May 2018

5-Year Implementation Strategy for the Management of Chautauqua Lake and Its Watershed

Prepared for Chautauqua Lake and Watershed Management Alliance

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TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

ABBREVIATIONS

µg/L	micrograms per liter
AEM	Agricultural Environmental Management
Alliance	Chautauqua Lake and Watershed Management Alliance
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
CRCF	Chautauqua Region Community Foundation
CCSWCD	Chautauqua County Soil & Water Conservation District
CLA	Chautauqua Lake Association
CSLAP	Citizens' Statewide Lake Assessment Program
EBM	Ecosystem-Based Management
FG	Focus Group
HAB	Harmful Algal Bloom
MCA	Multi-Criteria Analysis
mg/L	milligrams per liter
MMS	Chautauqua Lake Macrophyte Management Strategy
NRCS	Natural Resources Conservation Service
NYSDEC	New York State Department of Environmental Conservation
SWAT	Soil & Water Assessment Tool
SEIS	Supplemental Environmental Impact Statement
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
USEPA	United States Environmental Protection Agency
WMP	Chautauqua Lake Watershed Management Plan

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Executive Summary

The Chautauqua Lake & Watershed Management Alliance is a hub for the collective efforts of the active stakeholder community around Chautauqua Lake in southwestern New York State. The Alliance promotes and facilitates the implementation of projects designed to improve the health of the lake and its watershed. Watershed-related projects focus on reducing the external loading of nutrients and sediment to the lake as a means to restore and protect water quality conditions. In-lake projects aim to restore impaired uses of the lake by managing aquatic vegetation and reducing internal nutrient loading, thereby reducing the symptoms of excessive external loading. In 2017, heightened community concern about the health of the lake—and differing views on which expenditures and projects would have the most beneficial impact—led the Alliance to seek a more objective, transparent approach for prioritizing projects and allocating resources.

The resulting *5-Year Implementation Strategy for the Management of Chautauqua Lake and Its Watershed* (2018–2022) offers a structured decision-making process and template to guide decisions about which lake and watershed projects should be pursued and/or funded. The project team developed a multi-criteria analysis (MCA) tool based on the current science, engineering, and technology of lake and watershed management. These technical criteria are weighted with respect to input from the local community regarding what ecosystem functions are of greatest value.

The MCA tool enables the Alliance to explicitly address the tradeoffs inherent in prioritizing project opportunities. It applies decision criteria to evaluate projects, assigns a weighting factor to each criterion, and allows users to score the criteria consistently and objectively on a project-by-project basis. The criteria include environmental factors (italicized below), which are weighted most heavily, as well as social and economic factors. Separate criteria are applied to watershed and in-lake projects, and a set of general criteria is applied to all projects:

Watershed

- *Reduction in nutrient loading*
- *Reduction in sediment loading*
- *Hydrologic resilience*

In-Lake

- *Protective of human health*
- *Reduction of nutrients from lake ecosystem*
- *Protective of ecosystem health*
- *Longevity of effectiveness*
- *Management of invasive species*

General

- *Plan to measure and report effectiveness*
- *Consistency with existing plans and strategies, and/or consideration of emerging solutions*
- Commitment to stakeholder collaboration
- Outreach and education
- Potential for leveraging available non-local funding
- Disclosure of costs (up front and any future maintenance)
- Magnitude of up-front project costs
- Spatial scale of project

A key feature of the MCA tool is that it allows the Alliance and its collaborators to modify criteria and the weighting structure over time, thus promoting adaptive management while upholding standards of objectivity and transparency.

One of the challenges for the Alliance and its members is to strike a balance between watershed and in-lake management efforts, so the *5-Year Implementation Strategy* recommends a general allocation of resources to guide the relative investment of resources from 2018 to 2022. These allocations are divided among watershed measures, in-lake measures, and *monitoring*—a third category that will help the Alliance evaluate the impact of completed projects and provide a basis for adapting and refining the decision support tool. Given community concerns about the urgent need to reduce impairments to recreational uses of the lake, which is an economic engine for the region, the Strategy recommends apportioning 50% of available funds to in-lake measures in 2018, and gradually shifting that allocation toward watershed measures over the five-year period. Watershed measures would receive 30% of the funding allocation in 2018, and this proportion would increase toward 60% as funds are shifted away from in-lake measures over the course of the five-year period. Monitoring would receive a constant 20% of the allocation from 2018 to 2022.

The Strategy also addresses some uncertainties about the pool of resources and available techniques that will be available for managing Chautauqua Lake in the future. New York State Governor Andrew M. Cuomo's statewide Harmful Algal Bloom (HAB) initiative includes Chautauqua as one of 12 Priority Lakes for which Action Plans will be developed to address the emerging issue of cyanobacterial blooms. The Chautauqua Lake HAB Action Plan, anticipated for release in late May 2018, may affect the universe of permitted actions, the availability of funding, or monitoring priorities. The Alliance will be able to use the MCA tool to adapt to new opportunities, such as those that may emerge from the HAB Action Plan.

Finally, the Strategy offers some general recommendations for the Alliance and its members to ensure that future project proposals submitted for funding align with criteria outlined in the MCA tool, and for staffing and volunteer resources that will enhance the Alliance's capacity in the areas of administration, outreach, and technical expertise.

1 Objective and Scope of the Strategy

1.1 Need for the Strategy

Chautauqua Lake is a vital resource for the people who live in and visit southwestern New York State, as well as the community of plants and animals that make their home in the lake and watershed. For years, local governments and organizations have worked together to support studies, develop plans, and implement projects to protect this essential community asset. Their efforts have produced valuable knowledge about Chautauqua Lake and its watershed and have generated a myriad of ideas for protecting and restoring the lake's health.

These planning efforts are largely represented in three key documents published during the past decade. The 2010 *Chautauqua Lake Watershed Management Plan* (WMP; Bergmann Associates 2010) addresses watershed loading of nutrients and sediment to the lake and includes a wide range of recommendations and long-term measures. The 2012 *Total Maximum Daily Load (TMDL) for Phosphorus in Chautauqua Lake* (Cadmus Group 2012), prepared for the New York State Department of Environmental Conservation (NYSDEC), identifies and quantifies the sources of phosphorus and determines the loading reductions needed to bring the lake into compliance with state and federal standards. The 2017 *Chautauqua Lake Macrophyte Management Strategy* (MMS; Chautauqua County Department of Planning and Economic Development 2017) focuses on in-lake options for managing aquatic vegetation in ways that preserve and enhance lake uses while protecting environmentally critical areas. These three documents reflect the input and expertise of a wide array of regional stakeholder groups who bring knowledge, concern, and a strong motivation to maintain the lake as a healthy, functional, and ecologically diverse resource.

Many of the groups that supported development of these plans have been interacting for years to benefit the lake and watershed (see the MMS for a historical overview of their collaborations). In 2015, the Chautauqua Lake and Watershed Management Alliance (Alliance) was established as a hub for the collective efforts of the active stakeholder community. The Alliance works to promote and facilitate implementation of recommendations from the WMP, TMDL, and the MMS by prioritizing projects, securing funding, and allocating resources. The level of local interest and concern about the lake is reflected in the Alliance's broad membership, which currently includes 27 organizations and local government entities (Appendix A). Although the groups share a common interest in protecting the lake and watershed, each one brings a different focus and goals to the collaboration.

As the WMP, TMDL, and MMS illustrate, there is no shortage of work to be done in the watershed and lake, and Alliance members are eager to carry out the project recommendations put forth in these guiding documents. However, resources to support their efforts are finite. Alliance members seek funding from local governments and foundations, which struggle to prioritize requests and determine which expenditures/projects will have the most beneficial impact on the lake. Decisions

about finite resource expenditures are made more difficult by complex issues regarding lake ecology, environmental constraints, and differing perceptions about the causes of lake impairment. Some organizations are inclined to focus on long-term reductions of nutrient and sediment loading to the lake or on preserving its function as habitat for plant and animal life, while others are more concerned about maintaining the lake for recreational uses that appeal to homeowners and visitors, forming the backbone of the regional economy.

Recently, a heightened sense of urgency about the lake's health has generated differing views regarding which projects and initiatives are most important. The increased frequency, intensity, and duration of cyanobacterial blooms in lakes across the state, including Chautauqua, has focused attention on the public health implications of nutrient enrichment. In 2017, herbicide treatments to manage macrophytes occurred as part of a demonstration project after decades of reliance solely on mechanical harvesting and biological controls. The disagreements among stakeholders regarding appropriate interventions motivated the Alliance to enlist outside professional assistance to develop an implementation strategy that reflects lake and watershed science, emerging technologies, and local priorities.

1.2 Approach to Developing the Strategy: Multi-Criteria Analysis Tool

The project team recognized that a structured decision-making process is essential to guiding the rehabilitation and maintenance of Chautauqua Lake. The myriad water quality, habitat, aesthetic, and recreational impairments of the lake and watershed, and the many stakeholder's interests, necessitate a tool that can quantify the economic, ecological, physical/chemical, and social attributes of the various project opportunities. That is, a formal process is needed to compare various projects against their "value" toward achieving the goals established in the WMP, phosphorus TMDL allocation, and MMS.

The tool the project team developed for prioritization of projects reflects stakeholder input and the state of the science in lake and watershed management. This multi-criteria analysis tool enables the Alliance and its partner organizations to explicitly address the following tradeoffs inherent in prioritizing project opportunities:

- Explore the problem in a transparent and objective manner.
- Challenge and/or repeat the decision-making process using alternative criteria.
- Separate facts about expected outcomes from opinions about which is "better."

1.3 Implementation Strategy

This *5-Year Implementation Strategy for the Management of Chautauqua Lake and Its Watershed* (2018–2022) sets forth priority actions in three categories: 1) watershed measures to reduce nutrient and sediment loading; 2) in-lake measures to mitigate the impacts of eutrophication; and 3)

monitoring to assess progress and the need for additional actions or modifications to ongoing management activities. These remedial actions emerged from the recommendations of the WMP, phosphorus TMDL, and MMS focused on controlling watershed sources and maintaining designated uses of the waterways. Improvements to the wastewater collection and treatment system are not included in this *5-Year Implementation Strategy*; projects to address these point sources are planned and underway based on the recommendations of the *Integrated Sewage Management Plan for Chautauqua Lake* (OBG 2014).

New York State Governor Andrew M. Cuomo recently announced a statewide Harmful Algal Bloom (HAB) initiative to address the emerging issue of cyanobacterial blooms. Chautauqua was included as one of 12 Priority Lakes for which Action Plans will be developed. The Chautauqua Lake HAB Action Plan, anticipated for release in late May 2018, may modify the recommendations of this implementation strategy; these modifications may affect the universe of permitted actions, the sequence of projects, costs, funding opportunities, and/or monitoring priorities. The Alliance will be able to adapt to new opportunities, such as those that may emerge from the HAB Action Plan, using the prioritization multi-criteria analysis (MCA) tool developed for this project.

2 Environmental Setting

2.1 Ecoregional Context

The largest lake in southwestern New York State, Chautauqua Lake occupies a shallow, glacially carved valley formed by the retreating Wisconsin glacier during the last ice age, between 10,000 and 12,000 years ago. Water was first impounded behind a deposit (moraine) near the current City of Jamestown. As the ice continued to melt, advancing the edge of the glacier northward, a second moraine was deposited in the Bemus-Stow area. Water impounded behind this deposit formed a second lake to the north as the ice continued to melt. Eventually, glacial meltwater eroded the deposit between the two basins, creating the current lake morphometry (Mayer et al. 1978). The lake functions limnologically as two distinct waterbodies—a northern basin, which is approximately 7,000 acres, and a southern basin, which is approximately 6,000 acres. Key physical features of the lake are summarized in Table 2-1.

Table 2-1
Physical Characteristics of Chautauqua Lake

Characteristic	Lakewide	Northern Basin	Southern Basin
Surface area (acres)	13,132	7065	6067
Length (mi)	14.14	7.53	6.60
Maximum width (mi)	2.17	2.17	2.07
Average width (mi)	Not calculated	1.2	1.2
Maximum depth (ft)	75	75	26
Mean depth (ft)	Not calculated	26	12
Water residence time (years)	2.1	2.0	0.4
Shoreline perimeter (mi)	48.2	24.2	24.0

Source: Table 2, *Total Maximum Daily Load (TMDL) for Phosphorus in Chautauqua Lake* (Cadmus Group, 2012)

Chautauqua is a productive lake that has been significantly influenced by human activities. In the early 1800s, European settlers in the Jamestown area developed a timber-based economy; softwoods were harvested for lumber and transported downriver. Hardwoods in the lake watershed were cut and burned to produce potash and pearl ash. Once the virgin forests were cleared, grain crops and grasses were planted to support the emerging beef and dairy industries. These land-use changes led to erosion from the landscape and deposition of sediment within the lake basins. The nutrient and sediment flux and loss of tree cover during this era influenced the lake's ecology and productivity (Bloomfield 1978). The extensive littoral habitat (shallow regions where light can reach the sediment surface) supports an extensive and diverse macrophyte community. These macrophytes provide essential spawning and nursery areas for the lake's thriving fish community.

