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Cleaning Up Elk and Beaver Lakes: What Can be Learned from Other Lakes

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Prepared for the Victoria Golden Rods and Reels

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I. Purpose

Water quality in Elk and Beaver Lakes has been seriously declining since at least the early 1980s. These lakes are enormously important to Victorians, with close to two million visitors to the regional park in a given year. The lakes have traditionally been very popular with recreational users for fishing, swimming, and rowing.

The lakes' water quality has now become unacceptable. Elevated levels of nutrients such as phosphorus are causing a variety of problems. Blooms of potentially toxic cyanobacteria have become increasingly frequent. The Capital Regional District has posted signs for people and dogs to avoid the water during blooms. For the past two years, authorities have moved the Polar Bear swim to Thetis Lake because of the algae risk at Elk Lake. Excessive nutrients also exacerbate dense growth of aquatic weeds – which is problematic for rowers and anglers and dangerous for swimmers. Fishing success has declined in recent years, and invasive species such as bullfrogs and exotic fish have occupied the lakes.

The two largest external sources of nutrients are septic tanks and agricultural runoff coming from surrounding creeks. However, the main source of the nutrients is now internal, coming from sediment located at the bottom of the lake. Such nutrient-related problems are not unique – eutrophication is occurring in many southern Vancouver Island/Salt Spring Island lakes. Efforts are now underway to identify a process to deal with Elk and Beaver Lakes' water quality. Concerned conservation groups are considering solutions such as measures to:

- Reduce nutrients into lake, by:
    - Controlling stormwater runoff; and
    - Controlling septic runoffs through better regulation and monitoring of septic fields;
- Implement a 20-year-old Park Management Plan that called for aeration of the lakes, and other measures to improve water quality; and
- Treat the lake by adding alum or other materials, and other measures.

However, an overall plan to implement solutions has not yet been developed, since jurisdiction over the lakes is extremely fragmented. For example, Vancouver Island Health Authority has jurisdiction over human health and water testing issues; the District of Saanich has authority over land use/sewer/stormwater issues; the Capital Regional District has jurisdiction over septic tank inspections and implementation of the park management plan; the Province has jurisdiction over many water, fisheries and dam issues; and the federal government has jurisdiction over boating regulations and salmon fisheries issues in the watershed.

This paper intends to describe solutions from other jurisdictions to inform a fulsome study into a long-term management plan for Elk and Beaver Lakes.

II. Introduction

Every lake is unique. Specific strategies to address a lake's nutrient enrichment problems must focus on activities in the watershed and, if needed, in-lake restoration techniques. Long-term management considers the environmental, cultural, and biological factors affecting the lake and sets a priority on finding lasting solutions. Lake management is complicated and requires a coordinated effort of community groups, individuals, landowners, and government – and must involve scientific experts. To be effective, lake managers must commit to long-term strategies and investment.

There is a direct relationship between the amount of phosphorus in a lake and the amount of algae growing in the lake: as phosphorus levels increase, the amount of algae increases too. “Algal blooms,” which are rapid increases or accumulations in the population of algae in a water system, may result. The increased nutrient levels result in the state of “eutrophication.”[1] This increased nutrient load and subsequent increase in algae results in a depletion of oxygen. Once a lake reaches very high levels of phosphorus, other nutrients may limit the growth of algae. However, long-term management of excessive algae requires the removal of phosphorus sources to the water body as well. This is referred to as “**input management.**”

However, for the best chances of success, a combination of efforts to control nutrient sources through input management as well as **in-lake restoration techniques** is required – and there are a number of options available.

In determining how to approach cleaning up Elk and Beaver Lakes, it is useful to investigate some case studies of other lakes that have successfully dealt with or have been dealing with similar problems – and glean from those some best practices in lake restoration.

This report investigates the following four main topics and includes other lakes as case studies under each topic heading:

1) Technical Solution → what was used to deal with the elevated nutrient level in the water body?
2) Input Management → What efforts were made to deal with septic/agricultural runoff or sewage?
3) Involvement → who was involved in making the cleanup happen? How were multi-jurisdictional and multi-stakeholder issues handled?
4) Public education → Was the community mobilized to participate?

