Parks and Recreation Department. The rules, for the most part, are similar to those in effect at Lake Bloomington except that no individual leases are allowed and no motors, except trolling motors, are allowed on the lake. When we have had to use water from Evergreen Lake for our supply in the city, recreation has continued without interruption.

I have pointed out two methods of controlling human use of lakes. One being a process of doing all the controlling with city employees and the other a minimal amount by the city and the majority by lease agreement. Each method seems to be working equally well and each, I believe, has its rightful place.
OVERVIEWS OF THE ECONOMIC ASPECTS OF RECLAIMING A LAKE

William L. Miller*

INTRODUCTION

The economic aspects of lake reclamation can be grouped into those which involve economic efficiency and those which involve equity. Economic efficiency analysis includes determining the cost and benefit of dredging and the cost and benefit of watershed management. Analysis of the equity of lake reclamation requires determining who pays the cost and who receives the benefit.

Since the following paper examines the cost and benefit related to lake dredging, this paper will concentrate upon the cost and benefit of watershed management and briefly discuss equity issues related to lake reclamation. Watershed management to reduce soil loss into lakes or streams has several social benefits. It improves the quality of the water, it maintains the productivity of the soil, and it reduces potential flood damages. There are certain social costs associated with watershed management, such as, reduction in farm revenue, planning and implementing management programs, and monitoring the results of these programs.

CONSERVATION PRACTICES

Many alternative management practices have been used in the past and are currently being used to reduce the soil losses from watersheds. These structural and nonstructural measures reduce the rate water flows over the land surface in order to reduce soil movement and increase percolation of water into the soil. Structural practices include grass waterways, terraces, drainage structures, sediment basins, and channel stabilization. Nonstructural measures include crop rotations, reducing row crops in the rotation, minimum tillage operations, such as chisel plowing, maintaining surface residue, strip cropping, and farming on the contour. Since these are alternative methods to reduce the soil loss from agricultural land, many studies have been conducted to see which practices reduce the soil loss the most and which practices have the least soil cost.

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114
Figure 1 illustrates how alternative management practices might be used to control the soil loss from a farm field. Practice W-1 which is corn in straight rows results in a loss of over 30 tons of soil per acre per year. When the corn is planted on the contour, soil losses are reduced to between 25 and 30 tons per acre per year. If instead of raising corn the farmer used this field for a grass pasture (practice W-3), the soil loss would drop to about 2 tons per acre per year. Since the pasture would be less profitable for the farmer than corn production, he might prefer to adopt practice W-4 which is corn production on level terraces. That practice achieves the same low soil loss as grass pasture on this particular field. It is essential to recognize that the data presented in Figure 1 represents the results of practices applied to a specific field. Under different climatic conditions, soil types, slope steepness, and length of slope the application of these structural practices will result in different amounts of soil loss as measured in tons per acre.

![Graph showing soil loss by management practice](image)

**Figure 1.** Average annual sediment yield as affected by land use and conservation treatments.


Table 1 illustrates the impact of selected conservation tillage practices upon the soil loss from agricultural land. This table also shows how changes in the steepness of the slope influence soil loss from the land. On the 3.4%
Table 1. Soil loss from conventional, till-planting, and ridge-planting systems

<table>
<thead>
<tr>
<th>Tillage System</th>
<th>Slope (%)</th>
<th>Soil Loss (tons/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>3.4</td>
<td>20.1</td>
</tr>
<tr>
<td>Till-Planting</td>
<td>3.4</td>
<td>11.3</td>
</tr>
<tr>
<td>Ridge-Planting</td>
<td>3.4</td>
<td>6.8</td>
</tr>
<tr>
<td>Till-Planting</td>
<td>6.9</td>
<td>28.8</td>
</tr>
<tr>
<td>Ridge-Planting</td>
<td>6.9</td>
<td>8.0</td>
</tr>
<tr>
<td>Conventional</td>
<td>9.0</td>
<td>36.7</td>
</tr>
<tr>
<td>Till-Planting</td>
<td>9.0</td>
<td>25.1</td>
</tr>
<tr>
<td>Ridge-Planting</td>
<td>9.0</td>
<td>5.9</td>
</tr>
</tbody>
</table>


Slope, conventional tillage results in 20.1 tons of soil loss per acre per year but till planting reduces that loss to 11.3 tons. On land with a 9.0% slope, conventional tillage results in 36.7 tons of soil lost, till planting permits 25.1 tons to be removed, and ridge planting reduces soil loss to 5.9 tons per acre per year.

The conservation tillage practices are effective because they maintain more soil cover to protect it from the erosive action of rainfall. Table 2 indicates how important it is to maintain cover over the soil. In tests made on soil plots covered with various amounts of straw, it was determined that no straw cover would mean a 27.8 ton soil loss, but only 0.25 tons of straw per acre on the plots would reduce soil loss to 9.0 tons per acre per year. As more straw was applied to the plots, soil loss dropped to as little as 0.7 tons per acre with an application of 4.0 tons per acre of straw.
Table 2. Effect of straw mulch on soil erosion, rainulator runs on plots of 15-percent slope.

<table>
<thead>
<tr>
<th>Mulch (Tons Per Acre)</th>
<th>Erosion (Tons Per Acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>27.8</td>
</tr>
<tr>
<td>0.25</td>
<td>9.0</td>
</tr>
<tr>
<td>0.50</td>
<td>8.7</td>
</tr>
<tr>
<td>1</td>
<td>5.1</td>
</tr>
<tr>
<td>2</td>
<td>1.1</td>
</tr>
<tr>
<td>4</td>
<td>0.7</td>
</tr>
</tbody>
</table>


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**ECONOMIC EFFICIENCY**

Table 3 presents an example of the economic impact on a farmer's income that results from the adoption of conservation practices that reduce soil loss. For this farm, shifting from moldboard plowing to prepare the soil for corn and soybeans to chisel plowing reduced soil losses from 12.8 to 6 tons per acre per year, but also reduced the farmer's income by $1.32 for each ton of soil that was kept on the land. Reducing the soil loss further by shifting part of the land to less profitable wheat production resulted in a $8.37 loss for the farmer for each ton of soil retained on the land.

The farmer's reduction in income resulted from lower yields and higher costs of additional herbicides and pesticides needed when minimum tillage is practiced. Since these were not completely offset by the lower cost of fuel and labor associated which chisel plowing in contrast to moldboard plowing,
Table 3. Changes in management practices and cost to reduce soil loss on 580-acre farm: Black Creek Watershed

<table>
<thead>
<tr>
<th>Soil Loss In Tons Per A.</th>
<th>Management Changes</th>
<th>Cost Per Ton of Soil Loss Reductions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Corn Acres</td>
<td>Soybean Acres</td>
</tr>
<tr>
<td></td>
<td>Moldboard Chisel</td>
<td>Moldboard Chisel</td>
</tr>
<tr>
<td>12.8</td>
<td>197</td>
<td>-</td>
</tr>
<tr>
<td>10.0</td>
<td>-</td>
<td>197</td>
</tr>
<tr>
<td>8.0</td>
<td>-</td>
<td>197</td>
</tr>
<tr>
<td>6.0</td>
<td>-</td>
<td>197</td>
</tr>
<tr>
<td>4.0</td>
<td>-</td>
<td>197</td>
</tr>
</tbody>
</table>


The losses in revenue presented in Table 3 occurred under these soil type, slope, and climatic conditions. Note particularly that it is more costly per ton of soil retained on the land as amount of soil retained increases. The $0.74 cost per ton is modest for the first few tons retained; but as the soil loss is reduced by 4 tons per acre per year, the cost of $8.37 per ton becomes prohibitively expensive.

This aspect of watershed management is illustrated further in Table 4. As soil loss from the rolling topography in Owen County is reduced on a 500-acre farm, the reduction in net farm revenue per acre was only a few cents per acre from 8 tons to 4 tons per acre; but when the soil loss was reduced to 1 ton per acre per year, net revenue was reduced by $10.00 per acre.

EQUITY

Table 4 illustrates the equity aspect of watershed management. When a state-wide maximum soil loss standard is applied, the cost to farmers is higher for those with small farms in the rolling topographic regions of the southern part of Indiana such as Owen County. For any maximum level between 8 tons and
Table 4. Net revenue per acre for different levels of soil loss, Indiana, 1973

<table>
<thead>
<tr>
<th>Soil Loss Level</th>
<th>Owen County</th>
<th></th>
<th></th>
<th>LaPorte County</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>160-Acre Farm</td>
<td>500-Acre Farm</td>
<td>160-Acre Farm</td>
<td>500-Acre Farm</td>
<td>160-Acre Farm</td>
<td>500-Acre Farm</td>
</tr>
<tr>
<td>Unconstrained</td>
<td>$85.35</td>
<td>$93.36</td>
<td>$73.48</td>
<td>$82.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 T.</td>
<td>85.30</td>
<td>93.36</td>
<td>73.48</td>
<td>82.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>85.22</td>
<td>93.36</td>
<td>73.48</td>
<td>82.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>85.10</td>
<td>93.30</td>
<td>73.48</td>
<td>82.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>84.75</td>
<td>93.19</td>
<td>73.48</td>
<td>82.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>84.09</td>
<td>92.93</td>
<td>73.48</td>
<td>82.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>83.07</td>
<td>92.32</td>
<td>73.48</td>
<td>82.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>80.72</td>
<td>91.28</td>
<td>73.34</td>
<td>82.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>72.78</td>
<td>83.49</td>
<td>72.78</td>
<td>82.25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


1 ton that might be chosen, the larger farms in northern Indiana where the land is less undulating will incur lower reductions in net revenue per acre. This suggests equity issues develop in relation to geographic regions and farm size under soil loss standards.

The equity of lake reclamation in both the watershed management and dredging components will be influenced by the source of funds for conducting the operations and by the distribution of benefits. Financial support for the project might come from private or public sources. Public sources could be local, state or federal governmental units. The tax sources of these funds and the cost-sharing opportunities that exist will influence the cost of the project borne by the different groups of people.

Table 5 illustrates the source of funds for a watershed project in Indiana. Federal funds from P.L. 566 and the Land and Water Conservation Fund provided part of the financial support for the project. State funds collected from a
Table 5. Incidence of funding sources, by location, West Boggs Creek Watershed, Indiana

<table>
<thead>
<tr>
<th>Funding Source</th>
<th>Local Percentage of Cost</th>
<th>State Percentage of Cost</th>
<th>Federal Percentage of Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>P.L. 566</td>
<td>0.03</td>
<td>2.37</td>
<td>97.60</td>
</tr>
<tr>
<td>LWF</td>
<td>0.02</td>
<td>2.58</td>
<td>97.40</td>
</tr>
<tr>
<td>Cigarette Tax</td>
<td>1.00</td>
<td>99.00</td>
<td>-</td>
</tr>
<tr>
<td>Property Tax</td>
<td>100.00</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>


cigarette tax provided additional funds, and the local government drew upon property taxes to provide its contribution to the project. In addition to location of the funding source and tax sources, some equity studies examine the cost of the project borne by different income classes or age groups. These may be important distributional aspects to examine when analyzing the financial support of lake reclamation.

Another important aspect of equity is determining who benefits from lake reclamation. How much of the benefit goes to land owners around the lake who obtain higher property values? What is the financial gain for those people who receive water from the lake if it is used as a water supply lake? How will recreational use of the lake be enhanced by the dredging operation? These questions must be explored if those receiving the benefits are to be encouraged to pay the costs of the project.

The elements of economic analysis are efficiency and equity. What are the costs and benefits of lake reclamation and who pays the costs and receives the benefits. These two aspects need to be explored for both dredging operations and watershed management, because they both contribute to enhancing the water quality and storage capacity of the lake.
A CASE STUDY OF THE ECONOMIC BENEFITS OF RECLAIMING A LAKE:
LAKE PARADISE, MATTOON

Susan Rothrock Deo*

The economics of a lake reclamation program are important to every community considering such a project. The costs and benefits of relevant alternatives must be carefully weighed before the most appropriate choice can be made. Unfortunately, there has not been extensive research on the economics of lake reclamation, especially regarding dredging. Although definite values for all possible costs and benefits cannot be established, it is important that each community be aware of all the possibilities in order to make a more accurate assessment of the alternatives available. Over the past several years the University of Illinois' Water Resources Center has been interested in the actual values that might be placed on such a project. During the past year a study has been undertaken to begin quantifying some of these costs and benefits for a lake dredging and watershed management program at Lake Paradise in Coles County.

Lake Paradise covers approximately 170 acres and is the main source of water for the city of Mattoon. At a local rate of $1.75 per cubic yard removed, taking three feet of sediment from the lake would cost approximately $1.5 million. This includes the removal of 822,800 cubic yards of sediment for a total of $1.44 million, with the cost of handling and drying the sediment bringing the total to about $1.5 million. The cost of an efficient watershed management program is quite site-specific and yet to be determined for Lake Paradise. It must eventually be included on the cost side for accuracy, however.

One of the potential benefits of this project is the improvement in water supply. First of all, there is an increase in storage capacity. Currently, during dry periods the water supply in Lake Paradise is insufficient, and substantial amounts of water must be pumped from the larger Lake Mattoon which is further downstream. The reclamation of some of the storage capacity in Lake Paradise would save the city at least $5,500 per year in pumping costs. This is the cost of bringing an additional three million gallons (current daily usage in Mattoon) from Lake Mattoon to Lake Paradise 55 days a year (number days pumping saved by restoring this capacity to the lake).

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Another benefit is a reduction in the water treatment necessary as a consequence of the improvements in water quality. Since the water treatment filters would not need to be cleaned as frequently with the lower levels of suspended sediment this could save both time and energy. Also, the requirement for potassium permanganate, which is used to control taste and odor problems, would be reduced. At a cost of $700 per month, this chemical is currently being used for about five months of the year by the Mattoon water department. Assuming the improvement in water quality reduced the need for the chemical to only three months, $1,400 could be saved each year.

Recreational benefits have been shown to be the most important of water quality improvements in many situations. Research is presently underway that may result in more accurate values for the benefits of present and potential recreation at Lake Paradise, but a detailed study would be too costly and time consuming at the present. This improvement in water quality is more likely to result in an improvement in the quality of recreation at Lake Paradise than in a substantial increase in visits to the site. The yearly benefit can be sizeable, however. If a value of $3.00 is placed on each visit to Lake Paradise and the total yearly visits estimated to be 100,000, for example, a 10 percent increase in value as a result of water quality improvements would amount to additional benefits of $30,000 per year. Estimates from other studies show total recreational benefits for a similar lake to be around $50,000 per year, while the benefits from improving water quality on another lake have been suggested to be about $35,000 per year.

Perhaps the most frequently overlooked benefit is the sediment itself. Recent experiences within Illinois have shown the sediment useful for agriculture and for private uses. Findings of the Lake Paradise sediment analyses show this sediment to have good agricultural properties, favorable nutrient levels, and low levels of pesticides and heavy metals. Yielding 411,400 cubic yards when dry (the bottom sediment is about 50 percent water by volume), the sediment could cover 255 acres if spread uniformly one foot deep. It is possible that savings in fertilizer could amount to $10 per acre, totaling $2,500 per year for at least five years. (After being drained, the disposal site in one Illinois community has been farmed for at least seven years, with no addition of fertilizer.) Another possibility is selling the sediment as topsoil. If all of it were sold at the conservative value of $1 per cubic yard, the total one-time benefit would be $411,400.
Two other potential benefits that might be measured relate to the lengthening of the life of Lake Mattoon and the advantages of having a large and certain water supply. Improving the sediment trap efficiency of Lake Paradise and establishing appropriate management of the watershed is likely to extend the effective life of Lake Mattoon since the upper third of the Lake Mattoon watershed is the watershed of Lake Paradise.

Water shortage is a regional problem in the Mattoon area. With the insurance of an enlarged and well-managed water supply, the city of Mattoon could generate income by selling some of their excess water to other communities or individuals in the region. The monetary benefit of this depends upon the supply of, and demand for, the water.