Chautauqua Lake is a major cultural and recreational attraction in southwestern New York. The lake supports renowned fisheries, most notably the cool-water species muskellunge and walleye (as well as warm-water species, such as yellow perch and bass), and is a popular tourist destination. Overall, the lake has a significant positive impact on the local economy, attracting visitors and boosting local property values.

While scientists concur that the warm, shallow, productive lake of today is the consequence of its geological and land-use history, the complex interplay between natural conditions and cultural activities is not completely understood. The field of paleolimnology has developed techniques and models that can infer a time history of water quality and habitat conditions of lakes by testing sediment cores for geochemical data and preserved plankton species. Sediment coring of Chautauqua Lake has not been completed. A time history of the lake's trophic state could help educate lake and watershed stakeholders regarding realistic expectations for changes.

2.2 Regulatory Classification and Designated Use

New York State has classified Chautauqua Lake as a Class A waterbody, meaning that the lake shall be suitable for the following: a source of drinking water (following treatment, which includes coagulation, filtration, and disinfection); recreation on and in the water; fishing; and the propagation and survival of fish, shellfish, and wildlife. Several water quality indicator parameters are used to determine whether these designated uses are met. In Chautauqua Lake, data collected as part of the Citizens' Statewide Lake Assessment Program (CSLAP) since 1987 provide the basis to evaluate the water quality indicator parameters and assess whether designated uses are met. The CSLAP program is focused on nutrient enrichment, algal abundance, and water clarity. Because phosphorus is generally accepted as the predominant limiting nutrient for primary productivity in Chautauqua Lake (i.e., the growth of phytoplankton and macrophytes), its measure is a key indicator parameter. Recent research on Lake Erie indicates that nitrogen availability may play a role in the production of cyanotoxins by cyanobacteria, also known as blue-green algae (Gobler et al. 2016).

Results from the annual CSLAP monitoring indicate total phosphorus (TP) concentrations regularly exceed the state's TP guidance value of 20 micrograms per liter (µg/L)[1]; this guidance value was selected as protective of recreational uses. The elevated TP levels, along with warming waters, a relatively low nitrogen to phosphorus ratio, and changes in the lake's food web from invasive species such as dreissenid (zebra and quagga) mussels, have led to cyanobacterial (blue-green algal)

[1] New York State has promulgated a narrative standard for phosphorus in water, "None in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages" (NYSCRR §703.2). For ponded waters the narrative standard is interpreted using a guidance value of 20 µg/L, calculated as the average total phosphorus concentration in the lake's upper waters between June 1 and September 30.

blooms. These blooms threaten the viability of the lake for all its designated uses, including contact recreation, aquatic life protection, and as a source of potable water.

The persistent elevated summer TP concentrations in both basins led to the 2004 listing of Chautauqua Lake on state and federal compendia of impaired water bodies, known as the 303(d) list. Once the lake was listed, NYSDEC was required to identify and quantify the sources of TP and target reductions in TP loads to foster improvement in lake water quality, a process that culminated in the 2012 TMDL for Chautauqua Lake.

The annual CSLAP monitoring program focuses on trophic state indicator parameters and has expanded to include metrics related to cyanobacterial blooms (also referred to as harmful algal blooms, or HABs). Results of the 2017 monitoring effort are summarized in Table 2-2.

Table 2-2
Trophic State Characteristics of Chautauqua Lake (2017)

Characteristic	Northern Basin (June – September average)	Southern Basin (June – September average)
Water clarity (meters)	2.5	1.0
Total Phosphorus (mg/L)- Surface	0.049	0.083
Total Phosphorus (mg/L)- Deep	0.083	not measured
Total Nitrogen (mg/L)	0.428	0.676
Nitrogen: Phosphorus Ratio	10.3	9.5
Chlorophyll-*a* (µg/L) all phytoplankton	16.9	56.1
Chlorophyll-*a* (µg/L)- cyanobacteria	2.3	22
Sample dates with HAB- open water*	0	50%
pH (standard units)	8.1	8.0
Conductivity (µmho/cm)	175.6	179.2
Temperature (°C)-Surface	22.3	23.6
Temperature (°C)-Deep	19.4	not measured
Shoreline HAB- NYSDEC notification list	17 weeks (6/25/17 – 10/27/17)	

*Cyanobacterial bloom (HAB) threshold is 25 µg/L **Source:** CSLAP 2017 results (NYSDEC 2017)

2.3 Lake and Watershed Management: Knowledge and Tools

Chautauqua Lake and watershed have been the focus of numerous studies and evaluations designed to characterize existing condition, define types and sources of pollutants, and identify remedial measures. Three key documents completed in the past decade provide guidance on effective means to improving and protecting the lake for future generations.

The *Chautauqua Lake Watershed Management Plan* (Bergmann Associates 2010), or WMP, describes the nature of the watershed such as topography and soils, hydrology, land use, vegetative cover, population and development trends, and point and nonpoint sources of nutrients and sediment. In addition to the watershed-wide analysis, the WMP identifies priority subwatersheds that contribute disproportionate amounts of nutrients and sediment to the lake based on the nature of the landscape (e.g., soils, topography, hydrology) coupled with human uses (e.g., development density, vegetative cover, impervious surfaces, and management practices).

The WMP includes many recommended actions to reduce nutrient and sediment inputs to the lake; these recommendations encompass structural and nonstructural solutions. Examples include improved wastewater collection and treatment, streambank stabilization, local laws to improve stormwater management, enhanced inspection of on-site wastewater treatment systems, monitoring, education and outreach, dredging, land acquisition, green cover crops, buffers between agricultural fields and streams, and many others.

A separate effort directed at managing the aquatic plant community was completed with the release of the *Chautauqua Lake Macrophyte Management Strategy* (Chautauqua County Department of Planning and Economic Development 2017). The MMS analyzed the entire littoral zone of Chautauqua Lake and delineated zones based on human uses and environmental sensitivities. For each zone, the MMS identifies management techniques, including mechanical harvesting and herbicides, which can be used to balance human desires for recreational access with ecosystem protection.

The *TMDL for Phosphorus in Chautauqua Lake* (Cadmus Group 2012), issued by NYSDEC and approved in 2013 by the US Environmental Protection Agency (USEPA), utilizes mathematical models of the watershed and lake to quantify the relationship of TP load and water quality. These analytical tools were applied to estimate the amount of TP that can flow into Chautauqua Lake while meeting lake water quality standards. The implementation section of the TMDL document, developed in parallel with the WMP and reflecting stakeholder input, outlines the required reductions in point and nonpoint source phosphorus to meet the TP guidance value. Aggressive reductions are needed from wastewater treatment facilities and nonpoint sources, notably agriculture. Mathematical models like those used in the TMDL allocation are constructed using a series of estimates and assumptions and reflect the best information available at the time. This reality underscores the need for monitoring and assessment to fill significant data gaps, track what actions are most effective, and determine what additional measures are needed to meet water quality and habitat goals.

Taken together, these three key documents identify potential actions and projects to restore and/or maintain Chautauqua Lake for multiple uses. The TMDL model projections reveal that major reductions in external loading from point and nonpoint sources are required to reduce the lake's TP levels to meet the current NYSDEC guidance value. Practically speaking, the relatively small-scale

watershed actions identified within the WMP will require decades of diligent effort to produce measurable responses in Chautauqua Lake water quality. Consequently, in-lake measures are necessary to ensure the lake's multiple designated uses are met while longer-term watershed measures are implemented.

In addition to these three key documents, numerous other studies and evaluations have been conducted to characterize existing conditions, define types and sources of pollutants, and identify remedial measures in Chautauqua Lake and its watershed. Examples include aquatic vegetation surveys conducted by Racine-Johnson Aquatic Ecologists regularly since 2002 (e.g., Racine-Johnson Aquatic Ecologists 2008, 2017, and 2018); the State of the Lake Report (Wilson, Riforgiat, and Boria 2000); the Chautauqua Lake and watershed management pre-implementation study completed for Dewittville Creek and Crescent Creek (Academy of Natural Sciences and Bergmann Associates 2013); Chautauqua Lake dredging feasibility study (EcoLogic 2013); an erosion diagnosis and mitigation engineering study for Goose Creek and Dutch Hollow Creek (Barton & Loguidice 2014); a Final Supplemental Environmental Impact Statement addressing potential impacts related to the application of herbicides in targeted areas of Chautauqua Lake (Ellery Town Board 2018); and the annual CSLAP reports prepared by NYSDEC and the New York Federation of Lake Associations.

These multiple investigations and monitoring data sets provide snapshots of water quality and habitat conditions in the lake and watershed. However, there are opportunities to turn data into information, and ultimately to strategic information that can inform management. One example is the standard CSLAP in-lake monitoring program of the northern and southern basins. These data are extremely valuable in tracking changes in trophic status over time and comparing conditions among lakes. The CSLAP program is responsive to emerging issues; the volunteer monitors have been trained to sample shoreline blooms for HAB surveillance. However, the standard CSLAP monitoring program is not designed to address some of the important questions relevant to Chautauqua Lake management such as the significance and impact of internal phosphorus cycling on blooms of algae and cyanobacteria.

Other examples relate to analysis of watershed inputs. Without upstream/downstream or before/after stream monitoring it is difficult to determine how changing practices and land use patterns affect external nutrient and sediment loads. The lack of established stream gauges in the watershed limits capacity to estimate nonpoint source loads. Finally, baseline studies such as *Chautauqua Lake—Entering the 21st Century: State of the Lake* (Wilson, Riforgiat, and Boria 2000) can serve as a benchmark for comparison if sample locations and protocols are repeated.

2.4 Ecosystem-Based Management

The issues facing Chautauqua Lake are not unique. Development pressures, changing agricultural practices, a warming climate, more intense rainfall events, invasive species, and other factors

challenge the collective ability to manage water resources for multiple uses. In 2017, cyanobacterial blooms were documented in numerous waterbodies across the state, the country, and the world.

To help meet the challenge of managing natural resources for multiple uses, New York State and others have adopted a paradigm known as ecosystem-based management (EBM) that considers the entire ecosystem, including humans. The goal of EBM is to maintain ecosystems, including lakes and watersheds, in a healthy, productive, and resilient condition so that they can provide the services humans want and need.

The six guiding principles of EBM are listed below. It is encouraging to reflect on how well the ongoing collaborative, science-based efforts to manage Chautauqua Lake align with these stated principles:

1. Focus on the specific ecosystem and the factors affecting its health
2. Employ a scientific foundation for decision making
3. Define measurable objectives to direct and evaluate performance
4. Recognize the interconnections within and among ecosystems
5. Involve the stakeholders and focus on collaboration
6. Embrace an adaptive management approach to respond to new knowledge

The EBM approach underscores the on-going need to measure the effectiveness of management actions, analyze results, and adapt to new information. The inclusion of monitoring and assessment as a central element of the *5-Year Implementation Strategy* reflects this recognition.

3 Community Priorities and Concerns

3.1 Qualitative Data Collection and Analysis

To engage community members in the development of the implementation strategy, stakeholders from 42 organizations/municipalities (including the 31 founding members of the Alliance) participated in discussions of local priorities. The outreach process was designed to elicit qualitative data to help inform development of decision criteria and weighting factors for the MCA tool. Many of the respondents have overlapping roles and interests in the lake; for example, some are members of multiple organizations or are business or lakeshore property owners in addition to being members of a formal group.

The project team developed a questionnaire to glean information about the context in which the respondents engage in lake and watershed management, and to gather preliminary information about priorities for the lake and ranking of potential project-related criteria (Appendix B). Most questions were open ended. Questionnaires were distributed via email to a primary contact at each stakeholder group, with a request that they distribute to individual members/colleagues, or, if preferred, to confer and respond as a group. Thirty-four questionnaires were returned.

Nine focus groups were convened to capture a range of stakeholder perspectives. Email invitations went to leaders of 42 organizations/municipalities encouraging them to invite fellow members for a maximum of 15 participants per group and clarifying that their role would be to represent the interests of their stakeholder group in the session. Attendees were present from 35 of the 42 organizations, with a total of 70 participants (five people attended more than one session, so the tally for all sessions was 75). Focus groups and the number of participants are shown in Table 3-1.