[1] Eutrophication is the ecosystem's response to the addition of artificial or natural substances, mainly phosphates, to an aquatic system One example is the "bloom" or great increase of phytoplankton in a water body as a response to increased levels of nutrients.

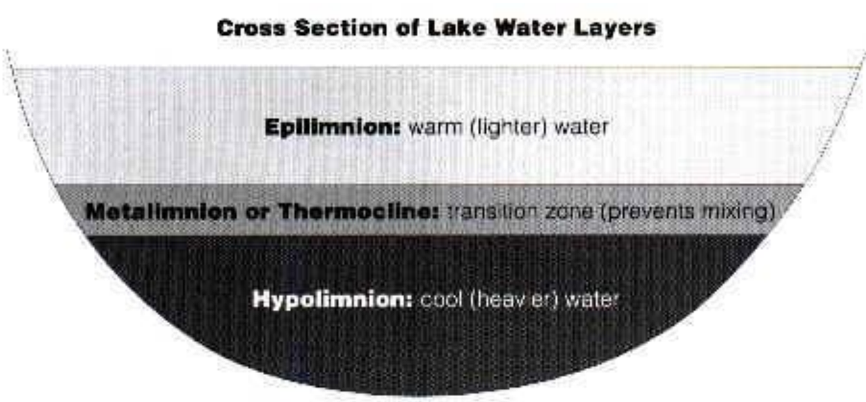
III. Case Studies

1. Technical Solutions: Aeration, Dredging, Alum

As mentioned, in many cases, it is not possible to immediately improve lake water quality by input management (controlling the nutrient sources of phosphorus). Frequently, many years will pass before a lake cleanses itself of accumulated nutrient loads, even with the application of the best input management practices. For this reason, in-lake restoration techniques have been developed to accelerate the recovery of lakes suffering from eutrophication. The suitability of each technique to the lake in question will vary, and each technique may not work for all lakes and all conditions. Implementation of any of these technical solutions should only occur after a lake specialist has evaluated the lake and recommended one or more of the options.

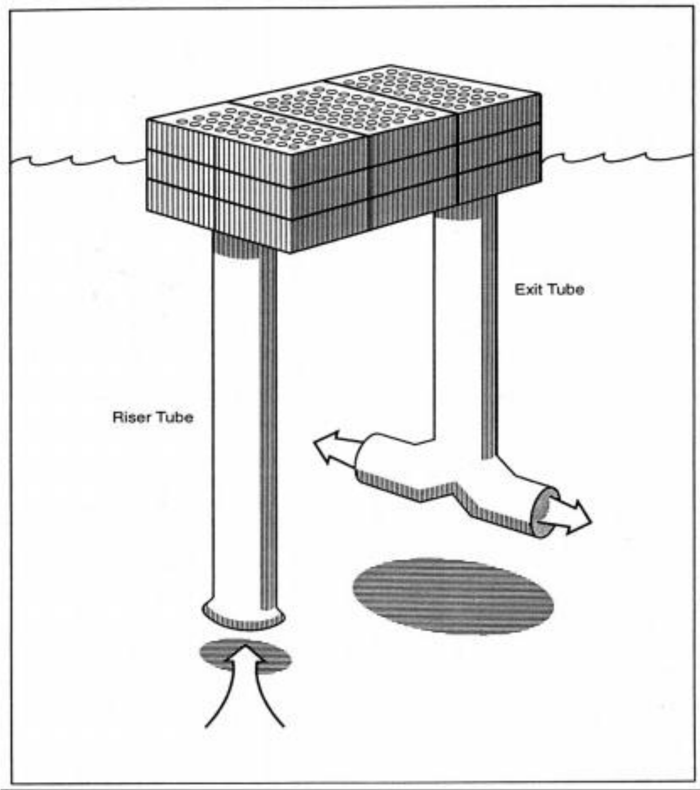
1.1 Aeration

The technique of aeration involves pumping oxygen into the deep, nutrient-enriched, oxygen-depleted layer that forms in deeper lakes called the hypolimnion. The goal of hypolimnetic aeration is to **maintain oxygen levels in this layer, as this will limit phosphorus release from the bottom sediments**.