Sometimes the benefits of improved water quality and quantity can be expressed in the form of increases in adjacent property values. Since the city owns the land around Lake Paradise, an increase in property values will not be as noticeable, although the city could conceivably increase the yearly rent for the lots on the lake. The values of the privately-owned cottages on the leased land may rise somewhat, thereby increasing tax income. However, if recreation benefits are to be included, this may be double-counting since benefits to recreation often are manifested in the form of increased property values.

No economic analysis would be complete without a comparison of the costs and benefits of the various alternatives being considered. For example, one alternative to reclaiming Lake Paradise is to build a new reservoir. The Soil Conservation Service estimates construction costs to be $150 to $300 per acre foot of storage to build a reservoir of the same capacity that the dredging alternative would restore to the lake (510 acre feet). This would cost between $76,500 and $153,000, not including expenses for land or special services such as road relocation. Buying just 100 acres, however, could raise this expense considerably. If the land averaged $2,000 per acre, this would add $200,000 to the total. Also, the next nearest site for a reservoir is about 30 miles downstream from Lake Mattoon, which would make the costs of pumping quite high. In order to make an accurate evaluation, all the benefits must be compared as well. For instance, if building a new reservoir, the city would probably make it larger than required to replace the amount of storage lost in Lake Paradise. With economies of size the cost per unit volume is likely to be less for a larger lake, therefore, it is necessary to compare the benefits as well as the costs in order to determine the most economic alternative.
There are also benefits which may be of considerable importance but are very
difficult to quantify and beyond the scope of this study. Some of these are the
improved aesthetics of the area, long-term maintenance of soil quality, preserva-
tion of valuable farmland in production, and enhancement of the community for new,
as well as present, residents and businesses.

Table 1 summarizes the approximate costs and benefits, both quantified and
unquantified. The costs have been annualized for ease of comparison since most
of the benefits are on a yearly basis. An annualized cost figure was obtained
using the capital recovery table for 7.5 percent interest (Water Resources Council
standard) and a 40-year period (possible life of the project). Even though
some of the larger values expected for benefits are still preliminary and uncertain
(especially regarding recreation), the estimated benefits are sizeable and
warrant further research on the economics of restoring this lake. These promising
results from the Lake Paradise study indicate that combining restoration and
management techniques may be an answer to the problems of some of Illinois' reservoirs.
### Table 1. Estimated Costs and Benefits of Restoring Lake Paradise

#### COSTS

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reclamation of 510 acre feet (166 million gallons) through dredging</td>
<td>$119,100/year</td>
</tr>
<tr>
<td>(payments on loan at 7.5 percent interest for 40 years)</td>
<td></td>
</tr>
<tr>
<td>Watershed Management</td>
<td>?</td>
</tr>
</tbody>
</table>

#### BENEFITS

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Supply</td>
<td></td>
</tr>
<tr>
<td>reduced pumping</td>
<td>$ 5,500/year</td>
</tr>
<tr>
<td>reduced water treatment filtering</td>
<td>?</td>
</tr>
<tr>
<td>addition of chemicals</td>
<td>$ 1,400/year</td>
</tr>
<tr>
<td>Recreation</td>
<td>$ 25,000-50,000/year</td>
</tr>
<tr>
<td>Sediment</td>
<td></td>
</tr>
<tr>
<td>sold as topsoil (one payment)</td>
<td>$411,400*</td>
</tr>
<tr>
<td>or spread on farmland (at least 5-year benefit)</td>
<td>$ 2,500/year</td>
</tr>
<tr>
<td>Extended Life of Lake Mattoon</td>
<td>?</td>
</tr>
<tr>
<td>Increase in Community Income</td>
<td></td>
</tr>
<tr>
<td>sale of water</td>
<td>?</td>
</tr>
<tr>
<td>attract new residents and industry</td>
<td>?</td>
</tr>
<tr>
<td>increase lake property values</td>
<td>?</td>
</tr>
<tr>
<td>Difficult to Quantify</td>
<td></td>
</tr>
<tr>
<td>aesthetic enhancement</td>
<td>?</td>
</tr>
<tr>
<td>increase in community income</td>
<td>?</td>
</tr>
<tr>
<td>increase in community pride</td>
<td>?</td>
</tr>
<tr>
<td>maintaining soil quality</td>
<td>?</td>
</tr>
<tr>
<td>maintaining current farm acreage</td>
<td>?</td>
</tr>
</tbody>
</table>

#### COST OF AN ALTERNATIVE

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of a 510 acre feet lake, purchase of 100 acres of land</td>
<td>$276,500-353,000</td>
</tr>
<tr>
<td>Pumping to City</td>
<td>?</td>
</tr>
</tbody>
</table>

*not a yearly value; over whole life of project (40 years)
USES OF DREDGED MATERIAL

Thomas R. Patin*

INTRODUCTION

This presentation looks at the uses and potential uses of dredged material and presents some of the problems and constraints that might be involved in accomplishing these uses of dredged material.

For a little background, all of the information presented was accumulated during and after the Dredged Material Research Program (DMRP). The program was initiated by the Office of the Chief of Engineers (OCE), Washington, D.C., and managed by the Corps research facility, the Waterways Experiment Station (WES) in Vicksburg, Mississippi. The 5-year, $32.5 million program started in March 1973 and ended in March 1978.

Productive uses of dredged material played a key role in the research efforts of the DMRP. In fact, the overall objective of the entire program directed that the research efforts would consider dredged material a manageable resource. Two major projects out of a total of four were specifically directed at using dredged material productively. Research within the Productive Uses Project was aimed at developing productive uses of dredged material from a nonwildlife use standpoint, whereas a second project area, the Habitat Development Project, was aimed at developing productive uses of dredged material from a wildlife use standpoint.

PRODUCTIVE USE POSSIBILITIES

There are probably any number of different classification schemes that could be used for classifying uses of dredged material. The Productive Uses Project classified the nonwildlife uses of dredged material into (1) industrial/commercial, (2) recreation, (3) agricultural, (4) material transfer, (5) waterway related, and (6) multiple purpose. In the wildlife use area, the Habitat Development Project categorized uses into (1) marsh development, (2) terrestrial habitat development, and (3) bird island or avian habitat development.

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Probably the most common nonwildlife productive use of dredged material, at least in the past, has been the industrial/commercial use. This would essentially include port and residential development of disposal sites. It's generally a high intensity use of the area for buildings or major structures. Probably every major port in the world has some industrial/commercial use of dredged material where these facilities have been built on former dredged-material disposal sites.

Recreational uses is a second category of nonwildlife use. It's generally related to the industrial/commercial use, although we usually see more open space use, for instance, golf courses, tennis courts, baseball fields, etc. The engineering characteristics of the material do not have to meet the high standards they would in the industrial/commercial use.

An example of a recreational use site is in East Potomac Park in Washington, D.C. This particular site is an island that has been developed into an 18-hole golf course, any number of tennis courts, jogging tracks, picnic areas, etc., generally open space use.

Other recreational sites and potential sites would include: a site called Patriots' Point in Charleston, South Carolina; Kelly Point Park in Portland, Oregon; and a potential site at Huron, in the Great Lakes area. Huron Site 1 is 63 acres in size, and present plans call for recreational uses of the site once it has been filled.

A third category of productive uses is agricultural use. It's not as common a use as the industrial/commercial and recreational uses but is found in a number of sites throughout the United States, and it does hold a potential for use. An old disposal site in Charleston, South Carolina called Daniel Island is presently the site of a truck farm. In Galveston County, Texas and in Columbia County, Oregon sites have been used for cattle grazing. Experiments have been carried out in Mitchell Bay, Ontario, Canada, by Public Works, Canada. Winter wheat was planted on a small plot of fine-grained dredged material.

In the DMRP, we combined dredged material from ten different disposal sites within the United States with somewhat nonproductive agricultural soils in the immediate area. We have raised rye and barley on these mixtures. As an example, we found that dredged material from a disposal site in the Chain O' Lakes, Illinois area, which contained dredged material from Fox Lake, could improve the
productivity of the somewhat coarse-grained nonproductive agricultural soils. The agriculture soil was a Boyer loamy sand from a nearby field. General results have shown that if a coarse-grained agricultural soil is mixed with a fine-grained dredged material, the productivity of that soil can usually be increased. On the other hand, if a coarse-grained dredged material is mixed with a fine-grained agricultural soil, the productivity is generally not increased.

Material transfer is a fourth category of nonwildlife productive use of dredged material. It differs in that here we are removing material from the disposal site for reuse as opposed to using the site itself. For instance, in Bay City, Michigan dredged material was removed from a disposal site to be used as cover material for a landfill. Similar operations are also being conducted in Wilmington, Delaware and Alameda, California. Dredged material is also being sold as fill material for such items as highway construction. The Philadelphia District has sold about 2.8 million cubic yards between 1972 and 1976. The Savannah District has given away a million cubic yards to the Department of Interior and to the U.S. Coast Guard. The Galveston District has sold about 500,000 cubic yards from disposal sites in the Houston ship channel. The Sacramento District has sold about 20 million cubic yards to the California Division of Highways for interstate highway construction.

Within the DMRP, with the aid of the Chicago District, a small field demonstration of reclaiming about 2 acres of barren strip-mine land with dredged material from a disposal site in Chicago was conducted. The material was trucked from Chicago, about 70 miles to Ottawa, Illinois where it was placed in a 3-foot lift on a leveled strip-mine area. Five species of grasses were planted and leachates and runoff water were monitored. So far, reclamation has succeeded, vegetation has flourished, and very little, if any, runoff or leachate contamination has resulted from the dredged material.

Within the state of Illinois, Argonne National Laboratory is presently conducting for the Corps of Engineers' Rock Island District a feasibility study examining the possibility of using dredged material to reclaim abandoned strip-mined land along the Illinois Waterway. This study is to include analysis of institutional as well as technical factors bearing upon successful implementation. The study will inventory abandoned strip-mined land suitable for reclamation along the water, inventory dredged-material supplies in the waterway, make
recommendations for the most suitable sites, and then draw up plans for some of the most appropriate sites. This study should be completed by the fall of 1981.

Waterway related use is yet another nonwildlife category of productive uses. This includes uses of dredged material for purposes closely related to the maintenance, preservation, and expanded use of a waterway; such as beach nourishment, shore protection, breakwaters, etc. The Fifth Street Marina in San Diego, California is a waterway-related use. Initially, dredged material was to be put into a diked area. As it turned out, the dredged material was used for construction of a breakwater, as needed by a marina in the immediate vicinity. For example, any number of beaches in Florida have been restored. Beach nourishment has also been practiced on the Great Lakes. In the Columbia River, Oregon dredged material has been used extensively for river control.

The last nonwildlife use is multiple use of a dredged-material disposal site. In Toronto, Canada, numerous commercial, transportation, and recreational facilities have been created in what is now known as Toronto's Aquatic Park. In Chicago, dredged material was used in the construction of Grant Park. Another such site is Swan Island in Portland, Oregon. Pelican Island in Galveston, Texas is an old disposal site, which today contains recreational areas, port terminals, manufacturing uses, commercial offices, a shipyard, and a college.

In the wildlife area of productive uses, there are sites such as the Pointe Mouillee State Game area on Lake Erie, where the Detroit District, in connection with other federal and state agencies, is actively involved in planning and constructing a dredged-material disposal area for restoring a marsh. The area will be actively managed for maximum wildlife use by the state of Michigan. It contains about 2,500 to 3,000 acres of marsh and about 700 acres of upland habitat behind the dikes. The area will be managed for seabird nesting, Canada geese use, and fishing.

In the DMRP, marshes were developed at seven sites throughout the United States. Upland, or terrestrial, habitats were developed at a total of five sites. The results are that techniques for establishing marshes and terrestrial habitats now exist, where before, none existed. The work was conducted in fresh- and salt-water, on coarse- and fine-grained materials, in river systems and open water systems, and in high and low energy environments.
Another wildlife productive use is avian habitat on dredged-material islands. For instance, in the Great Lakes 22 percent of the 1,977 Colonial Water Bird Species were located on dredged-material or man-made sites. At first glance, this may not seem impressive, but when you consider that 100 percent of all available sites are being used, it indicates that there may be a shortage of sites, and any such sites designed for bird use will be used intensively. Studies have shown that dredged-material islands throughout the United States have been extensively used by birds for a number of reasons. In fact, the Wilmington District in North Carolina actually manages dredged-material disposal islands for bird use. These management practices have been coordinated with the North Carolina state agencies, in which dredged material is put on islands to create barren areas for use by those birds that need barren nesting areas.

CONSTRAINTS

As you can see, productive use of dredged material is not new, and as always, when disposal of dredged material is concerned, there will be constraints. Constraints on productive uses come in many forms— from major technical constraints, to local citizen groups opposing a project—all of which have to be addressed.

On the technical constraints, the DMRP can offer help. We have published guidelines on (1) marsh and terrestrial habitat development, (2) management of bird islands, (3) strip-mine reclamation, (4) agricultural uses, (5) use in solid waste management, (6) long-distance movement of dredged material inland, and (7) guidance on planning and implementation considerations of productive uses on dredged-material containment areas.

Socioeconomic impacts are usually a major constraint. For instance, moving material inland for, let's say strip-mine reclamation, will, in fact, increase the sponsor's cost of the project. On the other hand, the value of the strip-mined land will be enhanced and therefore the property owner will benefit. The question arises, should the landowner pay for movement of the material?

Selling material should, in fact, return some monies to a project sponsor. So far, under the present guidance the Corps' experience has been that dredged material must first be classified as surplus government property. Then any monies collected for the sale of dredged material would go to the General Services Administration (GSA) as opposed to the Corps District. Presently,
potential benefits from productive uses are not considered in costing dredging projects. If it would be included, it could possibly aid in finding new disposal sites and in accomplishing productive uses.

Legal constraint can generally be classified as federal, state, and local. On the federal level, restraints are in the form of such laws as the National Environmental Policy Act, the Clean Water Act (404), the Resource Conservation and Recovery Act, the Coastal Zone Management Act, the Endangered Species Act, etc. For instance, if discharge is to occur within the waters of the United States, 404 becomes involved. On the other hand, if material is to be rehandled from a disposal site and carried inland in a dry condition, the Resource Conservation and Recovery Act may get involved. Site and material ownership is a key problem, in that the question always arises as to who owns the material once it is dredged.

The state role generally falls into two major categories: environmental protection laws and land-use control laws. Many of the environmental protection laws are patterned after similar federal laws. Laws governing wetlands protection, water quality, wild and scenic rivers, fish and game habitat, environmental impact assessment, all exist in many of the state codes. Land use control laws, such as land use and land-use planning, public land use controlling state-owned or submerged lands, sediment and erosion control, floodplain protection, agricultural zoning, local zoning, port district enabling laws, all exist within the state codes, and in many cases, are restraints to productive uses of dredged material.

Last, but not least, are the local laws which also play a key role in productive uses. Local zoning and comprehensive planning laws have to be examined before productive uses are considered.

We have found that, in most cases, planning is the key issue. If long-range planning is brought to bear and carried out, most problems will surface before actual construction begins. The initial constraints will be finding a market for the material. Once a need is found and a project appears feasible, coordination among the various federal, state and local agencies should begin at once. Other organizations, such as the various conservation groups and local citizen groups, should also be kept well informed about the initial project and any changes.
SUMMARY

Productive use of dredged material is not a new idea. Many forms of use have been developed in the past; potential new uses now exist and, as yet, unknown uses are possible. There is no definite list—it's generally a matter of finding a need and matching that need with the resource.
AN ECONOMIC ANALYSIS OF THE RECREATIONAL BENEFITS
OF WATER QUALITY IMPROVEMENT

Nicolaas W. Bouwes, Sr.*

In 1975 the Waupaca Lake District was formed when it became apparent that the two small lakes located within the city limits of Waupaca were experiencing water quality problems. The district requested and received state and federal aid for the implementation of a storm water diversion project, which consisted of storm sewer diversion, alum treatment, and lake aeration. The approximate total cost of this project was $430,000.

The public agrees there are positive impacts associated with improved water quality. However, as indicated above, there also exist costs to bring about the realization of such benefits. The obvious question then is whether the benefits associated with water quality change will justify the costs. Although it is of interest to determine whether the Waupaca project was justified, it is perhaps more important that issues such as these be determined ex ante to implementation to facilitate the decision-making process.