Table 3-1
Focus Group Summary

Focus Group (FG)	Stakeholders Represented (# participants)
1	Municipalities (11)
2	Agriculture and Parks (6)
3	Business and Tourism, including realtors (11)
4	Scientists (8)
5	Chautauqua Lake Association (9)
6	Chautauqua Lake Partnership (4)
7	Conservation and Environmental Groups (9)
8	Foundations (12)
9	Chautauqua Institution (5)

Each 90-minute focus group session included a welcome and introductions, an overview of the EcoLogic/Anchor QEA assignment, a brief summary of background studies and goals of the session, ground rules for focus group interactions, and facilitated discussion to gather input from participants. Open-ended questions posed to focus group participants included: 1) What is important to you, and what unique insights do you bring to this discussion? 2) How do you perceive the interactions among groups involved in management of Chautauqua Lake? 3) What are your reactions to our initial examples of criteria for project selection—what would you add or change on this list, and what factors would you like to see more heavily weighted? 4) Imagine that in a perfect world with unlimited resources, 15 years in the future, what are three adjectives to describe how you see Chautauqua Lake and its surrounding watershed? and 5) Now, in a more realistic vision of 15 years in the future, what do you see for Chautauqua Lake? Note takers captured the focus group conversations and compiled a detailed record.

Two reviewers independently examined completed questionnaires and focus group notes to identify themes that capture the range of concerns and priorities articulated in focus groups and questionnaires. Questionnaire rankings of sample criteria were considered in the development of MCA criteria weighting factors (although many respondents weighted all sample criteria as "extremely important," so these rankings were just one component considered in the establishment of weighting factors). Of particular interest were themes repeated across stakeholder groups in both questionnaire responses and focus groups, and themes independently observed by both reviewers. These themes were used to help frame the criteria presented in the MCA tool and were used in the development of weighting factors.

3.2 Summary of Themes

3.2.1 Lake Health and Function

Stakeholders who completed surveys and participated in focus groups highlighted the fact that Chautauqua Lake serves a wide array of functions. For many, one of the lake's paramount functions is as an economic asset, either personally or for the region as a whole. It is important as the cultural center of the county and as a recreational resource, with an aesthetic appeal that makes it the pride of the region for residents and seasonal visitors, "old-timers" and newcomers. Chautauqua Lake is also a source of drinking water and a place where children swim, so it is critical that the lake be managed in ways that will not present risks to human health. For some, the lake is at its essence a complex, dynamic ecosystem that deserves to be valued for qualities that are independent of human interests. Many stakeholders expressed the importance of protecting the lake for future generations.

Managing Expectations for Chautauqua Lake and Watershed. One theme that emerged from focus groups was the need to understand and be realistic about what is achievable and possible for Chautauqua Lake. Groups generally understand the lake's current status as eutrophic, but the degree

to which this status is tolerated, accepted, or embraced varies. Some stakeholders see the lake as "beautiful, complex, diverse" and expressed the hope that people could "learn to love the lake we have" (FG4). Most, however, were eager to manage the lake in ways that would slow eutrophication or improve the lake's economic and recreational value, and a few felt the lake's uses are threatened to an extent that justifies urgent, dramatic action. One participant stated, "People should not be misled about what can be accomplished with reduced external loads," suggesting that dredging and increased use of aquatic herbicides might rapidly reverse the lake's trophic progression (FG6).

Despite a desire for dramatic progress in the near term, stakeholders from several focus groups were cautious about unrealistic expectations. "No one thinks there's a silver bullet" (FG3); "Quick-fix solutions worry me" (FG4); "There needs to be education on anticipated timeframes for lake recovery" (FG6). The question of managing expectations revolves around balancing short-and long-term interests. One community member said, "we know we can't cure this with chemicals," but he also wondered "why is more not done in terms of dredging and herbicides?" (FG3). A scientist wary of dramatic in-lake measures expressed optimism about the possibility of "dialing back" the impacts of external nutrient loading to the point where the lake's North basin could be mesotrophic and the South basin could see reduced frequency, intensity, and duration of algal blooms and HABs.

Balancing Watershed and In-Lake Management. A central question revolved around whether it is better to devote resources toward: (a) managing on a watershed scale by reducing the influx of nutrients and sediment that accelerate the eutrophication process; or (b) managing the impacts of eutrophication in the lake itself by taking steps to reduce weeds, sediment, and algae that impede recreation and aesthetics in the near term. Although a focus on watershed measures is necessary to slow the rate of eutrophication, the timeframe for resulting improvements would be "generational." As one stakeholder from the Chautauqua Institution put it, "No one wants to pay taxes to see results in the next generation" (FG9). In general, watershed and in-lake issues are seen as a set of interrelated causes and symptoms, and some stakeholders expressed concern about proposed projects being too narrow in addressing just one issue or the other. As one Foundation member put it, "We are talking about 'the issue,' but when I look at it, what's the goal? Weed removal? Water quality? HABs? The lake is vital from an economic perspective. A holistic solution may be more important than a single polarizing topic" (FG8).

Community members shared insights about watershed and in-lake factors that affect Chautauqua Lake, and in some cases suggested steps that could be taken to address them:

- *Aquatic weed management* was considered by some to be indispensable to preserving the ongoing function of the lake as a regional resource. "Lake maintenance will always be an annual high-priority need" (FG5); "We need to focus on short-term weed management using all tools…and we need to optimize those tools" (FG6).

- *New or updated technologies* should be considered for in-lake management, drawing on sound research, options presented in the MMS, and successful case studies from similar lakes. As one stakeholder put it, "The MMS was meant to balance competing interests. A criteria should be whether project is consistent with recommendations in the MMS" (FG7).
- *Unintended consequences of aquatic herbicide use* was a concern for members of several focus groups, some of whom were wary of harming native plants or natural enemies of invasive species (FG2). Others worried about the possibility of herbicides turning Chautauqua into a cyanobacteria-dominated lake (FG4). "There's a public misconception that herbicides will take care of algal blooms" (FG7). "There are consequences to any management action, good and bad. One potential outcome is decreased macrophytes, increased algae" (FG4).
- *Development around the shoreline* is a concern, and code enforcement was seen as a potential area for improvement to ensure that development is carried out responsibly.
- *Shoreline management practices* present a question in terms of who is responsible for preventing or addressing issues. "Shoreline residents are creating their own problem with mowed lawns, lots of breakwall, no buffers" (FG4).
- *Shoreline maintenance* is important, several people mentioned, in terms of preserving lake aesthetics for residents and visitors.
- *Stormwater regulations* are an area for potential improvement to management. "We need uniform, enforceable stormwater regulations" (FG1).
- *Forestry practices* may have been underestimated as a source of nutrients entering the lake, according to participants in two focus groups.
- *Climate change* was discussed as a factor that is increasing the load of sediment due to stronger storms. "We're having more frequent intense storms with huge erosion. Just drive across bridges and creeks you can just see how it affects the lake" (FG2).
- *Agricultural best management practices (BMP*s) have been promoted by the Chautauqua County Soil & Water Conservation District (CCSWCD), which works with farmers to reduce agricultural sources of nutrients and sediment. While these efforts were acknowledged by a few participants, the scope and focus of these programs were not broadly understood. A few participants shared concerns regarding enforcement and monitoring of BMPs.

3.2.2 Human Health

A clear message from the vast majority of stakeholders was that human health is the number one priority for Chautauqua Lake communities. The high importance of addressing the threat posed by HABs was emphasized in numerous questionnaire responses and reiterated in focus group discussions. For some, concerns about human health risks related to HABs were just as relevant as those related to herbicide use in the lake, especially related to drinking water and swimming. In addition to being an overriding concern in and of itself, threats to human health were seen as having a cascading negative impact on the economic and cultural vitality of the region. "If human health is a

problem, then recreation is a problem" (FG3); "If recreation goes down the drain, Chautauqua Institution does, too" (FG9).

3.2.3 Cooperation and Collaboration

Interaction among Groups. There was widespread acknowledgement that coordination among Chautauqua Lake groups can be a challenge and that tensions have been elevated recently. As one local municipal leader put it, "Different groups don't agree." Some people feel that recent conflicts have served a purpose in terms of bringing issues to the forefront of public awareness. "It's important to be able to talk to each other… there are differing views" (FG4). "This 'stir' or debate that's been going on is moving things in the right direction, getting the conversation going" (FG9). However, the discord has been stressful for group members, some of whom described a sense of burnout or a reluctance to continue volunteering in what they see as a hostile environment. In addition, competition for resources is perceived as ultimately counterproductive in terms of solutions for the lake and the region. Foundation representatives explained that disjointed or competing requests for support have left funders reluctant to commit resources to projects that do not appear to be part of a coherent approach to protecting the lake. "There's no coordination among the groups asking for funding. We don't know what to do" (FG8).

Frustration, Fatigue, and a Question of Trust. Many stakeholders have been active volunteers and advocates for the lake and watershed for years. At the same time, there is a sense of frustration at a lack of progress and focused action. "There are lots of little projects, but no big stuff getting done" (FG1). "The public is tired of everyone saying they'll do something about the lake, but nothing ever happens. People are discouraged about studying but not fixing the problem" (FG1). Moreover, scientific uncertainty and differing opinions among local experts has fueled a sense of doubt among community members and concerns about the spread of misinformation. One participant in the Foundations focus group said, "It's two organizations framing the dialog on the lake. They've limited the issue." In the face of uncertainty and the sense that there is too little being done, a few people expressed the desire for a single authority to take charge of lake management. "Where's the adult in the room?" (FG8).

Improved Coordination. Despite these frustrations, most stakeholders saw a valuable social component of groups working together. Many participants emphasized the need for better communication as the key to building trust and improving collaboration across organizations (FG2, FG3, FG9). "There's an old quote: *Trust— you gain it in drops and you lose it in buckets.* There needs to be action! We need to create a dialog for those of us around the lake so if a person is upset, we can go to them and build trust" (FG3). "I want an entity that everyone is part of, that everyone would trust" (FG9). "If we reframe the goals, maybe we can learn how to stay in our lanes" (FG8). "We're all in the same boat, need to be rowing in the same direction" (FG1). "For anything to happen it has to be collaborative" (FG9). Participants cited examples of constructive steps taken by groups that are

effective in working collaboratively, such as reaching out and making overtures to cooperate, being transparent, and showing reciprocity in sharing information (FG5). Several people stressed the importance of holding regular meetings among organizations (FG2, FG7), but they acknowledged that it takes effort to make such meetings occur. "The Alliance is the best opportunity to continue that" (FG7).

3.2.4 Economic Concerns

Chautauqua Lake as an Economic Engine. Numerous stakeholders expressed the fear that Chautauqua Lake is at a tipping point that could be disastrous for the local economy. For businesses that are tied to tourism, there is a sense of urgent need to reverse the perceived decline and "keep the lake operational—people need to make a living in 4-5 months" (FG5). Public perception of the lake is also critically important for property values, as was highlighted by realtors in the Business/Tourism focus group. "There's tremendous concern among newcomers—'If I move here, what am I getting involved in?'" (FG3).

Lake Aesthetics, Safety, and the Bottom Line. Stakeholders expressed particular concern about odors that occur around the lake in late summer, which they generally attributed to the presence of decaying aquatic plants and algae. There were varying opinions about the extent to which this is a new problem, why it is happening, and its effect on tourism. There was less ambiguity about the impacts of HABs, which, when present, pose risks to those who swim in or drink water from the lake. "The most important thing is to keep Chautauqua Lake as 'Class A' drinking water" (FG5). The potential threat of HABs to the local economy was heavily emphasized by participants in the Business/Tourism focus group, as well as those affiliated with the Chautauqua Institution, "We must keep property owners paying taxes and buying homes because they don't want to move to a place where they might have to drink bottled water" (FG9).

Inequity and Scarcity. Several focus group participants mentioned the high property values and the resulting high proportion of taxes paid by lakeshore property owners, citing disparities in who derives the benefits of those expenditures. "Note that 1% of land in the county is on the shoreline, which represents 25% of property taxes" (FG3); "Not a dollar of the high taxes goes toward improvement of the lake. 28% of county property tax comes from shoreline residents, but none of it goes to the lake" (FG6); "26% of the county's wealth is associated with the lake, so without a healthy lake we have no economy" (FG2). Similar comparisons were drawn regarding the installation of sewers in some lakeside communities. "Building sewers was contentious. Very difficult and expensive" (FG8). Some stakeholders emphasized the fact that the county is among the poorest in New York, characterized by increasing poverty as one moves further from the lakeshore. A sense of unfairness was expressed by members of the Chautauqua Lake Association (CLA), which has managed lake vegetation for decades yet struggles to meet operating expenses even as the county's tax revenues have been higher as a result of this in-lake maintenance (FG5). The conflict over allocation of

resources and who derives benefits was dismissed by some as counterproductive. "Instead of fighting, grow the pie," one participant said, citing the need to draw additional state and federal funding. (FG1). One participant highlighted the challenges of this approach. "Government funding comes with strings attached, including cost sharing. Sometimes you can't come up with $130K to match a $1 million grant, so nothing happens" (FG2) (Note: Grant match requirements are typically 25 to 50% of total project costs, so the match needed for a hypothetical $1 million project would likely be greater than the value mentioned during the focus group.)

Return on investment. There were concerns about whether the investment in projects is commensurate with the resulting benefit. "Taxpayers want to know their money is being used for the benefit of the lake, so we need projects to be effective" (FG1). Demonstration of effectiveness is especially important given differing opinions about the underlying sources of lake impairment and their relative contributions, and whether some management techniques (e.g., weed harvesting, aquatic herbicides) might have unintended negative consequences.

3.2.5 Research and Monitoring

Community members repeatedly emphasized the need for improved understanding of factors affecting the lake's condition, despite impatience with multiple studies and not enough implementation in the past. The following suggestions for further study were raised by stakeholders who saw the need to "balance *doing* with *learning*":

- *Emerging issues,* such as HABs, require further study not only to understand and anticipate the extent of the problem but also to understand the potential impact of proposed solutions on the lake's ecology (e.g., impact of herbicides on algae). This topic is tied to the importance of adaptive management, as the major prior studies of the lake have not directly addressed HABs.
- *Nitrogen*, as well as phosphorus, should be considered as having an influence on lake ecology and impairments.
- *Internal sediment phosphorus loading* and its potential impact on the lake's phytoplankton abundance was estimated during the TMDL, but has not been confirmed. Detailed water column profiles and sediment analyses could provide a more accurate estimate of this flux and provide insight into the potential benefit of nutrient inactivation techniques.
- *Challenges of measuring BMP outcomes* were acknowledged by focus group participants, although it was suggested that it is possible to improve upon current methods. "It can be measured with a monitoring tool and P index. So, you could do better at measuring how much P is coming in" (FG2). It was suggested that quantifying BMP impacts would better enable agricultural managers to "take credit" for improvements and demonstrate success in terms of a return on investment (FG6). An important data gap is the lack of permanent stream flow gauges on the tributary streams.

- *Updated technology and additional studies* would improve the ability to prioritize future efforts in the watershed, several stakeholders pointed out. For example, LiDAR technology, in conjunction with subwatershed assessment and monitoring, will provide "better data, better estimates of land use" and ultimately to support decisions about conserving land that "gets biggest bang for the buck" (FG2). This approach is consistent with the practice of "Precision Conservation," discussed in Section 5.1.3.2. (Note: A LiDAR dataset was collected in 2017 for the Chautauqua Lake area and is now available through the New York State GIS Clearinghouse [2018].)
- *Objectivity* was a significant concern for some focus group members, who thought it advisable that the entity applying in-lake treatments be different from the entity measuring the effectiveness of that treatment.
- *Potential metrics for tracking improvements* were suggested, including the number of beach closures, water supply testing for cyanotoxins, mean/median home sales price, and tourism income (with bed tax and sales tax as surrogates).

3.2.6 Public Outreach and Education

Stakeholders expressed a need for enhanced outreach and education about the lake, and they shared suggestions for improving communication with the public in terms of coordination, messaging, audience, and format and delivery. Improved education and outreach were seen as steps that could improve transparency and an understanding of management efforts, as well as bringing about positive changes in human behavior to protect the lake.

Coordinated Outreach. Numerous organizations communicate with the public about Chautauqua Lake and its watershed, which can lead to fragmented information being distributed from different groups with varying focuses. The result, focus group participants explained, is that it is difficult for members of the public to get a clear sense of current issues and progress toward solutions. This point was stressed by members of the Business/Tourism focus group, who were especially attuned to this need because of their interactions with private landowners and government representatives. "There must be a gatekeeper who is facilitating a constant flow of information" (FG3). Several people saw a current lack of capacity and emphasized the need for additional resources to accomplish this goal. "Communication needs to be someone's job. It is not a volunteer role. Someone who helps groups communicate with each other and publish articles" (FG3); "This is a role the Alliance can play, but maybe we didn't invest enough to make it work" (FG3). One type of information specifically mentioned as a clear need was accurate and current data on the water quality status of the lake itself. "The Alliance needs to mature as a go-to place and holder of data" (FG8). Some people cited examples of excellent data management by other watershed organizations, including the Buffalo Niagara Waterkeeper (formerly known as Riverkeeper; it was noted that this organization has more than two dozen staff members).

Messaging. A major desired outcome of improved public outreach would be to reassure the community and seasonal visitors that there are things being done to protect and restore the lake. "Dashboard indicators" (FG8), or an overview of projects and progress, would help realtors respond to client questions about "what's being done" (FG3), and might enable those in the agricultural sector to claim some benefits of BMPs (e.g., reduced X amount of runoff; FG2). A centralized source of information about the lake could also help clarify topics about which there may be confusion, such as the history of lake management in the watershed or the role of regulatory agencies. Finally, stakeholders mentioned the importance of educating people in ways that might lead to changes in behavior that would benefit the lake.

Audience, Format, and Delivery. Outreach to newcomers and seasonal visitors was seen as a challenge, yet also as crucial to bringing about changes in human behavior (e.g., mowing and landscaping around lakeshore). Landscaping businesses and/or municipal public works personnel were seen as a potential target audience that presents an opportunity to encourage improved practices (e.g., local entities could be encouraged to engage in the NYSDEC Endorsed 4-hour Erosion and Sediment Control Training, or voluntary workshops on waterfront landscaping and lawn care best practices could be targeted at commercial providers in the area). Suggestions for information formats that should be initiated or expanded included more digital information (FG3), social media (FG2), and possibly Chautauqua Institution lectures, not only to reach seasonal visitors, but also scheduled during the off-season and designed to engage and inform year-round residents (FG3 and FG9).

4 Decision Support Tool: Multi-Criteria Analysis

A multi-criteria analysis tool was developed and applied to support the development of the *5-Year Implementation Strategy for the Management of Chautauqua Lake and Its Watershed*. The MCA tool embodies the important evaluation criteria established by the stakeholders themselves and will assist the Alliance and other stakeholders in the prioritization of project opportunities. The resource decisions necessary to evaluate the various project opportunities requires the analysis of multiple criteria. MCA is uniquely suited to facilitate the scoring or ranking of competing projects using multiple decision criteria to help guide the decision-making process (Hajkowicz and Collins 2007).

In the context of Chautauqua Lake and its watershed, MCA is designed to support sound decisions about whether to implement projects that may contribute to the goals of Chautauqua Lake guidance documents. Each project can be scored and compared with other competing projects using specific decision criteria that reflect current lake and watershed science, engineering, and technology concepts, as well as the values of the local community. This tool enables the Alliance and/or other stakeholders to evaluate the various tradeoffs inherent in prioritizing project opportunities.

Developing an MCA tool is a three-step process. The first step was to identify the decision criteria to be used to evaluate projects; criteria selected for inclusion in the Chautauqua Lake and Watershed MCA tool are described in Section 4.1. The second step was to assign weighting factors to the decision criteria incorporating stakeholder input and preferences (where appropriate); these weighting factors are outlined in Section 4.2. Finally, in step three, the MCA requires each criterion to be scored, as illustrated in Section 4.3.

4.1 Decision Criteria

Several sources of information were used to develop the decision criteria for the Chautauqua Lake MCA tool. Scientific metrics, such as a proposed project's expected reduction in nutrient loading, were identified based on understanding the functional relationships between lake and watershed conditions as referenced in the TMDL and WMP. These science-based lake management criteria were supplemented with criteria derived from priorities expressed by representatives of local stakeholder organizations. Additional criteria, such as implementation costs, were added to the decision tool to help the Alliance set priorities that reflect external and internal funding constraints.

Chautauqua Lake stakeholders clearly understand that a key component of the implementation strategy is a balance between watershed and in-lake management efforts. That is, the causes and the effects of eutrophication must be addressed to protect and restore the lake's designated uses in the long run. The need to evaluate watershed and in-lake management measures complicated the MCA tool, because some criteria apply to watershed and in-lake projects while others are specific to one or the other. To ensure both project types could be scored in an objective manner, the tool is

designed with general criteria common to both project types, as well as criteria that are specific to either watershed or in-lake projects.

4.1.1 General Criteria

Eight general criteria were developed to support the evaluation of both in-lake and watershed projects. The following is a list of those criteria, and the supporting rationale for their selection:

- **Plan to measure and report effectiveness.** Chautauqua Lake stakeholders (and the scientific community) recognize the importance of monitoring to improve the understanding of water quality conditions and the factors controlling these conditions, and to evaluate the effectiveness of applied remedial measures. An adaptive management approach requires an unbiased and accurate assessment of the effectiveness of control measures. Consequently, project scoring will incorporate the level of commitment to monitoring.
- **Consistency with existing plans and strategies, and/or consideration of emerging solutions.** An important aspect of the implementation strategy is to ensure that project options being evaluated are consistent with specific recommendations provided in the Chautauqua Lake guidance documents. Stakeholders also stressed the importance of considering newly emerging solutions that may hold promise (e.g., based on use or research in other lakes/watersheds) even if they were not identified in previous guidance documents.
- **Commitment to stakeholder collaboration.** Stakeholders widely acknowledged that coordination among the many Chautauqua Lake and watershed groups can be challenging. This criterion may incentivize collaboration and help funding organizations who, when faced with competing proposals, are reluctant to fund projects that do not appear to be part of a coherent approach to protecting the lake. It will also encourage groups to work together in constructive ways that build on each other's areas of expertise.
- **Outreach and education.** Stakeholders emphasized the importance of telling the public about improvements to lake health and the effectiveness of protection efforts, as well as educating people about behavior changes that could benefit the lake. This criterion will encourage managers to incorporate public outreach and education strategically as they plan projects.
- **Potential for leveraging available non-local funding.** This criterion was established to evaluate the alignment of proposed projects with current available funding opportunities (federal, state, or other).
- **Disclosure of costs (up front and any future maintenance).** In response to economic concerns raised by Chautauqua Lake stakeholders, this criterion was developed to evaluate projects based on how well the project's costs and assumptions are defined.
- **Magnitude of up-front project costs.** Overall project cost is another criterion to be considered in the evaluation of project options (i.e., more expensive projects may be more difficult to fund, but they may have a greater benefit to the lake than smaller scale projects).

- **Spatial scale of project.** This criterion assesses the scale of the proposed project. In a large lake and watershed such as Chautauqua, some projects may address a localized impairment or source. Projects that affect larger areas, or demonstrate a technology or practice with broader applicability, are scored higher. Spatial scale scoring values (discussed in Section 4.3) are defined differently for watershed and in-lake projects.

4.1.2 Criteria for Watershed Projects

In addition to the general criteria listed above, three criteria were developed specifically to support the evaluation of watershed projects. The following is a list of those additional criteria and the supporting rationale for their selection:

- **Reduction in nutrient loading.** This is clearly one of the most important factors affecting Chautauqua Lake water quality, including cyanobacterial blooms. This criterion will be scored based on the category of nonpoint source being addressed (e.g., streambanks, septic systems, stormwater runoff, forestry practices, and agricultural practices) and the magnitude of the source as estimated in the TMDL. The relative magnitude of the watershed sources are calculated on a lakewide basis (i.e., include both the northern and southern basins) after subtracting point sources and internal loading. Both surface water and groundwater transport of nutrients into the lake are included.
- **Reduction in sediment loading.** In addition to nutrient loading, sediment loading from the watershed (via direct runoff and/or tributaries) has an impact on Chautauqua Lake's water quality and aesthetics. Excess sediment loading can also impede recreational boater uses of the lake (e.g., limiting boat access in some areas due to shallow water depth). Sediments also carry in nutrients that may become available to the lake biota, including macrophytes. Therefore, scoring for this criterion is based on anticipated percent reductions in sediment loading. Guidance for evaluating and scoring with respect to this criterion can be found, for example, at the International Stormwater Best Management Practices Database (developed by the American Society of Civil Engineers, USEPA, and others).
- **Hydrologic resilience (consideration of climate change).** This criterion was included to evaluate whether potential watershed projects are designed to accommodate the effects of extreme hydrologic events resulting from a changing climate.