What insight can economics bring to bear on such issues as these? The purpose of this paper is to address such an issue by employing the method proposed by Bouwes and Schneider (1979), viz., by: (1) presenting a theoretical foundation from which an empirical analysis will build; (2) establishing a framework by which water quality can be accounted for in the model; (3) presenting a model which includes the essential water quality variable; and (4) synthesizing these components by advancing a method which can be applied ex ante to decision-making situations.

THEORETICAL MODEL

Consistent with the framework used by Maler, an individual's utility is represented as a function of consumption activities, A, and environmental services, E:

\[ U = U(A,E). \]

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By assuming the existence of weak complementarity, e.g., those situations where
the consumption of a private good, such as swimming in a lake, is a necessary
prerequisite of the enjoyment of a given environmental quality, such as water
quality of that lake, then it is possible to derive the benefits (costs) of a
quality change in a public good (environmental service) from information on the
demand for the private good.

This condition of weak complementarity is expressed in mathematical terms
by equation (2):

$$\exists U(0, A_2, \ldots, A_m, E_1, \ldots, E_n) = 0$$
$$\exists E_1$$

where consumption $A = A_1, \ldots, A_m$ and the accompanying environmental service
$E = E_1, \ldots, E_n$.

Also embodies in this notion of weak complimentarity is the assumption that
there are no option values, or that if the demand for some private good is zero,
then so is the marginal willingness to pay for some environmental quality. An
example is the case of water-related recreation, the use of which is influenced
by the level of water quality. Those who do not use the lake are then assumed
to be indifferent to changes in water quality.

It can now be shown that if condition (2) exists and there is no option
value, it is possible to compute the demand price for the environmental service.
Consider the income compensated demand curve $D_o$ for say, recreation trips when
quality of water is $WQ_0$ as depicted in figure 1. At the price $P_o$ the recreator
demands $T_o$ trips, and the consumer surplus is the triangle ABC. If the level
of water quality increases to $WQ_o^*$, it is assumed that this change will increase
the marginal utility per trip and shift the demand curve to position $D_o^*$, and the
recreator now demands $T_o^*$ trips. The new consumer surplus is represented by the
area DEC, and the net change in consumer surplus is given by the area BADE. 1/
This change in consumer surplus reflects what the consumer is willing to pay
for this change in water quality.

Calculation of the benefits associated with a change in water quality as
represented by willingness to pay can proceed in three stages: (a) A change
in price from $P_o$ to $P_o^*$: given the demand curve $D_o$, the individual must be
compensated by the corresponding consumer surplus ABC so as not to be made worse off
Figure 1
Benefits Under Complementing Conditions
by the price change. (b) A change in water quality from \(W_0\) to \(W_0^*\): given the assumption of weak complementarity, the consumer's utility is unaffected and thus there is no need for compensation. (c) A change in price back to \(P_0\): the consumer is willing to pay the new consumer surplus as represented by the area DEC. The net result is the difference between the consumer surplus before and after the water quality change. In other words, the consumer would be willing to pay BADE for a change in water quality. The first step in making such a determination is the estimation of the demand curve for recreation, as measured by trips (T), that is a function of water quality.

THE TRAVEL COST MODEL

Most recreational demand curve estimation procedures are based upon the travel-cost approach proposed by Hotelling. Simply stated this method hypothesizes that recreational demand estimations can be made by examining the correlation between recreators' frequency of visits and costs (money, time, etc.) incurred. The resulting estimated demand schedules can then be used to predict how recreators will react to price changes of recreating at a particular site thus allowing for the estimation of the site demand curve and consumer surplus.

This approach has been refined over the years by Trice and Wood (1979), Clawson (1959), Kneese and Bower (1968) and others. More recent statistical sophistications have been made through the use of individual observations rather than grouped data allowing better model specifications and more accurate resource evaluations (Brown and Nawas, 1973; Gum and Martin, 1975). All of these methods have been applied to evaluating the total recreational resource, but not in assessing the impact of a resource attribute, such as water quality.

Some of the more recent efforts to estimate the effect of a change in water quality on the value of recreation resources have concentrated on the estimation of those benefits that would be attributable to the change in one or more of the physical parameters that contribute to the quality of water, e.g., recreation benefits increase as the dissolved oxygen concentration level rises (Kneese and Bower, 1968; Davis, 1963). Stevens (1966) hypothesized that the quality of the recreation experience (fishing) is a function of angling success which is a function of water quality. Reiling et al. (1973) employed use-intensity factors of water-related activities that were supplied by Forest
Service and Environmental Protection Agency personnel. The major shortcoming of these efforts is that the techniques do not contain a systematic relationship between the subjective index used as a proxy for water quality and the physically measurable water quality parameters and, perhaps more importantly, with recreators' perceptions of water quality.

OBJECTIVE AND SUBJECTIVE WATER QUALITY RELATIONSHIP

Ultimately, the existence or nonexistence of benefits from a water quality change are determined by whether the water user recognizes an improvement. If an actual water quality change remains unnoticed, or if what is noticed is not valued by the recreationists, no benefits will result. In order to estimate ex ante the benefits that will accrue to recreationists as a result of a water quality improvement, it is necessary to predict how lake users perceive water quality.

Since water resource experts use objective and sophisticated criteria such as dissolved oxygen content, BOD in parts per million and turbidity standards, it is necessary to determine the relationship between this objective rating of water quality and the typical recreator's subjective rating.

To ascertain if such a relationship exists it is necessary to seek an objective water quality index. The choice is Uttermark's Lake Condition Index (LCI), which was developed in 1975 to classify all Wisconsin lakes larger than 100 acres. The lake classification index is based on penalty points accumulated for four parameters: dissolved oxygen in hypolimnion (0-6 penalty points); Secchi disk transparency (0-4 penalty points); fish winterkill (0-4 penalty points); and algae growth (0-9 penalty points). The penalty points range from 0-23. A lake with poor water quality would accumulate a large number of penalty points and would consequently have a high LCI value.

The relationship between the LCI and subjective water quality ratings had been previously examined by obtaining information from on-site interviews at eight southeastern Wisconsin lakes (Schneider and Bouwes, 1979). Recreators were asked to rate lake water quality on a 0-23 scale such as that used by the LCI. The effectiveness of the LCI in predicting the public's perception of water quality was tested by regressing the average subjective rating (\( \bar{R} \)) of all recreators for each lake on the corresponding LCI for that lake. The results of this were encouraging, yielding the equation:
\[
\begin{align*}
(3) \quad \ln \hat{R} &= 1.948 + 0.0364 \text{ LCI} \\
R^2 &= 0.998 \\
n &= 7.
\end{align*}
\]

The value(s) in parentheses are the computed t-values. With this equation and a limnologist's estimates of the changes in LCI that would take place with and without the project, the recreationist's subjective perception of this change could be predicted.

Encouraged by the results of this previous study, questions regarding users' water quality perceptions were included as part of a random statewide telephone survey of Wisconsin households. Each respondent was asked to rate the water quality of the lake in question on the same 0-23 scale. This survey provided a cross-section sample of 723 observations among 243 Wisconsin lakes. Attempts to duplicate the pretest results, though, proved unsuccessful as indicated by the initial regressions which yielded insignificant estimators and low coefficients of determination, suggesting that the LCI was not very effective in "explaining" the public's perception of water quality.

These results led us to believe that the problem lay in the different methodologies used in gathering information. In the previous research, responses were obtained by on-site interviews, whereas, the statewide data was gathered through a telephone survey of a representative sample. This survey was conducted in October and November of 1978 and questioned respondents about their recreational activities in the period between Labor Day 1977 and Labor Day 1978. We now believe that the telephone survey technique introduces a recall factor bias where the respondent, being distant in space and time from the lake, cannot give as accurate a rating as he/she could have if they had been interviewed at the site.

As indicated above, the most desirable procedure for estimating the benefits of water quality change is having a recreation demand model which includes a user's subjective water quality variable, and a link between this variable and a measurable, objective water quality variable, as used by the natural scientists, that will allow predication of change in the subjective variable. The next most desirable arrangement, that will still allow for an ex ante analysis, would be when the objective water quality variable is used directly in the demand equation.

This latter approach requires but a few observations on a large cross-section of many lakes of differing degrees of water quality, thereby allowing for a determination of the correlation between differing numbers of trips and water
quality. In the current analysis this condition is satisfied by the statewide sample which included 243 lakes with typically one, two, or three observations at each. In the previously referred to study (Bouwes and Schneider, 1979), the data were gathered at only eight lakes with many observations of each. Under these circumstances it was imperative that the individual's subjective water quality ratings rather than the LCI be used to determine the correlation between visits and water quality.

Although no correlation was established between the LCI and subjective ratings both were experimented within the estimation of the recreation demand curve. The LCI proved to be the significant predictor of behavior and is reported on in the next section.

THE STATISTICAL MODEL

The general form of the model used to estimate water quality benefits is that employed by Bouwes and Schneider (1979):

\[ T_{ij} = \alpha + \sum_{k=1}^{n} \beta_k X_{ijk} + e_{ij}, \]

where \( T_{ij} \) is the number of trips by decision-making unit \( i \) to lake \( j \), \( X_{ijk} \) is independent variable \( k \) for the decision-making unit \( i \) at lake \( j \), and \( e_{ij} \) is the error term. The primary objective is to estimate a statistical demand curve with reliable estimates of the structural variables—particularly those of the cost variable from which the resource value is derived and the water quality variable which is used to determine the economic significance of a change in water quality.

The initial general model included a set of regressors deemed to be consistent with economic theory and findings from previous recreation demand studies. Daytrips were hypothesized to be a function of the already mentioned cost and water quality variable as well as other variables deemed pertinent. Travel time is considered to be a cost of recreation and was included. Family income was included to account for the income effect on the decision maker. Tastes and preferences for water-related activities were represented by number of trips to all lakes visited. The number of other lakes visited was used to reflect substitutes. This choice is based on the assumption that it is only the lakes that the recreator is aware of that constitute the relevant substitutes in his choice set. Recognizing that other site amenities distinguish sites, other variables reflecting water quality, lake size, availability of facilities, etc., were included.
Various functional forms were attempted in the estimation of the demand relationship--linear, quadratic, semi-log, and log-log. Each was run with the variables specified in the general model. When each of the functional forms of the general models was run it was determined that heteroskedasticity was present. This was adjusted for in the manner proposed by Glejser (1969). Once the data was properly weighted to deal with the heteroskedasticity, the models were run again and variables were eliminated via F-tests to determine if their exclusion produced a significant difference.

Regressions based upon the entire statewide sample did not produce a significant demand equation. Since Northern Wisconsin lakes possess a considerably higher level of water quality, as determined by the Lake Classification Index, it was suspected that northern lake recreators might constitute a different population than southern lake users. Consequently, the state sample was divided into northern and southern counties and the regression analysis repeated. This effort provided statistically significant results that are reported below. Also, this subsample choice had intuitive appeal as the Shadow Lake is a northern lake used exclusively by daytippers.

As indicated, the data are based on individual observations. One of the justifications for utilizing data based on individual observations is that such reduces the multicollinearity between the cost and time variables that are present when zone averages are used, thereby allowing the inclusion of both in the estimation of the demand curve. When zoned averages are used, time is typically omitted. This produces a cost coefficient having too great a magnitude and hence an under-evaluation of the resource. However, for the case at hand the use of individual observations did not alleviate the problem of multicollinearity. Consequently, it was necessary to compensate for this problem. This problem can be addressed by either omitting one of the variables, which then produces a biased estimator for the remaining variable, or by constructing a composite variable which would account for the presence of both variables. This latter alternative is consistent with economic theory that prescribes determining a value for travel time and adding this to actual travel costs. In other words, costs are represented as:

\[
C_{ij}^\lambda = C_{ij} + \delta_i t_{ij}
\]

where \( C_{ij}^\lambda \) is equal to total trip costs for individual \( i \) to lake \( j \), \( C_{ij} \) is equal to round-trip travel costs, \( \delta_i \) is the opportunity cost of time for decision-making unit \( i \), and \( t_{ij} \) is round-trip travel time to lake \( j \).
In order to utilize this form of the cost variable it is necessary to determine the appropriate value for $\delta_i$, that is, what is the relevant opportunity cost of time. Cesario (1976) suggests that the value of time with respect to nonwork travel is between one-fourth and one-half of the wage rate. The former value was selected in an effort to maintain conservative benefit estimates. The opportunity value of time was determined from the reported income figures which were reduced to an hourly rate and applied to the round-trip travel time. The final estimated demand curve for visits is:

$$T_o = 16.1651 - 3.1533 \ln C^l - 5.4242 \ln LCI + .3312 Y \quad n = 52$$

(6)

where $T_o$ is the number of visits for the year, $C^l$ is the travel cost per trip plus the opportunity cost of travel time, LCI is the lake classification index, and $Y$ is the recreator's income.

ECONOMIC BENEFITS UNDER CURRENT AND ALTERNATIVE WATER QUALITY CONDITIONS

To estimate the flow of benefits attributable to the project, it is necessary to estimate those benefits that would accrue each year with and without the project—the sum of these represent the relevant benefits. To accomplish this, a two-step evaluation process is employed. This approach requires applying the derived statistical demand curve to each individual observation obtained at the site to be evaluated, and using the observed cost and visit data to reflect behavior at zero additional site cost. This is then used to estimate an aggregate demand curve for the total recreation experience from which the resource value is estimated. For example, by introducing a change in the costs term, $c$, into equation (6), the estimate of visits becomes:

$$T_c = 16.1651 - 3.1533 \ln (C^l + c) - 5.4242 \ln LCI + .3312 Y$$

(7)

substituting equation (6) into equation (7) and simplifying yields:

$$T_c = T_o + 3.1533 (\ln C^l - \ln (C^l + c))$$

(8)

Consumer surplus can be expressed as:

$$CS_i = \int_0^{c_{max}} [T_o + 3.1533 (\ln C^l - \ln (C^l + c))] dc$$

(9)

where $CS_i$ is consumer surplus for decision-making unit $i$ and $c_{max}$ is the level of added cost which results in no trips demanded.
To determine total benefits this result is then expanded by the representation rate of that observation. The representation rate, or weighting factor, \( \Psi \) is determined by the response rate: the total number of recreators at the site to be evaluated divided by the product of the average number of trips and party size of the sample and the number of observations in the sample. These expanded individual demand curves then are summed horizontally to construct the aggregate demand curve from which the resource value, \( \text{RV} \), is estimated, e.g., the area under this aggregate curve is represented by equation (10) and reflects the consumer surplus associated with the resource:

\[
\text{RV} = \sum_{i=1}^{n} \Psi CS_i.
\]

To estimate the annual benefits associated with a change in water quality, i.e., BADE in Figure 1, it is necessary to determine how a change in water quality will modify recreation behavior. To determine the effect of a water quality change, the demand equation can be rewritten as:

\[
T^*_o = T_o - 5.4242 (\ln (LCL + \ell) - \ln CLI)
\]

where \( T^*_o \) is the estimated number of trips demanded by decision-making unit \( i \) given a change in water quality as reflected by \( \ell \). Substituting \( T^*_o \) for \( T_o \) into equation (8) yields the desired results. Consumer surplus associated with a change in water quality, \( CS^*_i \), can now be estimated by:

\[
CS^*_i = \int_{o}^{c} [T^*_o + 3.1533 (\ln C^\lambda - \ln (C^\lambda + c))] \, dc.
\]

Total resource value with the change in water quality is determined by equation (13):

\[
\text{RV}^* = \sum_{i=1}^{n} \Psi CS^*_i.
\]

The resulting change in resource value under various levels of water quality can be determined by calculating the difference between the initial resource value, as determined by equation (10), and that occurring after the water quality change, as calculated by equation (13).