4.1.3 Criteria for In-lake Projects

In addition to the general criteria listed in Section 4.1.1, six criteria were developed to support the evaluation of in-lake project options. The following is a list of those additional criteria, and the supporting rationale for their selection:

- **Protective of human health.** As described in Section 3.2.2, almost every stakeholder indicated that human health is their number one priority. This criterion was included primarily

to evaluate and score chemical treatment alternatives, and as a way to differentiate these types of projects from nonchemical treatment project options. For guidance on how projects could be evaluated and scored with respect to this criterion, see (for example) USEPA's Integrated Risk Information System (IRIS), which provides non-cancer and cancer assessments for various chemicals, including many herbicides (listed under "A to Z QuickList of Chemicals").

- **Reduction of nutrients from lake ecosystem.** As with the watershed criteria, removing or suppressing the internal nutrient loading in Chautauqua Lake is one of the most important criteria related to improved water quality. Projects are scored based on the amount of anticipated nutrient reduction, removal, and/or inactivation. Nutrient removal by mechanical harvesting is estimated using a spreadsheet developed by Cayuga County Soil and Water Conservation District, with input from Racine-Johnson Aquatic Ecologists. The calculation files are available at the Alliance office. The mass of nutrients inactivated by a chemical treatment such as an alum application is a site-specific calculation based on area to be treated, dosage, and sediment geochemistry. These factors would be identified as part of an environmental impact analysis in accordance with New York State regulation and policy.
- **Protective of ecosystem health.** Similar to the human health criterion described above, this criterion was established to evaluate and score alternatives in terms of their anticipated impact on or toxicity to native Chautauqua Lake species (plants, mollusks, invertebrates, herbivorous insects, and fish). These data are available for registered pesticides. One source of guidance for evaluating and scoring projects with respect to this criterion is NYSDEC's *Recommendations Regarding the Use of Aquatic Herbicides in Fish-Bearing Waters of the State* (2015). For other proposed projects, such as dredging or nutrient inactivation, the potential impacts will be site-specific and would be identified through an environmental impact analysis in accordance with New York State regulation and policy.
- **Longevity of effectiveness.** This criterion was selected to evaluate the length of time that the project option is projected to be effective. Projects that are effective for a longer period of time are scored higher.
- **Management of invasive species.** This criterion was selected to address the ongoing challenges of controlling invasive species. Specifically, it will be used to evaluate whether a proposed project has an impact on invasive species. Higher scores would be assigned to initiatives that prevent, detect, or target new invasive species rather than species that are well-established with little prospect for eradication.
- **Enhancement of recreational uses.** Maintaining and improving recreational uses of the lake is a high priority for the community and is included as a criterion for in-lake remedial measures.

4.2 Weighting Factors

MCA requires assignment of a weighting factor to each of the criteria described in Section 4.1 to represent their importance the overall health of Chautauqua Lake and its watershed, as well as to the stakeholder community. The first step in assigning weighting factors was to group the various decision criteria into three categories: 1) Environmental; 2) Social; and 3) Economic. A predominant theme among stakeholders was the importance of managing the lake in ways that would protect human health, slow eutrophication, or improve the lake's economic and recreational value; therefore, *environmental* factors that would promote these goals were assigned greatest weight. Stakeholder concerns about *social* factors influencing public perceptions of the lake and the effectiveness of groups working to protect it were also an overarching theme, so these factors were assigned the second-highest weight. Project-specific economic factors were grouped together in a third category representing practical concerns for those seeking to maximize the impact of local *economic* resources devoted to lake management.

Each of the three criteria categories was assigned a weight by allocating a percentage that reflects the importance of each category (i.e., the highest weight is assigned to the most important category), and such that the sum of the three categories is 100%. The environmental category was assigned a weight of 50%, followed by social (30%), and economic (20%). The individual criteria within each category were then assigned a weight, which can range from zero to a maximum value equal to the weight assigned to that category. For example, the maximum weight that can be assigned to any criterion within the environmental category is 50. The same weight can be assigned to more than one criterion within each category (if desired), or each criterion can be given its own unique value. The weights assigned to criteria within each category do not need to sum to 100.[2]

Independent weighting factors were developed for the evaluation of watershed projects (by combining the general and watershed-specific criteria) and in-lake projects (by combining the general and in-lake-specific criteria). Tables 4-1 and 4-2 summarize the weights assigned to each of the various evaluation criteria for watershed projects and in-lake projects, respectively. Figure 4-1 offers an overview of criteria and weighting for all types of projects. The weighting factors are based on an initial assessment of the available information. The MCA tool can be used to evaluate how sensitive the scores of potential projects are to the weighting factors. Similarly, these weighting factors are adaptable to emerging issues and new information.

[2] It should be noted that there are no set rules for how to assign weights in an MCA. The specific values and the range of numbers used do not matter; all that matters is the relationship between the various numbers. For this application, the project team opted to apportion the three main categories (Environmental, Social, and Economic) as parts of a pie that sum to 100%. These percentages are only used only as a guide for how the individual criteria are then weighted (i.e., the maximum weight that can be assigned to any one criterion in each category cannot exceed the value assigned to the category as a whole). The individual criteria weights (i.e., the values in the last column of Tables 4-1 and 4-2) are the *only* weights that are used in the calculation of scores in the MCA. The last column in these tables clearly shows how the various criteria are weighted relative to one another.

Table 4-1
Summary of Weighting Factors for Watershed Projects

Category	Category Weight (%)	Criteria	Individual Criteria Weight
Environmental	50	Reduction in nutrient loading	50
		Plan to measure and report effectiveness	40
		Consistency with existing plans and strategies, and/or consideration of emerging solutions	40
		Reduction in sediment loading	30
		Hydrologic resilience	20
Social	30	Commitment to stakeholder collaboration	30
		Outreach and education	30
Economic	20	Potential for leveraging available non-local funding	20
		Disclosure of costs (up front and any future maintenance)	10
		Magnitude of up-front project costs	10
		Spatial scale of project	10

Table 4-2
Summary of Weighting Factors for In-lake Projects

Category	Category Weight (%)	Criteria	Individual Criteria Weight
Environmental	50	Protective of human health	50
		Reduction of nutrients from lake ecosystem	50
		Plan to measure and report effectiveness	40
		Consistency with existing plans and strategies, and/or consideration of emerging solutions	40
		Protective of ecosystem health	40
		Longevity of effectiveness	40
		Management of invasive species	30
Social	30	Enhancement of recreational uses	30
		Commitment to stakeholder collaboration	30
		Outreach and education	20
Economic	20	Potential for leveraging available non-local funding	20
		Disclosure of costs (up front and any future maintenance)	10
		Magnitude of up-front project costs	10
		Spatial scale of project	10

Figure 4-1
Overview of Criteria and Relative Weighting for All Project Types

Criteria Category	Watershed Projects	In-Lake Projects
Environmental	***Reduction in nutrient loading***	***Protective of human health***
	Plan to measure and report effectiveness	***Reduction of nutrients from lake ecosystem***
	Consistency with existing plans and strategies, and/or consideration of emerging solutions	Plan to measure and report effectiveness
	Reduction in sediment loading	Consistency with existing plans and strategies, and/or consideration of emerging solutions
	Hydrologic resilience	***Protective of ecosystem health***
		Longevity of effectiveness
		Management of invasive species
Social	Commitment to stakeholder collaboration	***Enhancement of recreational uses***
	Outreach and education	Commitment to stakeholder collaboration
		Outreach and education
Economic	Potential for leveraging available non-local funding	Potential for leveraging available non-local funding
	Disclosure of costs (up front and future maintenance)	Disclosure of costs (up front and future maintenance)
	Magnitude of up-front project costs	Magnitude of up-front project costs
	Spatial scale of project	Spatial scale of project

HIGHER WEIGHT

LOWER WEIGHT

NOTE: ***Bold italicized*** criteria are unique to the project type.

4.3 Scoring

MCA requires assignment of a score to each criterion to support the evaluation of project alternatives. For this Strategy, four scoring values were selected for each of the evaluation criteria described in Section 4.1 (0, 3, 6, and 9). Within each category, these values will serve as ratings (i.e., scores) for how well a certain project satisfies a particular criterion, with 0 being the lowest score and 9 being the highest score. Table 4-3 provides definitions of the scores assigned to each of the evaluation criteria.

Table 4-3
Definition of Scores Assigned to Evaluation Criteria

Criteria	Scoring Values
General Criteria	
Plan to measure and report effectiveness	**0**: No commitment to monitoring or communicating results of proposed action **3**: Monitoring by project applicant only **6**: Monitoring plan includes professionals not associated with project applicant (external) **9**: Commitment to external monitoring and assessment, and communication of findings
Consistency with existing plans and strategies, and/or consideration of emerging solutions	**0**: Proposed action inconsistent with existing plans or strategies **3**: Proposed action is not recommended in plans or strategies but is consistent with objectives **6**: Proposed action is recommended in an existing plan or strategy **9**: Proposed action is recommended as approvable for specific application in an existing plan or strategy, and/or has been demonstrated to hold promise as a newly emerging technology previously unidentified in guidance documents
Commitment to stakeholder collaboration	**0**: Only one organization involved **3**: Multiple organizations involved, specific roles undefined **6**: Multiple collaborators, with project role and inputs (e.g., staff time, equipment/materials) defined for each **9**: Multiple collaborators, with expected project outputs (e.g., outreach products, data/information, nutrient reduction actions) defined for each
Outreach and education	**0**: No outreach/education component **3**: Targeted to existing organization's subscribed audiences **6**: Conveys emerging knowledge regarding lake health to critical or broad audience **9**: Promotes behavioral change to critical or new audiences
Potential for leveraging available non-local funding	**0**: None **3**: Eligible for outside funds (up to 50%) to match local contribution **6**: Eligible for outside funds (50% to 75%) to match local contribution **9**: Eligible for outside funds (>75%) to match local contribution
Disclosure of costs (up front and any future maintenance)	**0**: Project costs and assumptions are not clearly defined **3**: There are substantial gaps in cost estimates and assumptions **6**: Most costs and assumptions are defined **9**: Costs and assumptions are fully defined

Criteria	Scoring Values
Magnitude of up-front project costs	**0**: Project costs not clearly defined **3**: Approximate cost greater than $1,000,000 **6**: Approximate cost between $100,000 and $1,000,000 **9**: Approximate cost less than $100,000
Watershed Project Criteria	
Reduction in nutrient loading	**0**: No impact on nutrient loading **3**: Plan addresses a source estimated to contribute <10% of total nonpoint source TP load per TMDL (septic, streambanks) **6**: Plan addresses a source estimated to contribute 10-25% of total nonpoint source TP load per TMDL (stormwater, forest practices) **9**: Plan addresses a source estimated to contribute >25% of total nonpoint source TP load per TMDL (agriculture)
Reduction in sediment loading	**0**: No impact on sediment load **3**: Plan or BMP has an anticipated sediment reduction efficiency of <20% **6**: Plan or BMP has an anticipated sediment reduction efficiency of 20-40% **9**: Plan or BMP has an anticipated sediment reduction efficiency of >40%
Hydrologic resilience	**0**: Designed for current conditions, no consideration of climate change **3**: Designed to accommodate 50-year hydrologic events **6**: Designed to accommodate 100-year hydrologic events **9**: Designed to accommodate greater than 100-year hydrologic events
Spatial scale of project	**0**: Unknown **3**: Small (e.g., localized scale such as individual land owners; <1,000 ft of stream segment) **6**: Medium (scale between localized and subwatershed scale) **9**: Large (e.g., subwatershed scale; >1 mile of stream segment)
In-lake Project Criteria	
Protective of human health	**0**: Probable toxic or carcinogenic effect **3**: Lack of scientific consensus regarding toxic or carcinogenic effect (weight of evidence points to low risk) **6**: Classified as "not likely" to be toxic or carcinogenic **9**: Scientific consensus of no harmful human health impacts
Reduction of nutrients from lake ecosystem	**0**: Does not remove nutrients from lake ecosystem **3**: Removes <25,000 pounds phosphorus **6**: Removes 25,000 – 50,000 pounds phosphorus **9**: Removes >50,000 pounds phosphorus
Protective of ecosystem health	**0**: High or moderate toxicity to native species (plants, mollusks, invertebrates, herbivorous insects, and fish) **3**: Slightly toxic to native species and/or classification as known or suspected endocrine disruptor **6**: Low toxicity to native species, no evidence of endocrine disruptor **9**: Classified as "practically non-toxic"

Criteria	Scoring Values
Longevity of effectiveness	**0**: Less than one recreational season **3**: One year (single recreational season) **6**: Two to five years **9**: More than five years
Management of invasive species	**0**: No impact on invasive species (IS) **3**: Target established IS (e.g., Eurasian watermilfoil, curly-leaf pondweed) **6**: Target new IS (e.g., Hydrilla, water chestnut) **9**: Prevention or early detection of new IS
Enhancement of recreational uses	**0**: No impact **3**: Affects <1 mile shoreline in the littoral zone, >50% in front of privately owned land **6**: Affects <1 mile shoreline in the littoral zone, >50% in front of land that is publicly owned or has deeded access **9**: Affects >1 mile shoreline in the littoral zone, >50% in front of land that is publicly owned or has deeded access
Spatial scale of project	**0**: Unknown **3**: Small (e.g., localized embayment or smaller [<1% of lake surface area]) **6**: Medium (1% –10% of lake surface area) **9**: Large (>10% of lake surface area)

4.4 Using the MCA Tool

The MCA tool is a customized Microsoft Excel spreadsheet that has been developed for the Alliance to use in setting priorities and working with partner organizations to evaluate project options for Chautauqua Lake and its watershed. This tool incorporates the initial weighting factors and scoring system described above and is set up in such a way that allows users to easily add or remove projects, score the various projects under consideration, and evaluate sensitivity of the results to assumptions regarding priorities and assigned weighting factors. The overall score for a project is calculated by multiplying the assigned weight and score for each criterion, and then summing those values for all criteria.