The rehabilitation effort at Shadow Lake in the town of Waupaca consisted of a storm water diversion system, in-lake alum treatments, and aeration of nearby Mirror Lake. The storm sewers were diverted in 1976, alum was added in 1977, and aeration began in 1977 at a total cost of approximately $430,000.
The flow of benefits will vary considerably depending on the elasticity of the demand curve, the change in water quality, the number of users, and the discount rate used to discount benefits (costs). The first of these is determined by the data and estimation procedure used and therefore will not be subject to change. The projections concerning water quality are based upon water quality experts' judgements and are considered correct. However, the last two factors, user number and discount rate, are subject to wide variations and require special consideration. This was accomplished through the use of sensitivity analysis.

User figures were available from previous Waupaca recreation user counts. As one might expect, these varied widely from year to year because of fluctuations in the weather. The year following project completion had many rainy and overcast days which resulted in only 40,132 users. However, in 1968, a very hot summer, the user population was 76,026. These figures will form the relevant bounds for the sensitivity analysis.

The flow of benefits are spread over the entire life of the project, and to compare this time stream of project benefits with the time stream of project costs, each must be reduced to a single number—their present value. The discount rate is the crucial parameter in this calculation. There are numerous, conflicting schools of thought regarding the appropriate discount rate. Two rates are used here to bracket this range: 7 1/8 percent and 15 percent, which reflect the rates suggested by the Water Resources Council to discount federal projects and the opportunity cost of capital in the private sector as approximated by the prime lending rate, respectively.

To perform an ex ante analysis of an expected water quality change it is necessary to (a) establish the resource value with current water quality conditions; and (b) determine the impact associated with a change in water quality both with and without the project.

With the information regarding total user population, average party, and average number trips of the sample, and the pertinent group information required by equation (8), it is possible to estimate the resource value under current water quality conditions by employing the procedure described above. The resource
The projected water quality conditions both with and without the project are presented in Table 1. The level of quality is expressed on the already discussed Lake Classification Index.

Table 1

<table>
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<th>LCI (W/o Project)</th>
<th>LCI Difference</th>
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<td>3</td>
</tr>
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<td>4</td>
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</tr>
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* Information provided by Doug Knauer, Limnologist, Wisconsin State Department of Natural Resources*
value is estimated to be $481,340 and $911,876 for the 40,132 and 76,026 usage populations, respectively.

The next step requires that the changes in water quality be incorporated into the estimation procedure for with and without the project. This is accomplished by substituting $T^*_0$ as determined by equation (11) into equation (8) and once again proceeding as indicated.

Total recreational benefits attributable to a change in water quality are presented in Tables 2 and 3 on a year-by-year basis for the two user populations. The impact of the higher 15 percent discount rate on these estimations is quite apparent, as is that of the greater use rate assumption. The low extreme is based on 40,132 and 15 percent discount rate of $248,403 (Table 2), and a high extreme is based on 76,026 and 7 1/8 percent of $1,349,818 (Table 3). Given that recreational benefits constitute but a subset of total benefits and that the actual value of recreational benefits most likely lies between the reported extremes, it would appear that the decision to undertake the storm sewer diversion project was a wise one.
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<th>Total Benefits</th>
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Totals: $574,335 $236,810 $104,526 $11,592 $678,862 $248,403

\(a/\) Total benefits are equal to the sum of the with project benefits and the without project benefits.
### Table 3. Annual Recreation Benefits at Shadow Lake Based on 76,026 Visits

<table>
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<th>Year</th>
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<th></th>
<th></th>
<th></th>
<th>Without Project</th>
<th></th>
<th></th>
<th>Total Benefits</th>
<th></th>
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</tr>
</thead>
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<td>Discounted at: 7 1/8%</td>
<td>15%</td>
<td>Changes in Consumer Surplus</td>
<td>Discounted at: 7 1/8%</td>
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<td>95,465</td>
<td>17,083</td>
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[To Be Continued]
Table 3 (Cont'd)

<table>
<thead>
<tr>
<th>Year</th>
<th>With Project</th>
<th>Without Project</th>
<th>Total Benefits</th>
</tr>
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<tbody>
<tr>
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<td>Changes in Consumer Surplus</td>
<td>Discounted at: 7 1/8%</td>
<td>Changes in Consumer Surplus</td>
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<tr>
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<td>2012</td>
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<td>2013</td>
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<td>2017</td>
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<td>362</td>
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<td>2019</td>
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<td>2020</td>
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<td>2022</td>
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<td>2025</td>
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<tr>
<td>2026</td>
<td>$97,053</td>
<td>3,329</td>
<td>103</td>
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</table>

Totals: $1,088,050 $448,625 $261,768 $29,128 $1,349,818 $477,764

a/Total benefits are equal to the sum of the with project benefits and the without project.
FOOTNOTES

1. To use consumer surplus as a measure of resource value it is necessary to make two basic assumptions. First, that all other prices other than the good in question are held constant. And second, that the benefits do not change the real income of the beneficiaries. In other words, the area under the demand curve reflects the Marshallian measure of consumer surplus. However, research by Willig has demonstrated that the above assumptions are not that restrictive that they should invalidate the resulting estimates of consumer surplus. He states that in those instances where the consumer's income elasticity is in the range of ± 1.0, and "if the surplus area under the demand curve between the old and new prices is 5 percent of income (or less), then the compensating variation is within 2 percent of the measured consumer's surplus." Certainly both of these assumptions are realistic for the case at hand.

2. The survey was designed to also provide the necessary socio-economic information to estimate the reaction demand curve, and allow comparisons of the state residents and project community residents re environmental understanding and attitudes.

3. The use of lower cost figures, other variable values remaining the same, yields more elastic demand curve estimates and consequently smaller accompanying resource values.

4. It is necessary to assume here that the demand functions are aggregates of homogeneous groups of recreators, i.e., similar tastes and preferences react the same to price changes, etc. (Maler, p. 184). However, this assumption is mitigated by the use of individual observations (Gum and Martin, p. 564).
REFERENCES


RECLAMATION AND RECREATION: THE RESIDENT'S PERSPECTIVE

James Absher*
Douglas Musser**

This paper reports some of the preliminary results of an attitude survey conducted in the summer of 1980 in and near the town of Mattoon, Illinois. The central issue was support by area residents for the renewal of Lake Paradise. This included attitudes toward water resource projects, recreation opportunities, environmental education, and funding associated with the project.

BACKGROUND

Lake Paradise is a small, 176-acre artificial impoundment approximately 4½ miles southwest of Mattoon. It was originally constructed in 1907 to supply water to a rapidly expanding railroad industry. Lake Paradise sits at the head of the Little Wabash River basin and is served by a drainage basin of some 12,000 acres. Twice prior to 1944, the lake was expanded in size, achieving peak total surface area of 220 acres. After World War II, Mattoon began to attract industry, and its population grew until Lake Paradise was unable to meet the area's water needs. In 1958, Lake Mattoon was constructed 5 miles downstream, with a much greater capacity than Lake Paradise. It was felt that the water supply for the Mattoon area was assured until well into the twenty-first century.

Most of the drainage basin serving Lake Paradise is prime agricultural cropland and as a result of this, it has suffered from severe nonpoint-source pollution (siltation). It is estimated that the surface area of Lake Paradise has been reduced by approximately 25 percent and its capacity has shrunk by 50 percent. Over the years, Lake Paradise has served a variety of functions: water supply for industry and transportation, commercial, and private recreation resource, and silt trap for downstream Lake Mattoon. In its present state, it can serve none of these functions adequately.

*Assistant Professor, Department of Leisure Studies, University of Illinois at Urbana-Champaign
**Research Assistant, Department of Leisure Studies, University of Illinois at Urbana-Champaign
COMMUNITY RESPONSE

Concern for the future of Lake Paradise and its role in Mattoon's future resulted in the establishment of Lake Paradise Regional Renewal, Inc., a not-for-profit organization made up of citizens concerned about the present and future condition of the lake.

Among their stated goals are:

1. The reclamation of Lake Paradise for better water supply and recreation.

2. The control of sediments and nonpoint-source pollutants on the Lake Paradise watershed.

3. The development of an educational program to improve understanding of the issues of water resources, recreation, and pollution.

In the fall of 1979, Lake Paradise Regional Renewal, Inc., commissioned the Office of Recreation and Park Resources at the University of Illinois to conduct a recreation potential study of the Lake Paradise area. One of the findings of the study was that a statistically validated survey of area residents should be conducted to determine recreation wants and needs. As part of an overall investigation by the Water Resources Center, the Department of Leisure Studies conducted a survey of area residents to determine their attitudes toward the Lake Paradise project. Some preliminary data from that survey follows.

ISSUES

The data we have chosen to present is directed toward the benefits expected by Lake Paradise Regional Renewal, Inc., as stated in their goals, i.e., water quality and quantity, awareness and support for the project, recreation uses, and the project in relation to education in the area. Other issues, of course, will affect the project's success. The most fundamental is control of incoming nonpoint-source pollution and siltation. This must be achieved or there will be no renewal of Lake Paradise, only a good cleaning of it. However, that lies somewhat outside the present scope of analysis. Within the above goals, we would like to focus particularly on the roles recreation and recreation planning play in reclamation project benefit analysis.
METHODOLOGY

A mail attitude questionnaire was sent to household units in the general vicinity of Lake Paradise. The population of Coles County is approximately 42,000 (1970 revised census) with 21,000 living in Mattoon. Our sample size was 600, and was stratified into three strata. Strata 1 represents urban dwellers of Mattoon itself; Strata 2 represents strictly rural dwellers near Lake Paradise; and Strata 3 consists of those residents who live immediately within the lake area. Overall response rate was 54 percent. The data you see today is only first-run frequency tabulation. In the future, we will run a more detailed and sophisticated analysis.

RESULTS

Table 1 illustrates general attitudes in the community concerning water quality and quantity. The perception of the importance of water is nearly universal (98.7 percent overall). It can be seen that generally it is felt that the present water supply and water quality are adequate. From 79.7 to 94.2 percent expressed satisfaction with these aspects. Also, overall water

<table>
<thead>
<tr>
<th>Statement</th>
<th>Overall</th>
<th>Strata 1</th>
<th>Strata 2</th>
<th>Strata 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water quality and quantity are important in my community</td>
<td>98.7</td>
<td>98.6</td>
<td>100</td>
<td>93.4</td>
</tr>
<tr>
<td>I am satisfied with the quality of water I presently receive</td>
<td>80.0</td>
<td>79.7</td>
<td>80.5</td>
<td>86.8</td>
</tr>
<tr>
<td>I am satisfied with the quantity of water I presently receive</td>
<td>93.6</td>
<td>94.2</td>
<td>88.7</td>
<td>86.8</td>
</tr>
<tr>
<td>Water quality in this community has decreased in the past 10 years</td>
<td>41.4</td>
<td>39.6</td>
<td>58.0*</td>
<td>43.8</td>
</tr>
<tr>
<td>Present water supplies will be adequate for the next 10 years</td>
<td>76.4</td>
<td>75.8</td>
<td>78.3</td>
<td>76.3</td>
</tr>
</tbody>
</table>

*63% of respondents in this strata get water from private wells.
Strata 1 = Mattoon residents
Strata 2 = Rural Coles County residents
Strata 3 = Lake Paradise residents
quality has not decreased much in the minds of the users (41.4 percent overall agreement). This bears further analysis, as there are several sources of water in the study area.

Interesting to note is the somewhat inconsistent response of the rural strata on the question of water quality decrease over the last ten years. This may be due to the fact that about 63 percent of this strata get water from private wells. However, overall the responses here are at variance with what we are told by the water experts; i.e., that water quality and quantity in the region have been decreasing. This would suggest the need for an intensified education effort.

Table 2 addresses previous knowledge of the project and perception of its benefits. What we see here is a fairly strong statement of support for the project as well as a confirmation of the positive effect of the information campaign by Lake Paradise Regional Renewal, Inc. About 72.6 percent have heard of the project and even more people, 80.3 percent, support the reclamation of the lake.

<table>
<thead>
<tr>
<th>Table 2. Knowledge of Lake Paradise project and perceptions of its benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you heard about the Lake Paradise renewal project in Mattoon, Illinois?</td>
</tr>
<tr>
<td>I am in favor of the Lake Paradise Renewal project.</td>
</tr>
<tr>
<td>Factors Which May Be Affected by the Lake Paradise Project</td>
</tr>
<tr>
<td>Recreation opportunity</td>
</tr>
<tr>
<td>Water supply</td>
</tr>
<tr>
<td>Real estate values</td>
</tr>
<tr>
<td>Community pride</td>
</tr>
<tr>
<td>Water quality</td>
</tr>
<tr>
<td>Quality of life</td>
</tr>
<tr>
<td>Retail business</td>
</tr>
<tr>
<td>Education opportunity</td>
</tr>
<tr>
<td>Traffic volume</td>
</tr>
<tr>
<td>Vandalism</td>
</tr>
</tbody>
</table>
Next in the table are a series of potential impacts, or benefit areas, which may be linked to the project. The residents were asked to respond if they thought that that item would improve if the lake was reclaimed. One item receives support well above all others: recreation opportunities (94.2 percent). A second group falls between roughly 81 and 87 percent. Thus, the principal benefits to be gained are perceived to be recreation opportunity first, then increased real estate values, increased water quality and quantity, and community pride and quality of life. Education opportunity (56.6 percent) is not perceived to be as large a benefit as we thought, but it still gets a statement of support. Overall, it appears that recreation is perceived as the major benefit of this project. There were no significant strata differences to these questions.

Table 3 shows attitudes toward present recreation opportunities in the region. Here we can perhaps infer why the recreation opportunities are seen as an important benefit from the lake reclamation. Once again there are no strong strata differences, so only one overall response is reported. Only

<table>
<thead>
<tr>
<th>Statement</th>
<th>Overall Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>The local government is doing a fine job of providing recreation opportunities in the Mattoon area.</td>
<td>33.6</td>
</tr>
<tr>
<td>There is adequate recreation opportunity for me and my family in Mattoon.</td>
<td>42.4</td>
</tr>
<tr>
<td>Present recreation opportunities in my community will be inadequate in the future.</td>
<td>78.6</td>
</tr>
<tr>
<td>I would welcome better recreation opportunities in my community.</td>
<td>94.0</td>
</tr>
</tbody>
</table>

33.6 percent feel that the "local government is doing a fine job of providing recreation opportunities." Similarly, only 42.4 percent feel that there are adequate recreation opportunities nearby. On the other hand, nearly everyone
(94.0 percent) felt that better recreation opportunities are welcome. We see a strong statement about the inadequacy of present opportunities in the region and the desire for better opportunities now and in the future.

Table 4 shows where most of the respondents go for water-related recreation. Lake Shelbyville, a large Corps of Engineers project nearby, provides a substantial portion of the overall use. There are strong differences among strata, with the heaviest use of Lake Shelbyville coming from the Mattoon city residents. Surprisingly, Lake Paradise, even in its present state, is serving as a recreation site for a large proportion of the area. Note especially the relatively heavy use this small local reservoir receives from rural and nearby residents (Strata 2 and 3) vis-a-vis the other, larger

<table>
<thead>
<tr>
<th>Area</th>
<th>Overall</th>
<th>Strata 1</th>
<th>Strata 2</th>
<th>Strata 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Paradise</td>
<td>13.4</td>
<td>10.3</td>
<td>25.0</td>
<td>67.8</td>
</tr>
<tr>
<td>Lake Mattoon</td>
<td>18.9</td>
<td>19.0</td>
<td>21.7</td>
<td>5.1</td>
</tr>
<tr>
<td>Lake Shelbyville</td>
<td>37.0</td>
<td>39.7</td>
<td>20.2</td>
<td>16.9</td>
</tr>
<tr>
<td>Other Areas</td>
<td>30.6</td>
<td>23.9</td>
<td>33.1</td>
<td>10.2</td>
</tr>
</tbody>
</table>

nearby reservoirs. Clearly, Lake Paradise still has much to offer and renewal is an opportunity to enhance its role even more.

Table 5 lends credence to the data from Table 4. Over 40 percent of the respondents still utilize Lake Paradise. It should be noted that recreation activities other than those which are necessarily water-dependent exist at Lake Paradise, i.e., picnicking, hiking, playground use, etc. By and large the greatest reasons for not visiting Lake Paradise are factors which would be greatly improved, if renewal were to occur. Poor fishing, poor facilities, water depth, and water quality are mentioned and could be easily improved as part of the renewal.
Table 5. Present recreational use of Lake Paradise (percent responding)

<table>
<thead>
<tr>
<th>Item</th>
<th>Overall Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Still visit</td>
<td>40.4</td>
</tr>
<tr>
<td>No longer visit</td>
<td>59.6</td>
</tr>
</tbody>
</table>

Reasons for no longer visiting:*

- Better recreation elsewhere
- Poor fishing
- Lost interest in Lake Paradise
- Poor facilities
- Too shallow
- Poor water quality
- Too expensive

23.5
15.9
14.3
13.2
11.2
10.4
0.3

*Multiple responses are possible.

The data in Table 6 address a similar topic: recreation activities thought to be appropriate for Lake Paradise. Note that nearly unanimous (91 to 99 percent) support is expressed for the popular outdoor recreation activities such as fishing, picnicking, hiking, sailing, and swimming. A lower level of support

Table 6. Activities well suited to the Lake Paradise area (percent in favor)

<table>
<thead>
<tr>
<th>Item</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishing</td>
<td>99.9</td>
</tr>
<tr>
<td>Picnicking</td>
<td>99.8</td>
</tr>
<tr>
<td>Nature study</td>
<td>97.6</td>
</tr>
<tr>
<td>Hiking</td>
<td>97.0</td>
</tr>
<tr>
<td>Biking</td>
<td>96.9</td>
</tr>
<tr>
<td>Camping</td>
<td>95.4</td>
</tr>
<tr>
<td>Boating, nonpower</td>
<td>93.5</td>
</tr>
<tr>
<td>Sailing</td>
<td>93.7</td>
</tr>
<tr>
<td>Jogging</td>
<td>93.9</td>
</tr>
<tr>
<td>Swimming</td>
<td>91.2</td>
</tr>
<tr>
<td>Golf</td>
<td>71.9</td>
</tr>
<tr>
<td>Power boating</td>
<td>48.2</td>
</tr>
<tr>
<td>Skeet/trap shooting</td>
<td>51.4</td>
</tr>
</tbody>
</table>
is given to golf (71.9 percent), power boating (48.2 percent), and skeet/trap shooting (51.4 percent). In general, the residents appear to prefer activities with a more nature-involvement or nature-appreciation type of a theme, rather than more mechanized or developed forms.

Table 7 seems to indicate a need within the community for increased and improved environmental education. Again, there is a dissatisfaction voiced with the role of the public school system (48.1 percent) and a strong statement of support for environmental trails and programs at Lake Paradise (90.3 percent).

<table>
<thead>
<tr>
<th>Item</th>
<th>Overall Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presently, the public school system is doing a fine job of educating the youth of our community about the environment.</td>
<td>48.1</td>
</tr>
<tr>
<td>I would favor the establishment of interpretive trails, environmental programs, and nature study areas at Lake Paradise.</td>
<td>90.3</td>
</tr>
<tr>
<td>If environmental programs were established at Lake Paradise, I would make use of them.</td>
<td>83.0</td>
</tr>
</tbody>
</table>

The important fact is that according to the recreation study done previously (Office of Recreation and Park Resources, 1979), Lake Paradise has a strong potential for meeting that need.

Table 8 addresses the sticky question of funding for the project and specific aspects of it. Support is not extremely strong, ranging from 56.8 percent to 66.5 percent depending on what aspect of funding is considered. There is support across the board for helping fund the project, and there are a variety of methods that could be used to do it. The strongest level of support is expressed for a combination of taxes and local business/industry
involvement (66.5 percent overall). Also, there is general support for the use of volunteer time as part of the renewal effort. There are also obvious side benefits from this latter approach in terms of community pride and stability. Of note is the weaker statement of support from the rural residents (Strata 2).

Table 8. Attitudes toward funding for the Lake Paradise renewal project (percent in agreement)

<table>
<thead>
<tr>
<th>Item</th>
<th>Overall</th>
<th>Strata 1</th>
<th>Strata 2</th>
<th>Strata 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am willing to help fund the cost of renewal of Lake Paradise.</td>
<td>65.1</td>
<td>67.3</td>
<td>45.8</td>
<td>65.1</td>
</tr>
<tr>
<td>I would support a bond issue designed to help pay for increased recreation opportunity in my community.</td>
<td>56.8</td>
<td>58.6</td>
<td>41.7</td>
<td>55.2</td>
</tr>
<tr>
<td>I would support a small increase in my taxes to improve recreation in my community if I knew that local business and industry would also help pay the costs.</td>
<td>66.5</td>
<td>67.5</td>
<td>59.2</td>
<td>65.1</td>
</tr>
<tr>
<td>I would be willing to help fund environmental programs either by bond issues, increased taxes, or contributions.</td>
<td>61.4</td>
<td>62.7</td>
<td>50.0</td>
<td>64.8</td>
</tr>
<tr>
<td>I'm in favor of donating my time and experience on a volunteer basis to help improve recreation in my community.</td>
<td>59.4</td>
<td>60.0</td>
<td>53.8</td>
<td>62.3</td>
</tr>
</tbody>
</table>
CONCLUSIONS

Overall, it appears that the project is favorable and would be well received in the Mattoon area. We see that the issues which are important to Lake Paradise Regional Renewal, Inc., (i.e., water quality and quantity, awareness and support for the project, recreation potential and the project's relation to area education) are also of importance to the community as a whole. Further, the community sees positive benefits from many aspects of the project, particularly recreation. However, many questions remain to be answered and anomalies exist in the data, particularly in the areas of how water quality and quantity, and education related to the project.

For us the data seem to support the idea that reducing benefit estimation to a dollar figure, while important, does not necessarily trace out all the important social benefits. We feel that an analysis will further substantiate this and provide clues as to how to gauge and incorporate qualitative as well as quantitative aspects of benefit estimation.

Most of the presentations in this round table so far have dealt with technical and physical aspects of lake restoration. Indeed, most research into lake restoration has been decidedly technical in flavor. This is entirely appropriate and necessary. Yet, most technical presentations acknowledge the need for greater understanding of the social and economic impacts when any particular technology is chosen or applied. In particular, recreation is widely considered to be an important aspect of water resource management but is quite often grossly simplified as part of the total cost/benefit analysis. Part of the problem here is the way in which recreation is seen as a benefit. We see recreation, particularly recreation planning, as a diagnostic tool as well as a means for amplifying and enhancing other social aspects of resource planning which are difficult to quantify, i.e., quality of life, community pride, and educational opportunity.

At this point, two examples will help to illustrate. From the beginning, the Lake Paradise Regional Renewal, Inc., has felt a golf course would be a welcome recreation opportunity and planned for one as part of the project. The survey indicates, however, that of the possible recreation activities which are suitable to the Lake Paradise area, golf rates relatively low in terms of its desirability. Other activities were favored consistently much more. Some of these were not expressly part of the original renewal proposal.
On the other hand, the Upper Little Wabash River Basin study (Office of Recreation and Park Resources, 1979) recognized that one of the strong potential uses of the Lake Paradise area was as an environmental interpretive center/living laboratory, mostly because of the various stages of primary and secondary succession it illustrates. Furthermore, our attitude survey shows strong community support for this type of usage. Yet, if planning for this use is not incorporated into the technical plans for the physical reclamation of the lake by whatever means, its utility as a wetlands living laboratory may well be literally dredged away.

Good recreation planning requires a concerted effort to gauge public awareness and knowledge about a project, its impacts, and alternatives. This allows for public input into important projects which in turn elicits added support for the given project. While increased recreation opportunity is itself a benefit (often quantified), planning and preparing for it can act synergically with other benefits which, while difficult to quantify, are substantial in terms of real positive project effects and public support for the project itself. We feel the preceding data tend to bear this out.

Briefly stated, recreation opportunities are almost universally perceived as positive benefits of the Lake Paradise renewal project. It has been argued that in order to maximize the positive effects of recreation opportunities planning, this planning should appear early in the conceptual stages of the project. The advantages of this are two-fold. First, the benefits of the recreation elements themselves will be maximized by tailoring them to the particular clients to be served. Second, the process by which the recreation aspects are considered and implemented can have valuable effects on other areas, notably project support and intangible social impacts such as quality of life or community pride. Thus, recreation benefits analysis as part of the lake reclamation process can be pre-economic and pre-institutional. Once the specific role which recreation can play is ascertained, more precise economic benefits can be attributed to particular recreational aspects, and in the process sounder institutional and social arrangements may emerge.

This role of recreation in planning is little understood yet potentially broad in its utility not only to water resource planning but to all natural resource planning and management as well.
THE CLEAN LAKES PROGRAM
Donna F. Sefton*

This presentation will provide a summary of Illinois Environmental Protection Agency's (EPA) lakes program activities--past, present, and those anticipated for the future, as well as the Federal Clean Lakes Program.

SECTION 208 WATER QUALITY PLANNING PROGRAM

Illinois EPA's lakes program was initiated in 1977 under the Water Quality Management Planning Program (WQMPP) authorized by Section 208 of the Clean Water Act. The purpose of this planning effort was to provide a basis upon which a comprehensive, coordinated program could be developed to protect, enhance, and restore Illinois' lakes. An assessment of problems was made for 353 lakes and a preliminary lake classification and prioritization system was developed based on the assessment data. A detailed presentation and discussion of the assessment, classification, and prioritization methodology and results may be found in Sefton (1978a; 1978b) and Boland et al. (1979).

The next step in the WQMPP was doing a more quantitative problem assessment to provide the data base necessary for lake water quality management decision making. Therefore, in 1979 the Illinois EPA sampled 64 lakes (Appendix I). Fifteen of these lakes were sampled monthly from May through October, while the other 49 were sampled twice--once in early summer and once in late summer. Three sites were sampled on each lake and surface and bottom water samples were taken if the site was greater than 10 feet deep. Sediment samples were also collected. The data obtained was computerized using the STORET system. A list of the sample parameters and preservation/analysis methodology are provided in Appendix II. Reports for the 15 intensively sampled lakes have been completed and are listed in the references section. A comprehensive report covering all the lakes is also being prepared.

Mr. Meyer has summarized some of the results of these 208 WQMPP studies in his presentation.

*Planning Section, Division of Water Pollution Control, Illinois Environmental Protection Agency, Springfield
AMBIENT LAKE MONITORING PROGRAM

The Ambient Lake Monitoring Program was developed and initiated in 1980. Its purposes are to establish baselines of lake water quality, characterize and define trends in the quality of Illinois' lakes, and identify and quantify new or existing water quality problems or problem areas. An outline of the monitoring program is provided in Appendix III. Fifteen lakes will be sampled on a continuing basis in the spring and summer for a range of water quality parameters and in the fall for fish flesh parameters. Lakes were chosen to represent various types and qualities of water bodies with differing morphological and hydrological characteristics located in various areas of the state.

VOLUNTEER LAKE MONITORING PROGRAM

We are in the process of developing a volunteer lake monitoring program which will be directed at lake associations, sportsmen's clubs, and private citizens. This volunteer program will provide baseline information for those lakes which we cannot possibly sample due to resource limitations and/or their nonpublic ownership; will help document trends in lake water quality; and will be an excellent way for citizens to learn more about their lakes and lake management. Sampling for the pilot program will begin in the spring and continue through the fall of 1981. Volunteers will be trained to take weekly Secchi disk measurements to determine the transparency of the water. Resources permitting, water samples will be collected from the volunteer's lakes by agency personnel twice during the sampling period and analyzed for suspended solids and chlorophyll content. Data obtained will be analyzed in a report and sent to participants at the end of the project. If successful, this pilot project may become an ongoing agency program. Signup sheets for the program are provided in Appendix IV.

NORTH AMERICAN LAKES MANAGEMENT SOCIETY

We have also been involved in the development and organization of the North American Lake Management Society, which was chartered on September 10, 1980 at the International Lakes Conference in Portland, Maine. The purpose of this society is to promote better understanding of lakes and their watersheds, as well as their protection, restoration, and management. Membership applications and further information on the society are provided in Appendix V.
SECTION 314 CLEAN LAKES PROGRAM

This program was authorized by Section 314 of the Clean Water Act, which stated, in part, that:

a. Each state shall prepare or establish and submit to the Administrator for his approval:
   1. an identification and classification according to eutrophic condition of all publicly owned freshwater lakes in such state,
   2. procedures, processes, and methods (including land use requirements) to control sources of pollution to such lakes, and
   3. methods and procedures, in conjunction with appropriate federal agencies, to restore the quality of such lakes.

b. The administrator shall provide financial assistance to the states for carrying out methods and procedures approved by him under this section. The Administrator shall provide financial assistance to states to prepare the identification and classification surveys required in subsection (a)(1) of this section.

The USEPA published specific regulations to administer the Clean Lakes Program in the Federal Register on February 5, 1980. A copy of these regulations, as well as a summary of them, are provided as handouts. The program highlights are summarized in Appendix VI.

The regulations established three types of assistance--lake survey and classification, Phase 1 diagnostic/feasibility study, and Phase 2 implementation awards. Awards may be made only to the state agency designated by the governor to receive the awards (i.e., the Illinois EPA). The awards are only for publicly owned freshwater lakes. These are lakes that offer public access through publicly owned contiguous land so that any person has the same opportunity to use the lake as any other. If user fees are charged, they must be used for maintaining the public access, recreational facilities, or improving water quality.

Phase 1 awards are available for diagnostic/feasibility studies to determine a lake's quality and characteristics and to evaluate and recommend a feasible
course of action to address identified problems. Phase 1 awards are for up to $100,000 federal funds per study and require a 30% nonfederal cost share. These studies were not eligible for funding in the past. Phase 2 cooperative agreements are available for actual implementation of recommended pollution control measures and lake restoration. They require a 50% nonfederal share. Phase 1 and Phase 2 awards are made independently and are not contingent upon one another.

As mentioned earlier, the new regulations require the state (i.e., the Illinois EPA) to serve as applicant for the funds as well as administer the program. However, the local agencies who wish to obtain Clean Lakes Program funds for their lakes must supply the 30% nonfederal match for Phase 1 and 50% nonfederal match for Phase 2 grants, as well as prepare the application materials. The Illinois EPA will provide technical assistance and information for application development; will review, certify, and prioritize the applications; will serve as applicant for the funds as required by the regulations; as well as administer the program, including procurement of contractors to perform the work, managing the contracts, and meeting necessary reporting requirements. The agency will receive a small portion of the grant to help offset these administrative costs.

The USEPA has developed a strategy to guide Clean Lakes Program development and growth for the next five years. The goal is to protect at least one lake with water quality suitable for contact recreation or restore a degraded lake to that condition within 25 miles of every major population center (Standard Metropolitan Statistical Area).

Factors currently used by the USEPA and the Illinois EPA in prioritizing Clean Lakes Program applications include: public benefit (accessibility, population served, lake uses, availability of recreational facilities, availability of other public lakes); feasibility of project (potential for water quality improvement, potential for improvement as a fish and wildlife habitat, permanence of improvements, ability to control pollution sources); local agency legal authority, management capability, and financial support; potential adverse environmental impacts; and quality and completeness of the application.

In July 1980, the Illinois EPA received a one-time grant of $100,000 federal funds (at a 70% federal/30% state cost share) to develop the state's lake classification and priority ranking. These funds will be used to verify and refine the preliminary lake classification and prioritization system developed
under 208 and to make information available for public use in the development of funding requests and lake/watershed management plans. The project period for this award is from July 1, 1980 through December 31, 1981.

Illinois also received awards for three Phase 1 diagnostic/feasibility study projects in July 1980 out of USEPA Region V's $2.8 million in FY-80 allocations. The grants were: $32,200 for a diagnostic/feasibility study of Lake of the Woods owned by the Champaign County Forest Preserve District, and $36,225 each for studies of Johnson Sauk Trail Lake in Henry County and Lake Le-Aqua-Na in Stephenson County, both owned by the Illinois Department of Conservation. The project periods for these are for two years from July 15, 1980. Contractor procurement is now underway for these studies. (An implementation grant of $951,000 was received by the Illinois Department of Conservation in 1977 for the restoration of lakes in Frank Holten State Park, St. Clair County, prior to development of these program regulations).