The tool has been constructed to facilitate the prioritization of very general projects as well as those that are more fully defined in terms of specific actions and expected outcomes. It currently includes a compendium of priority recommended actions culled from the WMP, the TMDL, and the MMS. These projects and their scores provided the project team with a range of projects to evaluate for inclusion in the *5-Year Implementation Strategy*. Projects to be evaluated by the MCA Tool have been organized into three tiers:

- *Tier 1* encompasses projects where many of the specific details are known (e.g., projects proposed to New York State as part of the Consolidated Funding Application [CFA] process).

- *Tier 2* encompasses more generic project types where specific project details are unknown and the number of assumptions are higher (e.g., the types of projects and recommendations described in the WMP, MMS, and other guidance documents).
- *Tier 3* was established to help local foundations evaluate funding requests from nonprofit organizations seeking general operational support and/or broadly defined efforts in the lake and watershed.

The three tiers are applied separately to watershed and in-lake project types. As such, there are six separate worksheets in the MCA tool for scoring watershed and in-lake project options within each of the three tiers:

- Watershed (Tier 1), Watershed (Tier 2), and Watershed (Tier 3)
- In-Lake (Tier 1), In-Lake (Tier 2), and In-Lake (Tier 3)

This organization of project opportunities into separate tiers allows for a more balanced evaluation of alternatives, because project definition declines and the underlying assumptions increase as reviewers move through the tiers. Also, because not all of the decision criteria described above will be applicable to each of the proposed projects in the different tiers, decision criteria in the MCA tool can be turned on or off as appropriate.

The tool will be housed at the Alliance who will facilitate its use by partners who are interested in applying it. In addition to prioritizing proposed projects and project types, the tool's criteria and scoring values may be quite valuable in helping groups conceive of new projects or plan proposals that include concrete steps for addressing community priorities and ensuring that project goals align with measurable expected outcomes.

5 5-Year Implementation Strategy

5.1 Resource Allocation

The Alliance is seeking guidance on the relative value of investing staff and/or community resources in two projects types—**watershed measures** to reduce the external loading of nutrients and sediment to Chautauqua Lake (*longer-term source controls*) and **in-lake measures** to help restore impaired uses, including managing aquatic vegetation and reducing internal nutrient loading (*shorter-term symptom management*). A third category, **monitoring,** is necessary to inform the adaptive management approach; that is, measure the effectiveness of remedial measures or interventions compared to baseline conditions.

The project team proposes the following principles to guide resource allocation over the next five years:

- **Watershed Allocations:** A sustained commitment to reducing watershed sources is necessary to protect Chautauqua Lake as a water supply and recreational asset for future generations.
- **In-Lake Allocations:** The current impairments to recreational uses must be addressed to protect the continued viability of the lake as an economic, social, and cultural asset.
- **Monitoring Allocations:** A meaningful proportion of the community's investment in the lake should be directed to monitoring and research to continually build the knowledge base about the sources and impacts of nutrient loadings, as well as the impact of completed projects on water quality indicators. Over time, this knowledge base can be used to refine the decision support tool.

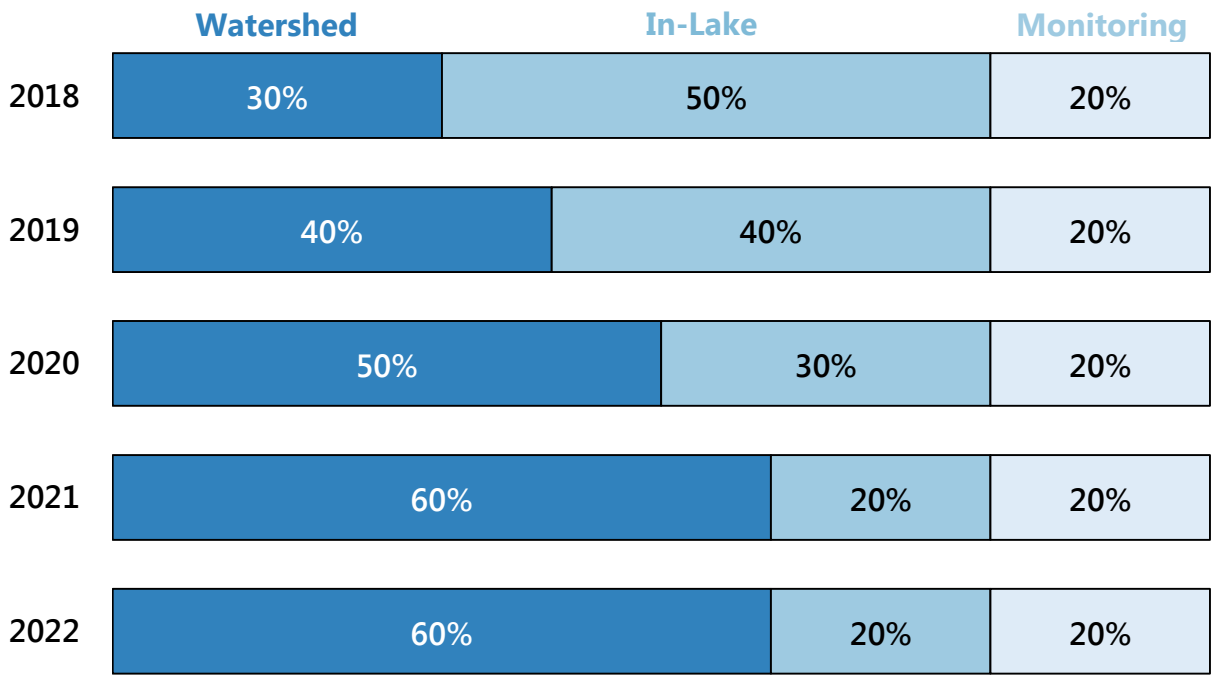
Using these principles, the recommended proportional allocation of resources from 2018 to 2022 varies (Figure 5-1). The allocation is structured as a proportion of available resources, since the total funding amount varies annually. The recommended allocations should be considered guidelines for the Alliance, since it is not possible to predict the multiple potential funding sources available to target specific issues on a year-to-year basis.

Given the importance of monitoring and research in guiding future decisions, 20% of resources should be directed to data collection and evaluation each year. Understanding the role of internal loading on HABs, for example, would guide decisions related to in-lake remedial measures. In a similar manner, stream monitoring and modeling can help identify specific areas and land uses that contribute disproportionate nutrients and sediment, and thus guide decisions regarding land-based remedial measures. In addition to investment in these research and monitoring programs, individual projects should incorporate measures to evaluate their effectiveness.

A larger proportion of resources is allocated toward in-lake projects at the beginning of the 5-year period, given the immediate need to address the current impairment to recreational uses, and based

on stakeholder input indicating a sense of urgency and the need to demonstrate a commitment to addressing in-lake issues. The in-lake projects have the potential to offer more immediate relief from excessive macrophyte growth, although this relief is typically short-lived. Ultimately, addressing the sources of impairment (i.e., excess nutrient loading) is the only sustainable approach to protect water quality, habitat, and human uses. Reduction in watershed sources is critically important to ensure the long-term health of the lake, which forms the basis for the increase in watershed resources over time. It is important to note that this recommendation should be revisited once the Action Plan for Chautauqua Lake is released as part of the governor's HAB initiative.

Figure 5-1
Resource Allocation, 2018-2022



5.1.1 Watershed

Reducing the external loading of nutrients to Chautauqua Lake is ultimately the only way to address the cultural (human-induced) eutrophication of the system and to minimize the frequency, magnitude, and duration of HABs. Although scientific uncertainties remain regarding the factors related to the recent widespread occurrences of HABs, three key elements include nutrient enrichment, warming waters, and invasive species, notably dreissenid mussels. Of these key elements, nutrient enrichment is most subject to local control. An ongoing commitment to reducing point and nonpoint sources of phosphorus and nitrogen is essential.

As estimated in the 2012 phosphorus TMDL, point sources account for approximately 20% of the external TP load to the lake. Moreover, wastewater phosphorus is associated with an elevated risk of algal and cyanobacterial blooms due to the high biological availability and seasonality of loading. Issues related to public sewers and onsite wastewater treatment systems (e.g., private septic systems) have been identified as critical implementation recommendations to improve the environmental health of Chautauqua Lake. Chautauqua County Sewer Agency is taking the lead on these efforts. Several plant upgrades have recently been completed or are underway, along with ongoing efforts to secure additional funding. Because these improvements are in process, the Alliance directed the project team to not include point source controls in the *5-Year Implementation Strategy*. The Strategy therefore focuses on efforts to reduce nonpoint sources from the watershed.

One challenge with implementing nonpoint source control projects is the requirement for active participation from the landowners. For **agricultural** lands, federal, state, and county agencies strive to build relationships through education, peer-to-peer networking, and financial incentives (cost sharing). Many watershed farmers have embarked on the Agricultural Environmental Management (AEM) program since completion of the WMP in 2010. AEM is a tiered program designed to identify and remediate potential sources of agricultural runoff by application of BMPs. With one or two exceptions, livestock farms in the Chautauqua Lake watershed are below the size threshold required to prepare a detailed nutrient management plan and file for a permit as a regulated Concentrated Animal Feeding Operation (CAFO). Therefore, the focus on voluntary compliance with BMPs is even more important in the absence of the regulatory permit process.

Recommended watershed measures to reduce agricultural runoff are tailored to specific conditions of soils, slopes, vegetative cover, management practices and infrastructure (e.g., manure storage capacity), weather, and many other factors. There is no single BMP that can effectively address every land parcel, animal husbandry operation, or cropping practice within the Chautauqua Lake watershed. Continued reliance on experts at the Soil and Water Conservation District, Natural Resources Conservation Service (NRCS), Chautauqua County Farm Bureau, and Cornell Cooperative Extension, among others, is essential for the Alliance as they evaluate funding support to various proposals. Directing resources at sources with the greatest fraction of biologically available nutrients will provide the most benefit to the lake.

However, there are data and information sources that can help in this assessment. NRCS's online *Field Office Technical Guide* is a compendium of the range in expected reductions in nitrogen, phosphorus, and sediment loss when various BMPs are installed (NRCS 2017). In addition, the New York State Soil and Water Conservation Committee (2014) has published an *Agricultural Best Management Practice Systems Catalogue* that describes BMPs applicable to the range of practices found in the state. Recent discussions at the regional HAB summits (March 2018) have focused on the efficacy of green cover crops, buffer areas along riparian (streamside) corridors, use of

site-specific decision tools to guide manure spreading, and constructed wetlands as means to mitigate agricultural nonpoint sources.

Permanent conservation of **forested areas** and **wetlands** can help to prevent erosion and nutrient/sediment loading in the watershed. Timber harvesting practices can in some cases contribute to nutrient/sediment loads (e.g., poorly planned or constructed skid trails); addressing this potential source will require active participation by local landowners.

Developed areas also contribute nutrients and sediment to Chautauqua Lake, so watershed municipalities play a critical role in ensuring that urbanization is carried out in ways that incorporate best land management practices and minimize stormwater runoff. While it is important to strike a balance between development and watershed needs, it should also be recognized that Chautauqua Lake's shoreline is 90% developed. Watershed municipalities are strongly encouraged to adopt, modify, and enforce local land use laws to guide actions by developers or private landowners in the watershed, and to adopt municipal BMPs in areas they manage directly.

Reduction factors for sediment and nutrient losses from these land-use categories are published in the compendia mentioned above, and case studies from across New York State are informative. The Alliance is well-positioned to provide leadership on these nonpoint source control issues; however, local capacity and ability to provide matching resources (funds or in-kind services) will continue to pose a challenge.