The FY-81 Clean Lakes Program allocations for Region V will range from $718,000 to $1.14 million, depending on whether the U.S. House of Representatives budget appropriations of $8.5 million, the Senate's appropriations of $13.5 million, or a compromise, is passed. Applications for FY-81 allocations must be submitted to USEPA Region V by November 14, 1980 for awards to be made in early 1981 out of the FY-81 allocations. Therefore, applications must be to the Illinois EPA by October 15, 1980 to allow time for application review, budget and A-95 material preparation, certification, and prioritization.

I'd like to make a few comments about the 314 program at this time. It is a program for determining a lake's water quality problems, examining the alternatives for lake protection and enhancement, and implementing the chosen alternative for improving the water quality of the lake. The Clean Lakes Program is not a dredging program for restoring lake capacity. Dredging is considered only as part of an overall lake improvement program after the sources of pollution have been controlled to the best practicable extent. Then it must be shown that it will result in water quality improvement and/or benefits.

FUTURE LAKES PROGRAM

The goal of all these activities I've presented here is a comprehensive, coordinated program to protect, manage, and reclaim Illinois lakes. An operational program of technical and possibly limited financial assistance in cooperation
with other agencies is envisioned for the future. The program will be aimed at providing information on lake assessment, protection, and management to enable lake managers to help themselves. This workshop is a step in that direction.

Illinois' lakes program is in its infancy. We are still in the process of developing the database, expertise, and institutional framework necessary to carry out an operational program. Its ultimate success is largely dependent on the local "grass-roots" support and demonstration of need for the program. Right now the program is dependent on federal funding and will be in the future until the legislators and governor become aware that citizens in Illinois really care about their lakes and want to have such a lakes program.

I feel that as the public becomes more aware of the benefits accrued by protecting and enhancing their lakes (estimated to be 8 to 1 for each USEPA dollar invested in the Clean Lakes Program), and they begin to see improvement in their lakes, the program will grow dramatically in the future.

REFERENCES


Hite, Robert L., Martin H. Kelly, and Marvin M. King. 1980c. *Limnology of Lake of Egypt, May-October, 1979.* Marion, Illinois: Monitoring Unit, Division of Water Pollution Control, Illinois Environmental Protection Agency.

Hite, Robert L., Martin H. Kelly, and Marvin M. King. 1980e. *Limnology of Raccoon Lake, May-October, 1979*. Marion, Illinois: Monitoring Unit, Division of Water Pollution Control, Illinois Environmental Protection Agency.


# APPENDIX I


<table>
<thead>
<tr>
<th>LAKE NAME</th>
<th>COUNTY NAME</th>
<th>SURFACE AREA (Acres)</th>
</tr>
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<tr>
<td>Siloam Springs Lake</td>
<td>Adams</td>
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</tr>
<tr>
<td>Horseshoe Lake</td>
<td>Alexander</td>
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<td>Mt. Sterling Lake</td>
<td>Brown</td>
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<td>Lake of the Woods</td>
<td>Champaign</td>
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<td>*Lake Taylorville</td>
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<td>Sangchris Lake</td>
<td>Christian, Shelby</td>
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<td>*Lincoln Trail Lake</td>
<td>Clark</td>
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<td>*Lake Mattoon</td>
<td>Coles, Cumberland</td>
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<td>*Paradise Lake</td>
<td>Coles</td>
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<td>Skokie Lagoons</td>
<td>Cook</td>
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</tr>
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<td>Wolf Lake</td>
<td>Cook</td>
<td>419.0</td>
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<td>*Lake Shabbona</td>
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<td>Walnut Pt. St. Lake</td>
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<td>Paris East Lake</td>
<td>Edgar</td>
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<td>McLeansboro New Reservoir</td>
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<td>Gladstone</td>
<td>Henderson</td>
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<td>Johnson Sauk Trail Lake</td>
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<td>Sam Parr State Lake</td>
<td>Jasper</td>
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<td>*Lake of Egypt</td>
<td>Johnson, Williamson</td>
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<td>Lake Storey</td>
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<tr>
<td>Bangs</td>
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<td>*Cedar Lake</td>
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<td>*Round Lake</td>
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<td>Lake Decatur</td>
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<td>Macoupin</td>
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<td>*Otter Lake</td>
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<td>Madison</td>
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<td>*Raccoon Lake</td>
<td>Marion</td>
<td>925.0</td>
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<td>*Stephen A. Forbes Lake</td>
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<td>Argyle Lake</td>
<td>McDonough</td>
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<td>Spring Lake</td>
<td>McDonough</td>
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<tr>
<td>Crystal</td>
<td>McHenry</td>
<td>228.0</td>
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<tr>
<td>Dawson Lake</td>
<td>McLean</td>
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<td>Lake Bloomington</td>
<td>McLean</td>
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<td>Lake Lou Yaeger</td>
<td>Montgomery</td>
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<td>Morgan</td>
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<td>*New Pittsfield Lake</td>
<td>Pike</td>
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<td>Olney E. Fork Reservoir</td>
<td>Richland</td>
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<td>Lake George</td>
<td>Rock Island</td>
<td>167.0</td>
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<tr>
<td>Glen O Jones Lake</td>
<td>Saline</td>
<td>105.0</td>
</tr>
<tr>
<td>Harrisburg Lake</td>
<td>Saline</td>
<td>208.9</td>
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<tr>
<td>Lake Springfield</td>
<td>Sangamon</td>
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<td>Lake Le-Aqua-Na</td>
<td>Stephenson</td>
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<td>Spring Lake</td>
<td>Tazewell</td>
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<td>Vermilion</td>
<td>56.6</td>
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<td>Washington</td>
<td>295.0</td>
</tr>
<tr>
<td>Sam Dale State Lake</td>
<td>Wayne</td>
<td>194.0</td>
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<tr>
<td>Crab Orchard Lake</td>
<td>Williamson</td>
<td>6,965.0</td>
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<td>*Devil's Kitchen Lake</td>
<td>Williamson</td>
<td>810.0</td>
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<td>Marion Reservoir</td>
<td>Williamson</td>
<td>220.0</td>
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<td>Pierce State Lake</td>
<td>Winnebago</td>
<td>162.2</td>
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*Intensively sampled lakes
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<tr>
<th>PARAMETER</th>
<th>SAMPLE CONTAINER</th>
<th>PRESERVATION</th>
<th>METHOD OF ANALYSIS (REFERENCE)</th>
<th>UNITS OF MEASUREMENT</th>
<th>DETECTION LIMITS</th>
<th>ANALYSIS</th>
<th>GENERAL USE STANDARD</th>
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<tr>
<td>Temperature</td>
<td></td>
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<td>In situ determination using Yellow Springs Instruments (YSI) model 57 dissolved oxygen meter (1).</td>
<td>0°C</td>
<td>nearest 0.1°C</td>
<td>Field determination</td>
<td></td>
</tr>
<tr>
<td>Dissolved Oxygen (DO)</td>
<td></td>
<td></td>
<td>In situ determination using YSI model 57 dissolved oxygen meter (1).</td>
<td>mg/l O2</td>
<td>0.1 mg/l</td>
<td>Field determination not less than 5 mg/l</td>
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<tr>
<td>Transparency</td>
<td></td>
<td></td>
<td>Secchi disk (2).</td>
<td>feet</td>
<td>nearest 0.1 foot</td>
<td>Field determination</td>
<td></td>
</tr>
<tr>
<td>Total Suspended Solids (TSS)</td>
<td></td>
<td></td>
<td>Filtration on glass fiber filter, determination of increase in weight upon drying at 103-105°C (3, p. 266).</td>
<td>mg/l TSS</td>
<td>1 mg/l</td>
<td>Regional EPA lab</td>
<td></td>
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<tr>
<td>Volatile Suspended Solids (VSS)</td>
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<td></td>
<td>Loss in weight of TSS filter upon ignition at 550°C (1, p. 272).</td>
<td>mg/l YSS</td>
<td>1 mg/l</td>
<td>Regional EPA lab</td>
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<tr>
<td>Turbidity</td>
<td></td>
<td></td>
<td>nephelometrically using Hach model 2100A turbidimeter (3, p. 204).</td>
<td>NTU</td>
<td>0.05 NTU</td>
<td>Regional EPA lab</td>
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<td>Conductivity</td>
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<td></td>
<td>YSI Model 18 5-C-F Conductivity meter or Electrolytic Conductivity Measuring Set, Model MC-1.</td>
<td>umhos/cm</td>
<td>nearest 1 umhos/cm</td>
<td>Field determination</td>
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<td>Alkalinity</td>
<td></td>
<td></td>
<td>Titration of 10 ml sample with 0.02 N NaOH to phenolphthalein and brom cresol green-methyl red end point (4).</td>
<td>mg/l CaCO3</td>
<td>nearest 5 mg/l</td>
<td>Field determination</td>
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<td>pH</td>
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<td>Sargent &amp; Neph model PBL pH meter, calibrated in field.</td>
<td>pH</td>
<td>nearest 0.1 units</td>
<td>Field determination in range 6.5-9.0</td>
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<td>Nitrate + nitrite-N (NO3-N-N)</td>
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<td>Cadmium reduction method on Technicon AutoAnalyzer (3, p. 219).</td>
<td>mg/l N</td>
<td>0.01 mg/l</td>
<td>Regional EPA lab</td>
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<td>Ammonia-N (NH4-N)</td>
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<td>Phenate method on Technicon AutoAnalyzer (3, p. 219).</td>
<td>mg/l N</td>
<td>0.01 mg/l</td>
<td>Regional EPA lab</td>
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<tr>
<td>Total Kjeldahl-N (N)</td>
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<td></td>
<td>Digestion at 170°C followed by determination of ammonia as above.</td>
<td>mg/l N</td>
<td>0.1 mg/l</td>
<td>Regional EPA lab</td>
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<tr>
<td>Total nitrogen (N)</td>
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<td></td>
<td>Digestion to convert all phosphorus forms to orthophosphoric followed by determination using ascorbic acid reduction method using Technicon AutoAnalyzer (3, p. 256).</td>
<td>mg/l P</td>
<td>0.01 mg/l</td>
<td>Regional EPA lab</td>
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<td>Total Dissolved Phosphorus (DTP)</td>
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<td>Field filtration followed by TP analysis as above.</td>
<td>mg/l P</td>
<td>0.01 mg/l</td>
<td>Regional EPA lab</td>
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<td>Total Organic Carbon (TOC)</td>
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<td>Acidification to remove carbonate and carbon dioxide followed by injection into Beckman TOC Analyzer.</td>
<td>mg/l C</td>
<td>1 mg/l</td>
<td>Regional EPA lab</td>
<td></td>
</tr>
<tr>
<td>Chloride (Cl)</td>
<td></td>
<td></td>
<td>Ferricyanide method using AutoAnalyzer (3, p. 321).</td>
<td>mg/l Cl</td>
<td>1 mg/l</td>
<td>Regional EPA lab</td>
<td></td>
</tr>
<tr>
<td>Sulfate (SO4)</td>
<td></td>
<td></td>
<td>Methyl thymol blue method using AutoAnalyzer (3).</td>
<td>mg/l SO4</td>
<td>10 mg/l</td>
<td>Regional EPA lab</td>
<td></td>
</tr>
<tr>
<td>Fecal Coliform</td>
<td>6 oz. glass</td>
<td></td>
<td>Filtration of sample through 0.45μm membrane filter followed by incubation for 24 hrs. at 44° F and containing MFC culture media (6, p. 137).</td>
<td>#/orangans per/100ml</td>
<td>10000/ml</td>
<td>Regional EPA lab</td>
<td></td>
</tr>
<tr>
<td>Total Arsenic (As)</td>
<td></td>
<td></td>
<td>All forms converted to arsenic which is then burned in quartz furnace to produce atomic absorption flame, vaporized by atomic absorption.</td>
<td>mg/l As</td>
<td>1 mg/l</td>
<td>Champaign</td>
<td></td>
</tr>
<tr>
<td>Total Mercury (Hg)</td>
<td>6 oz. glass</td>
<td></td>
<td>Digestion with HNO3 and potassium periodate to convert all forms to inorganic Hg followed by phosphorus reduction step to convert all inorganic Hg to metallic Hg, then measurement by cold vapor atomic absorption (3, p. 177).</td>
<td>mg/l Hg</td>
<td>0.05 mg/l</td>
<td>Champaign EPA lab</td>
<td></td>
</tr>
<tr>
<td>Total Metals (Pb, Cu, Fe, Zn, Mn, Cd, Cr)</td>
<td></td>
<td></td>
<td>Digestion with hot dilute HCl-HNO3 followed by analysis by direct aspiration atomic absorption (3, p. 280).</td>
<td>ug/l elemental metal</td>
<td>50 ug/l Pb, 10 ug/l Cu, 5 ug/l Zn, Cd, Cr</td>
<td>Champaign EPA lab</td>
<td></td>
</tr>
<tr>
<td>Chlorophyll (CHL)</td>
<td></td>
<td></td>
<td>Concentration by filtration, extraction with acetone, determination of optical density and calculation of concentration by standard formula (6 and 7).</td>
<td>ug/l CHL</td>
<td>1 ug/l</td>
<td>Western IL University</td>
<td></td>
</tr>
<tr>
<td>Phytoplankton (PHY)</td>
<td></td>
<td></td>
<td>Concentration by filtration followed by direct microscopic examination.</td>
<td>organisms/ml</td>
<td></td>
<td>Western IL University</td>
<td></td>
</tr>
<tr>
<td>Organics (OGB)</td>
<td></td>
<td></td>
<td>Determination by gas chromatography.</td>
<td>ug/l organic compound</td>
<td>0.01 ug/l</td>
<td>Springfield EPA lab</td>
<td></td>
</tr>
</tbody>
</table>

A pilot ambient lake monitoring program was developed and initiated by Agency staff at select lakes statewide to characterize and define the baseline conditions of Illinois lakes and impounded waters. A list of the lakes to be sampled and an outline of the sampling program are found below.

<table>
<thead>
<tr>
<th>Lake Name</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cedar Lake</td>
<td>Lake County</td>
</tr>
<tr>
<td>Long Lake</td>
<td>Lake County</td>
</tr>
<tr>
<td>Round Lake</td>
<td>Lake County</td>
</tr>
<tr>
<td>Otter Lake</td>
<td>Macoupin County</td>
</tr>
<tr>
<td>Pittsfield City Lake</td>
<td>Pike County</td>
</tr>
<tr>
<td>Devil's Kitchen Lake</td>
<td>Williamson County</td>
</tr>
<tr>
<td>Stephen A. Forbes Lake</td>
<td>Marion County</td>
</tr>
<tr>
<td>Lake of Egypt</td>
<td>Johnson County</td>
</tr>
<tr>
<td>Raccoon Lake</td>
<td>Marion County</td>
</tr>
<tr>
<td>Decatur Lake</td>
<td>Macon County</td>
</tr>
<tr>
<td>Lake Springfield</td>
<td>Sangamon County</td>
</tr>
<tr>
<td>Crab Orchard Lake</td>
<td>Williamson County</td>
</tr>
<tr>
<td>Highland Silver Lake</td>
<td>Madison County</td>
</tr>
<tr>
<td>Marion City Reservoir</td>
<td>Williamson County</td>
</tr>
<tr>
<td>Lake Centralia</td>
<td>Marion County</td>
</tr>
</tbody>
</table>

Program Outline:

A. Sampling Frequency
   
   Spring - Water quality
   Summer - Water quality
   Fall - Fish contaminant

B. Water Quality Parameters
   
   Dissolved oxygen, secchi transparency, pH, alkalinity, conductivity, total suspended solids, volatile suspended solids, color, chlorophyll a, total phosphorus, dissolved phosphorus, nitrate-nitrite nitrogen, ammonia nitrogen, total kjeldahl nitrogen, TOC, temperature, fecal coliform, chloride, COD, and turbidity.