5.1.2 In-Lake

Examples of in-lake measures include macrophyte management, nutrient removal or inactivation, and dredging. The MMS provides a detailed review of **macrophyte management** techniques, such as mechanical harvesting and herbicide treatments; the MMS document applied a zoning approach to define regions of the lake's littoral zone based on environmental sensitivity and human uses. Macrophyte management techniques that are recommended, not recommended, and precluded from each zone are listed. This detailed zoning approach provides a sound foundation for the Alliance and others to identify alternatives designed to improve recreational access and human uses while protecting the lake's ecosystem. The MMS is not a regulatory document; similar to the WMP, it provides guidance based on scientific analysis and local input. As new macrophyte management techniques or herbicides are developed and approved, it will be important to update the MMS regarding their recommended use in the designated zones.

The NYSDEC required completion of a Supplemental Environmental Impact Statement (SEIS) prior to permitting an herbicide treatment program in Chautauqua Lake. In 2018, the Town of Ellery completed an SEIS as part of a permit application for applying aquatic herbicides in targeted areas of

the lake (Ellery Town Board 2018). The Final SEIS summarizes recent plant surveys and results of a pilot test of herbicide combinations on native and invasive species.

Nutrient inactivation can be an effective technique for reducing the release of sediment-bound phosphorus to the overlying water, which is defined as internal loading. Shallow lakes with a long history of elevated phosphorus loading from the watershed can exhibit significant internal loading that increases the risk of algal blooms, including HABs. The phosphorus TMDL estimated that internal loading contributes 55% of the annual phosphorus load to Chautauqua Lake's south basin and 25% to the north basin. Although the internal loading is an estimate, it is the single largest phosphorus source to the lake ecosystem.

This well-established lake management technique applies certain chemicals, such as aluminum sulfate (alum), sodium aluminate, or a combination, to the lake waters. The chemicals react with water and form an aluminum hydroxide floc that settles to the sediment and continues to sorb and bind phosphorus. An alum treatment program is not a permanent solution. The treatment can be effective for a decade or longer before the phosphorus binding sites are depleted. Other chemicals such as polyaluminum chloride, iron salts, and calcium have also been applied to lakes as nutrient inactivators.

Alum has been widely used in other states to mitigate internal phosphorus loading. However, NYSDEC has not approved its application to lakes for more than a decade. An interagency working group has been exploring regulatory pathways to enable nutrient inactivation. The recent governor's HAB initiative has highlighted the potential value of including nutrient inactivation among the tools for reducing the risk of cyanobacterial blooms (Kishbaugh 2018). Regulatory reviews and approvals have not yet been completed.

There are other lake restoration measures designed to mitigate internal phosphorus loading. One technique is to modify the depth at which water is released from a lake or impoundment so that the deep water (hypolimnion) enriched in soluble phosphorus from sediment flux is withdrawn. The morphometry of Chautauqua Lake may preclude this alternative, since the northern basin contains the deep water and the lake level control is at the southern basin. An engineering feasibility study would be required to fully evaluate hypolimnetic withdrawal.

A second technique for reducing internal sediment phosphorus load is hypolimnetic oxygenation, which adds sufficient oxygen to the deeper waters to prevent development of anoxic conditions at the sediment-water interface. In iron-rich systems, maintaining oxidizing conditions prevents the release of soluble phosphorus. Additional monitoring and sediment testing would be required to quantify the oxygen demand needed to prevent development of reducing conditions at the sediment water interface as well as quantify the sediment geochemistry.

Removal of sediments by **dredging** has also been evaluated. The Town of Ellicott was awarded a Local Waterfront Revitalization Program grant for a Dredging Feasibility Study of Chautauqua Lake. The feasibility study (EcoLogic 2013) examined the costs, potential benefits, environmental considerations, and permitting issues associated with removing sediment from nearshore areas of Chautauqua Lake as a means to restore impaired navigational and recreational uses. The report concluded that dredging is costly and funding is scarce. Five nearshore priority areas, where sediment deposition threatens recreational uses, were identified. Sediment samples from the priority areas were tested for physical and chemical characteristics. An engineer's opinion of cost (i.e., planning-level estimate) to remove 126,000 cubic yards of deposited sediment from the nearshore priority areas was approximately $10 million. For reference, the removal of that volume of sediment would be analogous to dredging 1 foot of sediment from about 80 acres of the 13,000-acre lake.

Stakeholders have recently suggested dredging in an effort to reduce internal phosphorus loading by removing decomposing organic matter, primarily macrophyte biomass. There are significant data gaps associated with evaluating the potential efficacy of this project: confirmation of the contribution of internal loading to the lake's phosphorus budget; analysis of phosphorus content through the sediment profile to ascertain whether newly-exposed sediments would be lower in phosphorus content; impacts on benthic organisms; and the costs of dredging, dewatering, and ultimate disposal.

Two issues complicate efforts to implement a large-scale dredging effort in Chautauqua Lake. The first issue is arsenic levels in the sediments. NYSDEC has issued guidance for management of sediment and dredged materials; sediments are classified as A, B, or C using a suite of indicator chemical parameters (NYSDEC 2004). Two investigations indicate that the arsenic content of lake sediments are likely to exceed the Class A (uncontaminated) threshold of 14 µg/g. Researchers from SUNY Fredonia sampled 98 locations throughout the lake in 1972 and reported an average arsenic concentration of 22.1 µg/g (Hopke et al. 1976). In 2012, sediments from five nearshore areas identified as priorities for dredging were tested as part of the Dredging Feasibility Study (EcoLogic 2013). Sediments collected from four of the nearshore areas contained arsenic levels within the Class A limits. However, arsenic levels in the sample from the Celoron and Burtis Bay area was reported at 23 µg/g, which is over the Class A threshold. The elevated arsenic levels, a legacy of past herbicide treatment, do not preclude dredging, but they greatly increase the costs. Sediment removed from the lake would require special handling, and would likely be sent to the Chautauqua County Landfill for disposal or use as cover material. Sediment pore water would require advanced treatment prior to its return to the lake.

The second issue is the lack of a suitable large site close to the lake that could serve as a centralized sediment management facility. Because the shoreline is highly developed, sediment dewatering would have to occur at various smaller sites proximate to dredged areas.

5.1.3 Research and Monitoring

Despite the years of analysis and monitoring of Chautauqua Lake and its watershed, significant data and information gaps remain that affect the community's collective ability to support specific projects with confidence. Some gaps are endemic to the challenge of addressing the recent cyanobacterial blooms; regional and national experts concede that the reasons for the surge in HABs are complex and not completely understood. Other gaps relate to the lack of baseline data, which are critical for evaluating trends and patterns across time and space and lake and watershed responses to management decisions and/or BMPs. Sampling plans need to reflect the myriad spatial and temporal heterogeneities that exist in the lake. No single dataset or value can ever truly represent the "health" or "condition" of the entire lake or watershed; as with any complex system, uncertainty can be reduced but not eliminated.

However, resources for data collection should prioritize data or information gaps deemed most critical for managing Chautauqua Lake. This can be achieved through the collaborative development of a comprehensive sampling and analysis plan that seeks to reduce redundancy, capitalize on existing data and information, and focus resources on the most important gaps related to management decisions. Moreover, a well-developed data analysis and interpretation plan can keep data collection focused on specific objectives and support the process of turning data into information, and ultimately to strategic information to support management decisions.

Several important data gaps have been referenced in this implementation strategy. For watershed projects, understanding the specific locations and practices associated with elevated nutrient export is essential for setting priorities for remedial actions. In addition, the effectiveness of management practices that have been implemented needs to be quantified. For in-lake projects, understanding internal phosphorus loading, from both aerobic and anaerobic sediments, is essential. In addition, data on wind-driven currents and turbulence could help to provide a better understanding of herbicide dispersal and transport.

As introduced in Section 2.4 (Ecosystem-Based Management), adaptive management requires a commitment to monitoring and assessment. Technological advances, such as buoys with multiparameter probes and sensors, and partnerships among universities and state and federal agencies have expanded local capabilities to understand and document watershed and lake dynamics.

The *5-Year Implementation Strategy* includes monitoring to establish a baseline and provide a foundation for the Alliance partners to agree on priority projects. Two important projects are outlined in the next sections.

5.1.3.1 Internal Loading

The TMDL estimate of internal phosphorus loading from sediments must be confirmed and updated through additional water column monitoring and chemical analysis of the sediments in order to fully assess the potential impact of nutrient inactivation or hypolimnetic oxygenation.

Detailed monitoring of phosphorus profiles (concentrations measured at multiple depths through the water column) in the northern and southern basins is necessary to document the areal extent, timing, and magnitude of phosphorus release from the sediments. Some limited water quality profile monitoring was conducted in 2007 by Princeton Hydro (Princeton Hydro 2007) and again in 2014 by Jeffrey Owen from the Department of Environmental Science at Hankuk University of Foreign Studies. These investigations demonstrated that internal phosphorus release occurs at some deep locations in Chautauqua Lake. Phosphorus release from sediments in shallower regions of the lake that do not undergo stable thermal stratification has not been quantified. Sediment resuspension from boating, winds, and waves affects many shoreline areas around the lake; the impact on the lake's nutrient budget is not quantified.

In addition to detailed phosphorus testing of the lake's water column, chemical analysis of the lake sediments is needed to inform decisions regarding nutrient inactivation and oxygenation. Geochemical testing of the various sediment phosphorus pools (e.g., labile, iron-bound, aluminum-bound, and refractory) is necessary to calculate the appropriate application rate of nutrient inactivants and to estimate the potential impact of adding oxygen to the deep waters.

5.1.3.2 Subwatershed Prioritization

Since completion of the WMP in 2010, there have been advances in watershed modeling tools that enable estimates of discharge and flux of nutrients based on soils, slopes, land use/land cover, and practices such as manure management and crop rotation. Ultimately, a model such as the Soil & Water Assessment Tool (SWAT) developed by the U.S. Department of Agriculture and Texas A&M University could provide valuable insights into directing resources for nonpoint source control measures to priority subwatersheds. Monitoring data are required to calibrate and verify a model.

This task can be approached in a step-wise manner. The first step is to compile and review all monitoring data that have been collected within the watershed. The second step is to obtain recent GIS files for land use, topography, impervious surfaces, and slopes for each subwatershed to Chautauqua Lake. These two steps will enable the project partners to identify geographical areas or land-use categories for which data are lacking. A focused monitoring program can be designed based on this analysis.

Water quality monitoring of key tributary streams can be implemented in an efficient manner by focusing on runoff events, particularly in the spring. The use of automated samplers and a state-certified analytical laboratory are recommended.

The outcome of an integrated monitoring and modeling program would assist the Alliance and its member organizations to define priority actions to reduce watershed nonpoint source pollution. The tool, after calibration and verification with local data, can be used to run management scenarios for various practices in the watershed to identify specific regions and practices contributing a disproportionate load of nutrients or sediment to the lake. Moreover, the model can be used to forecast changes in a future climate.

In addition, technologies and methods related to "Precision Conservation" can be used in conjunction with models like SWAT to "create a more detailed representation of where nutrients and sediment are flowing off the land" (Allenby and Burke 2012). Precision conservation modeling has been carried out in the Chesapeake watershed using the Chesapeake Conservancy's USEPA-funded methodology, and is a potential tool for prioritizing sites for BMPs and conservation of watershed features such as collecting, storing, filtering, and delivering clean waters to Chautauqua Lake. A LiDAR dataset is now available for the Chautauqua Lake area (NYSGIS Clearinghouse 2018), and this information could be used by Alliance members in combination with land-use GIS to identify parcels for conservation based on hydrologic/hydraulic characteristics. This approach to source water protection will ultimately control the flux of nutrients and other potential sources of contamination to the lake ecosystem. Such methods facilitate a targeted approach to conservation of parcels on which management and restoration efforts are likely to have the greatest beneficial impact, making the most of limited financial resources.

5.2 Prioritizing Specific Projects

The project team applied the MCA tool to identify priority projects for the Alliance to focus on during the next five years, from 2018 to 2022. Both watershed and in-lake measures were ranked. In addition, strategic research and monitoring efforts were identified, including development of a watershed model such as SWAT. Table 5-1 summarizes the prioritization exercise; additional explanation is presented in this section.

To select among watershed-related projects, the team used an updated list of priority recommendations from the WMP to define the options. The WMP recommendations are for generic project types, that is, not referenced to a specific location. Consequently, the potential projects were scored and ranked using the Watershed-Tier 2 criteria and weighting factors. The outcome of applying the decision tool was that projects addressing agricultural nonpoint sources ranked highest; this is consistent with the TMDL modeling that concluded that agricultural sources—entering the lake via surface runoff and groundwater seepage—represent the largest external phosphorus load to the lake. The highest project scores were calculated for buffer areas, cover crops, and contour strip cropping practices. Other priorities are projects addressing stormwater runoff from developed areas.

Table 5-1
Project Priorities, 2018–2022

Year	Watershed	In-Lake
2018	Agricultural BMPs: buffers, cover crops, contour strip-cropping (depending on land owner participation) Green infrastructure for stormwater management Municipal code enforcement Watershed pollution prevention education ***Data compilation and land-use files (such as LiDAR and subsequent analysis) for subwatersheds to prepare for modeling***	Mechanical harvesting Enhanced shoreline cleanup Herbicide treatment (per MMS) ***Detailed monitoring to assess internal phosphorus load*** ***Sediment geochemical testing***
2019	Agricultural BMPs: buffers, cover crops, contour strip-cropping (depending on land owner participation) Municipal stormwater Forestry practice inventory Watershed pollution prevention education ***Stream monitoring*** ***SWAT model (or similar)***	Mechanical harvesting Enhanced shoreline cleanup Herbicide treatment (per MMS) ***Detailed monitoring to support EIS and permitting for nutrient inactivation program or hypolimnetic oxygenation, if warranted based on 2018 results***
2020	BMPs as guided by watershed model projections ***Stream monitoring: before and after BMPs***	Mechanical harvesting Enhanced shoreline cleanup Herbicide treatment (per MMS) ***Effectiveness of nutrient inactivation (if implemented)***
2021	BMPs as guided by watershed model projections ***Stream monitoring: before and after BMPs***	Mechanical harvesting Enhanced shoreline cleanup Herbicide treatment (per MMS) ***Effectiveness of nutrient inactivation (if implemented)***
2022	BMPs as guided by watershed model projections ***Stream monitoring: before and after BMPs***	Mechanical harvesting Enhanced shoreline cleanup Herbicide treatment (per MMS) ***Effectiveness of nutrient inactivation (if implemented)***

Key: ***Research and monitoring*** measures indicated in bold italics.

In a similar manner, in-lake measures were culled from two sources—project proposals under consideration by Alliance members and the guiding documents, primarily the MMS. These in-lake projects were evaluated and scored as Tier 2 proposals, reflecting the level of available detail. This analysis revealed that nutrient inactivation to control internal phosphorus loading was the highest priority, followed by mechanical harvesting and herbicide treatment in accordance with the MMS.

During the 5-year planning horizon, a focused effort is needed to define the specific practices and regions of the watershed where investments in agricultural BMPs are most needed. This will require investment in monitoring and development of predictive tools, as well as continued outreach and education to enlist willing landowners.

Because of the complexity of grant funding processes, the Alliance members and staff will need to continue to be adaptable and envision work programs on a multi-year planning horizon. This is particularly significant with respect to one of the Alliance's core missions: seek outside funds for lake and watershed projects. For NYS funds, the CFA process opens each year in early May, with applications due in late July. Eligibility requirements and priorities vary from year to year, as do funding levels. The short window to develop a proposal that aligns with the state's annual priorities, documents the commitment of local stakeholders, and commits the required local match is challenging.

Awards are announced in the fall. Depending on the involved agencies, finalizing the state assistance contract and developing the detailed workplan may extend over a 9- to 12-month period. As a result, it can be a year or more before work can begin on a priority project supported by outside funds. The *5-Year Implementation Strategy* therefore must account for multiple projects at different stages of development.

5.3 Adaptive Management

Due to of the dynamic nature of the lake and watershed, coupled with changes in funding opportunities, emerging technologies, and shifts in regulatory acceptance of remedial measures, the list of priority projects will certainly change over time. Knowledge gained from monitoring will also provide insights to support modifying the priority measures. Finally, both individual landowners and municipal leaders may become more willing to participate with programs as education and outreach efforts grow in impact.

For all these reasons and more, the concept of adaptive management must remain a guiding principle during the 2018 through 2022 planning horizon. The Alliance should revisit the Strategy each year, with a focus on discussing what works well and what does not and provide information for reviewing priorities. The MMS recommended an annual roundtable early each year, where the various agencies and organizations interested in lake and watershed management convene to

discuss their plans, identify opportunities for collaboration, and establish data-sharing protocols. While this recommendation was developed in the context of macrophyte management, the annual roundtable discussion can be expanded to incorporate watershed measures, in lake measures, and monitoring for effectiveness.

5.4 General Recommendations for the Alliance

5.4.1 Align Grant Proposal Requirements with the Criteria Used in the MCA

The MCA tool includes criteria based on lake and watershed management principles supplemented by findings of the community outreach effort undertaken for this project. However, the grant proposals that come before local funders do not typically address these criteria, nor are they structured to provide sufficient information for others to fully score them based on the prioritization tool. Adapting the local funding request templates to incorporate specific criteria included in the prioritization tool can raise awareness of the desired outcomes of projects and may also create an incentive for organizations to collaborate. Applicants' awareness of the criteria and scoring values that will be used to evaluate their proposals could potentially elevate the quality of proposals received, as proposers will have a clear incentive to address community priorities and ensure that project goals align with measurable expected outcomes. Since the tool can be used to compare proposed projects to each other, foundations may want to consider synchronizing their schedules for soliciting/reviewing applications related to lake and watershed projects.

5.4.2 Staffing

The Alliance is staffed by two professionals who bring essential skills and knowledge in the areas of financial management, organizational development, community stakeholder engagement, project management, and water resources science and engineering. As funding becomes available to implement projects on Chautauqua Lake, additional resources may be necessary to capitalize on the opportunities. For example, administrative support will likely be needed to coordinate multiple projects and ensure record-keeping meets all requirements. Communication and outreach is another important responsibility that will continue to expand. The challenge of effective nonpoint source management is to engage with the individuals engaged in land management decisions. A continued commitment to community engagement is necessary for long-term success.

5.4.3 Role of Scientific Advisors

Some of the criteria and weighting factors included in the decision tool require familiarity with the technical literature regarding lake and watershed management techniques and case studies of their effectiveness. The Alliance is structured to include a scientific advisory committee with expertise in various fields. The committee can collectively serve as a valuable resource to the Alliance in prioritizing projects and developing an annual workplan.

6 References

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Appendix A
Founding Members, Chautauqua Lake & Watershed Management Alliance

FOUNDING MEMBERS, CHAUTAUQUA LAKE & WATERSHED MANAGEMENT ALLIANCE[3]

Municipalities

County of Chautauqua
Towns of Busti, Chautauqua, Ellery, Ellicott, and North Harmony
Villages of Bemus Point, Celoron, Lakewood, and Mayville

Utilities

Chautauqua Utility District
Jamestown Board of Public Utilities
North Chautauqua Lake Sewer District
South & Center Chautauqua Lake Sewer District

Business and Tourism Groups

Chautauqua–Cattaraugus Board of Realtors
Chautauqua County Chamber of Commerce
Chautauqua County Visitors Bureau
Chautauqua Property Owners Association
Mayville–Chautauqua Community Chamber of Commerce

Nonprofit Organizations

Chautauqua Institution
Chautauqua Lake Association
Chautauqua Lake Fishing Association
Chautauqua Lake Partnership
Chautauqua Watershed Conservancy
Jamestown Audubon Society (now, Audubon Community Nature Center)
Roger Tory Peterson Institute

Agriculture and Parks

Chautauqua County Soil & Water Conservation District
NYS Office of Parks, Recreation and Historic Preservation–Allegany Region

Foundations

Cummins Foundation
Holmberg Foundation
Lenna Foundation

[3] In 2017–18, there are 27 members in the Chautauqua Lake & Watershed Management Alliance.

Appendix B
Questionnaire for Stakeholders, Chautauqua Lake & Watershed Management Alliance

Chautauqua Lake & Watershed Management Alliance
Questionnaire for Stakeholders

Background

The Chautauqua Lake & Watershed Management Alliance (Alliance) has engaged a team of environmental scientists and engineers from EcoLogic and Anchor QEA (the Eco/AQ team) to develop a **5-Year Implementation Strategy for the Management of Chautauqua Lake and Its Watershed (Strategy)**. The Strategy will incorporate the priorities of the many interested parties and involved agencies (stakeholders) within the Chautauqua Lake watershed. The Eco/AQ team will host a series of focus groups in late January/early February 2018 to get input from stakeholders regarding their vision for a well-managed lake and watershed. Participants in these focus groups will discuss environmental, social, fiscal, and other factors that will be used to rank and prioritize alternatives for watershed and in-lake measures. This questionnaire is being distributed in advance of the focus groups so that participants can consider questions and discuss them with colleagues in advance.

How Input Will Inform the Strategy

Your input will ensure that the Strategy incorporates the insights and priorities of organizations directly involved with Chautauqua Lake and its watershed as part of a comprehensive, science-based implementation strategy. Specific responses to the questionnaire will not be published as part of the Strategy.

Submission and Deadline

We encourage you to submit responses by **Wednesday, January 24, 2018** (and we will continue to accept responses until February 15, 2018). Save the completed (electronic) document with a new name and email it to Elizabeth Myers, EcoLogic LLC: emyers@ecologicllc.com. (Alternatively, you can print the questionnaire and submit a paper response to EcoLogic LLC, 9 Albany St., Suite 3J, Cazenovia, NY 13035.) Your organization may choose to complete a single questionnaire, or you are welcome to distribute copies internally to your individual membership for them to complete on their own. There is no limit on the number of completed questionnaires each organization and its individual members can submit.

Part I: Lake and Watershed Management

1. Alliance Members and Roles

1a. I am a member of (place an X next to all that apply):

- ☐ Chautauqua Lake & Watershed Management Alliance
- ☐ Chautauqua Lake Association
- ☐ Chautauqua Lake Partnership
- ☐ Chautauqua Watershed Conservancy
- ☐ Local Foundation involved in this region
- ☐ Water resources management agency (including NYSDEC)
- ☐ Agricultural support/management agency (including Soil & Water Conservation District)
- ☐ College or university engaged in lake and watershed management issues
- ☐ Business community
- ☐ Local government (indicate Town, Village, County, or municipality name: _____)
- ☐ Other, please note: _____

1b. What stakeholder group(s) does your organization represent (e.g., shoreline property owners, business owners, researchers, agricultural producers)?

1c: Does your role in these stakeholder group(s) include ACTIVE PARTICIPATION in Lake and/or Watershed Management?

☐ **Yes**

☐ **No** — ***If you respond "No" to Question 1c, please skip to Question 5.***

2. Use of Existing Plans and Strategies

Chautauqua Lake Documents	**2a. Are you familiar with it?**	**2b. What aspects do you find helpful?**	**2c. Does your organization play a role in implementing recommendations? If so, how?**
Watershed Management Plan	Y/N		
Macrophyte Management Strategy	Y/N		
Phosphorus Total Maximum Daily Load (TMDL) Implementation Plan	Y/N		

3. Priorities and Projects

3a. What types of projects does your organization support or implement?

3b. With whom do you partner?

3c. How does your organization set priorities for choosing projects or allocating resources? (what criteria are used?)

3d. If there are competing projects that cannot all be undertaken, how do you weigh costs and benefits?

3e. If unlimited funding were available to manage Chautauqua Lake and watershed how would your program change?

4. Evaluation

4a. How do you measure the effectiveness of your organization's actions with respect to Chautauqua Lake?

4b. What impediments does your organization face in accomplishing its goals with respect to Chautauqua Lake?

4c. What would make the 5-year Implementation Strategy a success to your organization or peers?

5. Stakeholder Concerns

5a. How important are these issues to you or your organization's stakeholders?

Issue	Not important	Slightly important	Moderately important	Very important	Extremely important	Don't know
Overall water quality						
Lake aesthetics						
Boating recreation						
Swimming recreation						
Tourism						
Lake shore property values						
Ecosystem health						
Fish community health						
Rare/threatened/ endangered species						
Human health						

5b. Are there other lake-related issues not mentioned above that are especially important to you or your stakeholders? If so, please explain:

Part II: Criteria for Ranking

The following list includes potential factors that may be considered when deciding whether to implement a management action in the lake or the watershed. Please indicate how important each factor is to you and/or your organization in setting priorities.

Issue	Not important	Slightly important	Moderately important	Very important	Extremely important
Longevity of effectiveness (short-term vs. long-term)					
Scientific consensus of risk to human health					
Scientific consensus of risk to ecosystem health					
Cost-to-benefit Ratio					
Scale of the projected improvement (lake-wide vs. localized)					
Regulatory acceptance/feasibility of permitting					
Impact on fish community					
Impact on cyanobacterial and/or Harmful Algal Blooms (HABs)					
Impact on recreational access					
Impact on sediment loading to the lake					

Part III: Contact Information

Would you like to discuss your ideas in more detail? If so, please let us know how to reach you:

Name: _____
Phone: _____
Email: _____
Address: _____

Thank you for participating!