C. Fish Contaminant Parameters
   
   Dieldrin, DDT, PCB, aldrin, endrin, methoxychlor, heptachlor, heptachlor epoxide, chlordane, lindane, benzene, hexachloride, toxaphene, mirex, hexachlorobenzene, and mercury.
APPENDIX IV

Illinois Environmental Protection Agency
Volunteer Citizen Lake Monitoring Program

This is your chance to learn about your lake or a lake nearby. The Illinois Environmental Protection Agency will conduct a Volunteer Citizen Lake Monitoring Program for interested citizens across the state. Data gathered on each lake will be used to determine the water quality of lakes in Illinois.

The sampling period will begin in the spring and continue through fall of 1981. Volunteers will be trained to take secchi disc measurements to determine the transparency of the water. Data obtained will be analyzed in a report on each lake, and sent to participants at the end of the project.

The Agency is presently compiling a mailing list of citizens interested in discovering more about the quality of their lake. Please sign below to indicate your interest. The Agency will contact interested citizens with further details.

NAME ________________________________

ADDRESS ________________________________

STREET ___________________ CITY ______ ZIP ______

TELEPHONE ________________________________

HOME ___________________ OFFICE ______

NAME OF LAKE ________________________________

CITY ___________________ AFFILIATION ______

ORGANIZATIONAL AFFILIATION ________________________________

Return to:

Donna F. Sefton
Planning Section
Division of Water Pollution Control
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, IL 62706
APPENDIX V

NORTH AMERICAN LAKES MANAGEMENT SOCIETY

The North American Lakes Management Society was chartered on September 10, 1980, in Portland, Maine, for the purpose of promoting better understanding of lakes, ponds, reservoirs, impoundments, and their watersheds as ecological units. The Society is interested in protection, restoration, and management of these water bodies.

The objectives of the Society are:

- to promote the exchange of information on the technical and administrative aspects of lake management;

- to promote public awareness of lake ecosystems;

- to encourage public support for national, state, and local programs promoting lake management;

- to provide guidance to public and private agencies involved in or planning lake management activities;

- to improve the professional status of all persons engaged in any aspect of lake management;

- to identify needs and encourage research on lake ecology and watershed management.

Membership in the Society is open to any individual or organization with interests in lake management, including scientists, planners, engineers, lakeshore property owners, consulting firms, governmental agencies, and concerned citizens in the United States, Canada, and Mexico.

NORTH AMERICAN LAKES MANAGEMENT SOCIETY

MEMBERSHIP APPLICATION

Name: ____________________________________________

Affiliation: ______________________________________

Address: _________________________________________

________________________________________________

Membership Categories

___ Personal $15 / year

___ Family $25 / year

___ Public/Non-profit $25 / year

___ Corporate $50 / year

Return to: Joel G. Schilling, Treasurer
           c/o Minnesota Pollution Control Agency
           1935 West County Road B-2
           Roseville, Minnesota  55113
APPENDIX V  (cont'd.)

For further information, write:  North American Lake Management Society
                              Post Office Box 68
                              East Winthrop, Maine  04343

or contact:  President G. Dennis Cooke  President-Elect Thomas U. Gordon
            Department of Biological  Cobbossee Watershed District
            Sciences                              15 High Street
            Kent State University                  Winthrop, Maine  04364
            Kent, Ohio  44242

Secretary Robert J. Johnson  Treasurer Joel G. Schilling
                              Minnesota Pollution Control Agency
                              5312 Taney Avenue
                              Alexandria, Virginia  22304
                              1935 West County Road B-2
                              Roseville, Minnesota  55113

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Lafayette, California  94549

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New York Department of Environmental Conservation
Lake George, New York  12845

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Guadalupe-Blanco River Authority, Box 271
Seguin, Texas  78155

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University of Washington
Seattle, Washington  98195

Southeast Region
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Tallahassee, Florida  32301

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Pierre, South Dakota  57501

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Gareth Goodchild
Ministry of Natural Resource
4422 Whitney Block
Queens Park, Toronto, Ontario

At-Large
Matthew Scott
Department of Environmental Protection
Augusta, Maine  04333

At-Large
Donna F. Sefton
Illinois Environmental Protection Agency
Springfield, Illinois  62706

At-Large
David Morency
Entranco Engineers
100 116th Avenue S.E.
Bellevue, Washington  98004
APPENDIX VI

SECTION 314 CLEAN LAKES PROGRAM ASSISTANCE

1. Awarded only to designated state agency (Illinois EPA)

2. Only for public owned freshwater lakes (Public access through publicly owned contiguous land)

3. Types of assistance
   a. Lake Survey and Classification
   b. Phase 1 Cooperative Agreement - Diagnostic/Feasibility Study
      - Up to $100,000 federal funds per award
      - 70% Federal/30% local cost share
   c. Phase 2 Cooperative Agreement - Implementation
      - 50% Federal/50% local cost share

4. Responsibilities of Illinois EPA
   a. Provide technical assistance and information
   b. Serve as applicant to USEPA
   c. Review, certify, prioritizing applications
   d. Administer program (procurement, contract management, reporting)

5. Responsibilities of Locals
   a. Prepare application materials
   b. Supply 30% local match for Phase 1 or 50% local match for Phase 2
ILLINOIS STATE LAKE MANAGEMENT PROGRAM

Peter J. Paladino*

The Illinois Department of Conservation (IDOC) Division of Fisheries has the management responsibility for 82,920 ponds and lakes (Table 1). Ponds are classified as 5.9 acres or less in size and represent 96.6% of this total. Lakes are those water areas 6.0 acres and larger. Lakes represent only 3.4% of the total number of water areas but account for 77.2% of the total pond and lake water acreage. The department owns or leases 211 ponds and lakes totalling 29,900 acres. Public ponds and lakes owned by other state, county, or municipal agencies are represented by 631 water areas totalling 76,600 acres. In addition to these two categories, organizational, commercial and private water areas number 82,078 and total 135,700 acres.

Illinois' lake resource is represented primarily by man-made ponds and lakes (Table 2). Approximately 95% by number and 67% by water acreage. These water areas are represented by farm ponds, IDOC fishing lakes, municipal water supply lakes, power plant cooling lakes, and lakes created by surface mining operations. Naturally occurring ponds and lakes account for 5% by number and 33% by water acreage. The majority of these lakes are backwater lakes along the many rivers and streams in Illinois. The remainder of the natural lakes are glacial lakes in the extreme northeastern portion of Illinois and sinkhole lakes along the Mississippi River.

This brief summary of the lake and pond resource in Illinois provides the background for describing the Illinois State Lake Management Program, which is a separate section within the Division of Fisheries. The section is arranged into four fishery regions which conform to the boundaries of the state planning regions. These regions are then broken into a total of 17 fishery management districts each of which are staffed by a district fisheries biologist. These districts range in size from two to eight counties. Figure 1 shows the state planning regions, and Figure 2 the fishery region and district alignment. Appendix A is a directory of the Springfield fisheries staff and the regional and district fisheries biologists.

*Impoundment Staff Biologist, Division of Fisheries, Illinois Department of Conservation

180
Table 1. Statewide summary of Illinois surface water resources (1978)*

<table>
<thead>
<tr>
<th>Water Resource Type</th>
<th>Classification</th>
<th>Number</th>
<th>Acres</th>
<th>Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Michigan</td>
<td></td>
<td>1</td>
<td>976,640.00</td>
<td>976,640.00</td>
</tr>
<tr>
<td>(I11. portion only)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reservoirs</td>
<td></td>
<td>3</td>
<td>54,580.00</td>
<td>54,580.00</td>
</tr>
<tr>
<td>Impoundments:</td>
<td>State</td>
<td>211</td>
<td>29,876.15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Public</td>
<td>631</td>
<td>76,570.85</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Organization</td>
<td>1,974</td>
<td>24,808.70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Commercial</td>
<td>505</td>
<td>3,037.70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Private</td>
<td>79,599</td>
<td>107,887.80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>82,920</td>
<td>242,181.20</td>
<td></td>
</tr>
<tr>
<td>Miles</td>
<td>0-20 ft. wide</td>
<td>4,915.4</td>
<td>7,159.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21-100 ft. wide</td>
<td>5,916.5</td>
<td>29,884.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>101-300 ft. wide</td>
<td>992.4</td>
<td>17,753.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>301 plus ft. wide</td>
<td>1,379.7</td>
<td>201,778.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>13,204.0</td>
<td>256,574.00</td>
<td></td>
</tr>
<tr>
<td>GRAND TOTAL SURFACE WATER ACREAGE</td>
<td></td>
<td></td>
<td></td>
<td>1,529,975.20</td>
</tr>
</tbody>
</table>

*As of December 31, 1978.
Table 2. Number and acres of impoundments by size categories (1978)

<table>
<thead>
<tr>
<th>Size Categories Acres</th>
<th>IMPOUNDMENTS</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Artificial Total Acreage</td>
<td>Number</td>
<td>Natural Total Acreage</td>
<td></td>
</tr>
<tr>
<td>0.1 to 0.4</td>
<td>42,594</td>
<td>9,616.60</td>
<td>1,526</td>
<td>386.90</td>
<td></td>
</tr>
<tr>
<td>0.5 to 0.9</td>
<td>18,468</td>
<td>11,697.60</td>
<td>838</td>
<td>581.70</td>
<td></td>
</tr>
<tr>
<td>1.0 to 5.9</td>
<td>15,444</td>
<td>29,865.60</td>
<td>1,192</td>
<td>2,995.20</td>
<td></td>
</tr>
<tr>
<td>6.0 to 10.9</td>
<td>1,017</td>
<td>7,860.90</td>
<td>202</td>
<td>1,639.70</td>
<td></td>
</tr>
<tr>
<td>11.0 to 40.9</td>
<td>860</td>
<td>16,047.50</td>
<td>307</td>
<td>6,292.90</td>
<td></td>
</tr>
<tr>
<td>41.0 to 100.9</td>
<td>156</td>
<td>9,148.90</td>
<td>90</td>
<td>5,624.70</td>
<td></td>
</tr>
<tr>
<td>101.0 to 500.9</td>
<td>77</td>
<td>16,356.60</td>
<td>78</td>
<td>16,361.30</td>
<td></td>
</tr>
<tr>
<td>501 plus</td>
<td>39</td>
<td>61,203.00</td>
<td>32</td>
<td>46,502.10</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>78,655</td>
<td>161,796.70</td>
<td>4,265</td>
<td>80,384.50</td>
<td></td>
</tr>
<tr>
<td>PERCENT</td>
<td>94.86%</td>
<td>66.81%</td>
<td>5.14%</td>
<td>33.19%</td>
<td></td>
</tr>
</tbody>
</table>

COMBINED TOTAL OF ARTIFICIAL AND NATURAL IMPOUNDMENTS

<table>
<thead>
<tr>
<th>Size Categories Acres</th>
<th>Number</th>
<th>Percent</th>
<th>Acreage</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 to 0.4</td>
<td>44,120</td>
<td>53.21</td>
<td>10,003.50</td>
<td>4.13</td>
</tr>
<tr>
<td>0.5 to 0.9</td>
<td>19,306</td>
<td>23.28</td>
<td>12,279.30</td>
<td>5.07</td>
</tr>
<tr>
<td>1.0 to 5.9</td>
<td>16,636</td>
<td>20.06</td>
<td>32,860.80</td>
<td>13.57</td>
</tr>
<tr>
<td>6.0 to 10.9</td>
<td>1,219</td>
<td>1.47</td>
<td>9,500.60</td>
<td>3.92</td>
</tr>
<tr>
<td>11.0 to 40.9</td>
<td>1,167</td>
<td>1.41</td>
<td>22,340.40</td>
<td>9.23</td>
</tr>
<tr>
<td>41.0 to 100.9</td>
<td>246</td>
<td>0.30</td>
<td>14,773.60</td>
<td>6.10</td>
</tr>
<tr>
<td>101.0 to 500.9</td>
<td>155</td>
<td>0.19</td>
<td>32,717.90</td>
<td>13.51</td>
</tr>
<tr>
<td>501 plus</td>
<td>71</td>
<td>0.08</td>
<td>107,705.10</td>
<td>44.47</td>
</tr>
<tr>
<td>TOTAL</td>
<td>82,920</td>
<td>100.00%</td>
<td>242,181.20</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

Ponds (0.1 to 5.9 Acres) 80,062 96.55% 55,143.60 22.77%
Lakes (6.0 acres Plus) 2,858 3.45% 187,037.60 77.23%
Figure 1.
State Planning Regions
Figure 2.

DIVISION OFFICE LOCATIONS

Region I

Region II

Region III

Region IV

Region V

Regions

Districts

District Office

Regional Office

Central Office

Pathologist Office

Streams Office

Reservoirs Office

Lake Michigan Office

Havana Field Station

Spring Grove Hatchery

Little Grassy Hatchery
The goal of the Illinois State Lake Management Program is the protection, enhancement, and utilization of aquatic life and its habitat for the people of Illinois (Figure 3). Illinois' Lake Management Program is a mix of applied management, information and education, and management consultation. The fisheries district is the basic unit in this program. Water areas are prioritized on the basis of ownership classification, and the majority of field management occurs on state and public waters. Management on these waters involves moderately intensive monitoring of fish populations, limited aquatic vegetation control, fish harvest estimates by creel surveys, fish stocking, and control of undesirable recruitment of panfish and other species.

Figure 3. Division of Fisheries goals

The Division goal is the protection, enhancement and proper utilization of aquatic life* for the people of Illinois.

This broad goal is broken down into the following strategic goals:

**Protection**

--Protect land and water resources from contamination by substances and materials harmful to fish and aquatic organisms.

--Protect aquatic habitat from physical degradation and destruction to the fullest extent.

--Protect endangered native aquatic life species for their social and ecological values.

--Establish harvest regulations to adequately protect aquatic life.

**Enhancement**

--Manage fish and other aquatic life resources for optimum recreational, social and economic benefits.

--Manage public lands and waters to provide productive ecosystems for fish and other aquatic life.

--Encourage and develop consideration of fish and other aquatic life needs in the management of private lands and waters.

--Develop public awareness of ecological facts and principles related to fish and other aquatic life resources.

--Encourage the acquisition and development of quality fishing areas.

**Utilization**

--Provide diverse opportunities for recreational uses of fish and other aquatic resources.

--Encourage the continuance of a commercial fisheries industry compatible with the resource base.

*Aquatic life includes all fish, amphibians, reptiles, crayfish, and mussels.
Organizational, commercial, and private water areas received limited attention so far as actual field management is concerned. A good deal of consultative management is provided annually. During the past twelve months, 4,096 consultative cases were reported. These inquiries range from what are some sources of fish for stocking to why does the water from a lake taste so bad. Every conceivable question concerning lakes and ponds has most likely been responded to at some time.

The Division of Fisheries has developed and printed a number of management booklets directed towards the private pond owner. These publications were developed to provide the private lake owner with a source of information concerning lake management. A review of these publications will provide you with an appreciation of the broad range of information which our district fisheries biologists attempt to make available to pond and lake owners. These efforts range from individual field contacts to short extension workshops where presentations are made in the classroom or at a given lake site. These efforts over the last fifteen years have exerted a tremendous impact on the quality of pond fisheries and lake management in Illinois. They have also created a cadre of informed private pond and lake owners who serve as sources of information to other lake owners.

The Division of Fisheries has funded research projects with several universities in Illinois in an effort to develop new management capabilities which will result in enhanced management of our state lakes. Research in progress deals with genetically typing the various largemouth bass stocks in Illinois, evaluation of threadfin shad introductions on predator species, evaluation of the grass carp/bighead carp hybrid for aquatic vegetation control, and evaluation of fish size limits. In addition to these formal research projects, the State Lake Program Section conducts a variety of management investigations each year. Last month we conducted a complete census of all fish during a renovation of Walnut Point Lake. This provided us with an evaluation of various fish sampling techniques and fish population estimates as compared to the actual fish population in Walnut Point Lake.

In addition to these activities and programs, the Illinois State Lake Management Section has been involved on a limited basis with programs dealing with inland lake renewal and watershed management. Mr. Gary Erickson, Region II-III Fishery Supervisor will address these topics.
Appendix A.  IDOC Fisheries Division Directory

MAIN OFFICE:

Mike Conlin, Division Chief
600 North Grand Avenue West, Springfield IL 62706
217-782-6424

James Allen
Administrative Assistant

Larry Dunham
Fiscal Operations

Arnold (Bill) Fritz
Special Projects Biologist

Tom Johnson
Hatchery Biologist

Charles (Chuck) Muller
Data Analyst

Peter Paladino
Impoundment Biologist

Richard Rogers
Fisheries Resource Analyst

Clerical Staff:

Edith Campbell
Enid Davis
Kathie Dunmoneaux
Ann Hovey
Billie Knight

REGION 1 (Districts 1, 2, 3 & 4)

Leo Rock, Regional Fishery Supervisor
2612 Locust St., Sterling IL 61081
815-625-2968

District 1 (Boone, Carroll, DeKalb, Jo Daviess, Stephenson, Winnebago)

Alec Pulley, District Fishery Biologist
Lake Le-Aqua-Na State Park, Rt. 2., Lena IL 61048
815-369-4282

District 2 (Bureau, Henry, Lee, Ogle, Rock Island, Whiteside)

Mike Sale, District Fishery Biologist
Farm Bureau Bldg., White Pines Rd., Oregon IL 61061
815-732-6184

District 3 (Fulton, Henderson, Knox, McDonough, Mercer, Warren)

Kenneth Russell, District Fishery Biologist
245 North Cherry St., Galesburg IL 61401
309-343-2617

District 4 (LaSalle, Marshall, Peoria, Putnam, Stark, Tazewell, Woodford)

Wayne Herndon, District Fishery Biologist
Realty Center, 133 N. Parkway Drive, Pekin IL 61554
309-347-5110 or 5119

Joseph Bystry, Fishery Technician
Coleta IL 61017
815-336-2215
REGION II-III (Districts 5, 6, 7, 8, & 9)

Gary Erickson, Regional Fishery Supervisor
110 James Road
Spring Grove, IL 60081
815-675-2385

District 5 (DuPage, Kane, McHenry)

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District 6 (Cook, Lake)

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BIOMANIPULATION AND LAKE RESTORATION
ON STATE WATERS IN ILLINOIS

Gary Erickson*

Water quality and aquatic habitat are of prime importance in the long-term management of a sports fishery. Almost all the species of fish in a high quality sports fishery management program are intolerant of low dissolved oxygen, high carbon dioxide, high turbidities, and many of the conditions associated with highly eutrophic aquatic habitats. All of these fish at one stage in their life cycle are dependent upon the lowest trophic level of the waters for their food supply. This level is composed of algae, and its rate of production is known as the primary productivity of the waters. Maintenance of optimum levels of primary production is highly dependent upon the water temperatures and available nutrients and sunlight. Sunlight availability is one parameter that can be greatly influenced by the composition of the fish population. Due to their feeding activity, excessive numbers of bottom-feeding fishes contribute to the suspension of bottom sediments, decreased water clarity, and subsequently, reduced primary productivity.

Using the fish toxicant rotenone to remove the fish species responsible for conditions of high turbidity results in the total rehabilitation of the fish population. Previously, rotenone, an organic compound, has been applied during the fall for fish removal. Recent research reveals the efficacy of the toxicant can be increased by application just prior to ice cover. This inhibits the degradation of the rotenone and allows a much longer exposure time to the more tolerant species. Following this treatment, water clarity rises to the point where improvements of five- to eight-fold are not uncommon.

Rehabilitation of fish populations can also be conducted as selective or partial treatments. The former method is utilized to affect a target species, e.g., small bluegill or gizzard shad, in order to achieve a more balanced species composition. The latter method of partial rehabilitation involves the treatment to remove a portion of the population, e.g., stunted panfish.

*Fishery Biologist, Region 2, Illinois Department of Conservation, Spring Grove
Just as particular fish species inhabiting the lake are able to affect their habitat, the watershed of a given lake has even a more pronounced effect. The majority of state-owned lakes are manmade and are vulnerable to perturbations within the associated watershed. These watersheds are characterized by agricultural row crop practices which are exposed and unstable the majority of the year.

The result of these watershed-related problems is primarily sedimentation in the receiving lake basins. Sedimentation affects the aquatic ecosystem at a multitude of trophic levels. Initially the effects are seen as the larger suspended particles settle out as they reach the static impoundment. As the silt drops out of suspension, benthic organisms are displaced or are unable to survive. Aquatic vegetation is also forced out due to low light penetration by the silt in suspension or by being buried by the encroaching sediment. The invertebrates inhabiting the vegetation are subsequently lost, eliminating the forage for various fish species. As the sedimentation continues, what was once aquatic habitat, in severe instances, becomes lost to terrestrial habitat.

In conjunction with the silt particles, there are also the contaminants adhering to the particles and thus being carried to the lake. These contaminants can include everything from nutrients, herbicides and insecticides to heavy metals. In the lakes where we have sedimentation it is usually associated with high nutrient levels and excessive biological production. This production begins as the sediment settles and the conditions become optimum for the blooms of green and blue-green algae.

Where the blooms are intense, fishkills have been documented and artificial aeration used as a stopgap measure. Artificial aeration is used primarily to improve aquatic habitat susceptible to wide variations in dissolved oxygen concentrations. This condition usually arises in shallow impoundments or impoundments subject to excessive nutrient input. Aeration can alleviate these variations by creating a circulation pattern, exposing the waters to the atmosphere and allowing carbon dioxide to escape. Aeration used in this manner can provide short-term improvements. However, this is treating the symptoms and not the cause. The Division of Fisheries is pursuing this method of improving four of our state lakes so as to optimize sports fishery population. The use of aeration, although a cosmetic approach, allows us the time needed to arrive at long-term solutions.
Although we experience high nutrient levels in selected lakes, our fish contaminant sampling program, in cooperation with the Illinois Department of Public Health, Illinois Environmental Protection Agency, Illinois Department of Agriculture, and the U.S. Food and Drug Administration, has found no other serious contaminant residues in state-owned waters. However, an isolated occurrence in the spring of 1978 revealed how the condition of the watershed can affect the receiving water. A heavy rain subsequent to the application of a pesticide for corn rootworm in the watershed of Pierce Lake at Rock Cut State Park caused a fishkill. The kill removed 90 percent of the sunfish in the lake plus many largemouth bass and walleye. The total value of fish killed amounted to $4,850.

Because we would like to avoid that scenario of sedimentation and water quality degradation, we are actively working in the fields with landowners to protect and restore their land, in turn increasing the life expectancy of our impoundments. An example of this cooperation is the Lake Le-Aqua-Na Project in Le-Aqua-Na State Park in Stephenson County in northwest Illinois. Here the District Fishery Biologist worked with local landowners in the watershed to stabilize the streambank and fence the stream corridor to prevent livestock direct access to the stream. The program was entirely voluntary with landowners donating the land along the stream channel to be fenced. The majority of the watershed is pastureland with the remaining area forested. Attempting to institute this type of a voluntary program in an intensive row crop agricultural watershed would be difficult—if not impossible—and for good reason. What is needed is financial incentive to allow a portion of the stream corridor to be taken out of production. Incentive programs could be instituted through numerous agencies, including the U.S. Department of Agriculture, Illinois Department of Agriculture, U.S. Environmental Protection Agency, and Illinois Department of Conservation.

Pursuing additional avenues to restore and protect our waters, we became involved with the Clean Lakes Act (Section 314) in 1976 with the Frank Holten State Park Project near East St. Louis. The three lakes are the remains of what was once a natural oxbow of the Mississippi River. Their capacity was being diminished due to sedimentation, and the water quality indicated excessive nutrients. The application called for the relocation of the drainage ditch
into the lake, an inverted siphon under the drainage ditch, and dredging for removal of the accumulated sediments. The project was approved for a total of $1,854,000, of which 50 percent or $927,000 was funded by the Clean Lakes Program. This project is still ongoing with 40 percent completed. The dredging program remaining to be completed constitutes 60 percent of the project.

We have also prioritized six state-owned lakes for diagnostic/feasibility studies to alleviate sedimentation and excessive nutrient levels. Presently the top two have been accepted for Phase I grants through the Clean Lakes Program, and two others are being prepared. The ones recently approved are Lake Le-Aqua-Na in Stephenson County and Johnson Sauk Trail Lake in Henry County both in northwestern Illinois. The proposals for both are essentially the same due to similar conditions of sedimentation and highly eutrophic conditions. Individual cost for each proposal is $49,500 with 70 percent federally funded and 30 percent funded by IDOC. This will provide for a monitoring program, diagnostic study, and feasibility study.

It is this concern and participation in the program for watershed management that has led the Division of Fisheries to create a position devoted entirely to watershed management and lake restoration. This individual will be responsible for programs related to improving and protecting the associated watersheds to our state-owned lakes. Achievement of these goals will be pursued through the implementation and coordination of resources presently available in addition to investigation of potential avenues for watershed improvement.

In our attempts to restore our state waters, we are very mindful at the same time to maintain optimum levels of primary productivity for fish production. If nutrient removal techniques were effective to the point of creating an oligotrophic condition, or one poor in nutrients, primary productivity would be drastically reduced. In turn, the quality and the quantity of the sports fishery would decline. Therefore, it is necessary to maintain productive waters. This is of prime importance, because, as a survey conducted throughout the state in 1976 revealed, sportfishing is second only to swimming in outdoor recreation pursuits for our state's residents (Illinois Department of Conservation, 1978).
REFERENCE

APPENDIX A. PROGRAM

ROUND TABLE ON RECLAIMING AND MANAGING LAKES IN ILLINOIS

October 10-11, 1980
Ramada Inn Convention Center
Champaign, Illinois
Sponsored by the WATER RESOURCES CENTER
in cooperation with
ILLINOIS ENVIRONMENTAL PROTECTION AGENCY and
ILLINOIS INSTITUTE OF NATURAL RESOURCES

Friday - October 10, 1980

8:30 a.m. REGISTRATION, Coffee & Doughnuts

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>9:30</td>
<td><strong>Overview: Lake Resources in Illinois</strong></td>
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<tr>
<td></td>
<td>Donald Vonnahme</td>
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<td>Division of Water Resources</td>
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<td>Illinois Department of Transportation</td>
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<tr>
<td>10:00</td>
<td><strong>The Clean Lakes Program</strong></td>
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<td></td>
<td>Donna F. Sefton</td>
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<td>Division of Water Pollution Control</td>
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<td>Illinois Environmental Protection Agency</td>
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<tr>
<td>10:15</td>
<td><strong>Major Problems of Lake Water Quality in Illinois</strong></td>
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<tr>
<td></td>
<td>Michael Meyer</td>
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<td>Division of Water Pollution Control</td>
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<td>Illinois Environmental Protection Agency</td>
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<tr>
<td>10:30</td>
<td>**The Lake Lansing Restoration Project: Its Goals, Successes and</td>
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<td></td>
<td>Disappointments**</td>
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<td></td>
<td>Richard L. Sode</td>
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<td></td>
<td>Ingham County Drain Commissioner</td>
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<td>Mason, Michigan</td>
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<tr>
<td>11:00</td>
<td><strong>Some Considerations in the Restoration and Preservation of Lakes</strong></td>
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<td></td>
<td>Krishan P. Singh</td>
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<td>Surface Water Section</td>
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<td></td>
<td>Illinois State Water Survey</td>
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<tr>
<td>11:30</td>
<td><strong>Uses of Dredged Material</strong></td>
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<td></td>
<td>Thomas R. Patin</td>
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<td>U.S. Army Corps of Engineers</td>
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<td>Vicksburg, Mississippi</td>
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<tr>
<td>12 noon</td>
<td><strong>LUNCH</strong></td>
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</tbody>
</table>


Friday - October 10, 1980

LAKE RECLAMATION

1:00 p.m.  Overview of Intake Treatment Techniques
John Tranquilli
Illinois Natural History Survey
V. Kothandaraman
Water Quality Section, Peoria
Illinois State Water Survey

1:30  A Major Water Quality Problem in Illinois: Soil Movement from
the Watershed and Channel
Robert D. Walker
Cooperative Extension Service
University of Illinois

2:00  Controlling Sediment by Watershed Management Techniques
Harvey Sundmacker
Soil Conservation Service
United States Department of Agriculture

2:30  BREAK

2:45  Biological Aspects of Eutrophication
Michael R. Lynch
Department of Ecology, Ethology and
Evolution
University of Illinois

3:15  Illinois Department of Conservation Lake Renourishment Programs
Gary Erickson
Division of Fisheries - Region 2
Illinois Department of Conservation

3:30  Illinois State Lake Management Program
Peter J. Paladino
Division of Fisheries
Illinois Department of Conservation

3:45  Legal Aspects of Reclaiming Lakes: Activity Permits and Constraints
David R. Boyce
Division of Water Resources
Illinois Department of Transportation

4:15  Recreation and Reclamation: The Residents' Perspective (Lake Paradise)
James Absher and Douglas Musser
Department of Leisure Studies
University of Illinois

5:00  SOCIAL HOUR

7:30  EVENING INFORMAL ROUND TABLE
Glenn E. Stout
Water Resources Center

Dennis Cooke, Department of Biological Sciences, Kent State University
Ed Herricks, Environmental Engineering, University of Illinois
Eric Seagren, Mudcat, Inc., St. Louis, Missouri
Dorie Turpin, Water Resources Center, University of Illinois
Dean Van Wie, Dodson-Van Wie Engineering, Mattoon, Illinois
Jo Ann Wesner, Lake Environmental Services, Lake Zurich, Illinois
Saturday - October 11, 1980

8:30 a.m. REGISTRATION, Coffee

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Presenter(s)</th>
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<tbody>
<tr>
<td>9:00</td>
<td>Overview of the Economic Aspects of Reclaiming a Lake</td>
<td>Glenn E. Stout, William Miller, Water Resources Center, Department of Agricultural Economics, Purdue University</td>
</tr>
<tr>
<td>9:30</td>
<td>A Case Study of the Economic Benefits of Reclaiming a Lake:</td>
<td>Susan R. Deo, Water Resources Center, University of Illinois</td>
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<td></td>
<td>Lake Paradise, Mattoon</td>
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<tr>
<td>9:55</td>
<td>An Economic Analysis of the Recreational Benefits of Water Quality</td>
<td>Nicolaas Bouwes, Department of Agricultural Economics, University of Wisconsin</td>
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<td>Improvements</td>
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<td>10:25</td>
<td>Chemical Characteristics of Lake Sediments</td>
<td>Michael J. Barcelona, Aquatic Chemistry Section, Illinois State Water Survey</td>
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<tr>
<td>10:55</td>
<td>In-Lake Control of Vegetation:</td>
<td>G. Dennis Cooke, Department of Biological Sciences, Kent State University</td>
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<td></td>
<td>Section 314 Funding</td>
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<tr>
<td>12 noon</td>
<td>LUNCH</td>
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</tbody>
</table>
Saturday - October 11, 1980

LAKE MANAGEMENT

1:00 p.m. Water Quality Monitoring Programs
David Jones
Illinois Institute of Natural Resources
Allison Brigham
Aquatic Biology Section
Illinois Natural History Survey

1:30 Prevention of Shoreline Erosion by Physical and Structural Methods
Dwight A. Niccum
Effingham, Illinois

2:00 Methods for Controlling Human Use of a Lake
Donald Ferguson
Bloomington Water Department
Bloomington, Illinois

2:30 Institutions for Lake Management
Donald Uchtmann and M. R. Grossman
Department of Agricultural Economics
University of Illinois

3:00 Funding Aspects of Lake Management
Richard Burd
Office of Local Management Services
Illinois Department of Commerce and Community Affairs

3:30 ADJOURN

PLANNING COMMITTEE

Glenn E. Stout, Water Resources Center
Susan R. Deo, Water Resources Center
David Jones, Illinois Institute of Natural Resources
Linda C. Keasler, Water Resources Center
W. J. Roberts, Illinois State Water Survey
Donna F. Sefton, Illinois Environmental Protection Agency
Dorie E. Turpin, Water Resources Center
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