From: Washington Department of Ecology, "Algae Control Program" (accessed 23 October 2015), online: <http://www.ecy.wa.gov/programs/wq/plants/algae/lakes/LakeRestoration.html>.

Aeration can improve habitat and fish populations by improving their food supply by providing more oxygenated waters. While several local lakes have experienced improved water quality after the installation of an aerator, aerators remain expensive to operate and may not be successful in all cases. It can also be difficult to supply adequate oxygen without *stirring up* the bottom sediments, which can cause subsequent algal blooms.



Hypolimnetic Aerator. From: Ken Ashley, "Langford City Council Parks and Recreation meeting: Langford Lake Aeration" (24 September 2012) Powerpoint at Adobe p 23, online: <http://www.cityoflangford.ca/assets/Lifestyle/Documents/Langford%20Lake%20presentation%20-%20Sept%2024%202012.pdf>.

At Langford Lake, a popular local recreational spot for fishing, boating, and swimming in Langford, BC, data collected over the past 20 years shows that the lake is eutrophic likely due to runoff from its highly urbanized watershed. An aerator was first installed in 1984 to address the internal loading[2] of excess phosphorus, but the first aerator did not meet the oxygen consumption rate of the sediments and so was ineffective. In 1985, a more efficient aerator was installed and by 2005, data showed that the aerator had reduced internal nutrient loading and that fish habitat had expanded – indicating that the aerator was succeeding in increasing oxygen content in the water. The temperature profiles that year were similar to pre-aerator lake conditions. It was believed that water quality was no longer continuing to deteriorate due to the ongoing operation of the aerator; however, it became apparent that the aerator had become less effective over time. A report completed in 2007 recommended that an assessment of the functioning of the aerator would determine whether it needed updating or replacing and a new aerator was installed in 2012 with funding secured by Langford City Hall. The total cost was $250,000,

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[2] "Internal loading" refers to the fact that lake sediments can be a major source of phosphorus. If deep-water oxygen becomes depleted, a chemical shift occurs in bottom sediments. This shift causes sediment to release phosphorus to overlying waters. This internal loading can be natural but is often the result of phosphorus pollution: BC Lake Stewardship and Monitoring Program, "Langford Lake (1973-2004)" at 5, online: <www.bclss.org/library/doc_download/104-langford-lake.html>.

though Langford was reportedly to receive $100,000 from the Habitat Conservation Trust Foundation.[3] In 2009, the Foundation provided $17,425 for the operation and maintenance of aerators in Langford Lake and Glen Lake, discussed next. The lake experienced an algal bloom during the winter of 2012, just months after installing the new aerator, though this was attributed to the aerator being turned off too early for the winter season.[4] Then in January 2013, a swimming advisory was issued for the lake due to an algal bloom.[5]

Glen Lake, which is an urban fishery and swimming spot also in Langford, has dealt with elevated phosphorus levels from internal loading as well as agricultural runoff and septic fields. In order to improve water quality, an aerator was installed in 1985 to deliver oxygen to deeper levels of the lake. At Glen Lake, the aerator was traditionally inspected annually and in 2005, it was replaced after it was found (similar to Langford Lake) to be suffering from corrosion and decreased performance. Water quality data was collected consistently between 1981 and 2009 and phosphorus levels were found be declining consistently and there have not been extreme summer phosphorus levels since the aerator was installed. Although the effectiveness of the aerator has not been conclusively proven since other factors may have contributed to the decrease, such as the move from a septic to a sewer system (discussed in section 2.1, below), the aerator has likely played a role in the improved health of Glen Lake. A 2009 report from the Ministry of Environment found that Glen Lake had "moderate water quality conditions," though it may have experienced an algal bloom in the summer of 2008.[6] (In order to function effectively, the aerator must run uninterrupted from May to October -- and in 2008 the aerator was not turned on until July. It is not clear why this happened, although there is some suggestion that the practice of yearly inspection had fallen away as a 2009 list of recommendations included the suggestion that yearly inspection would help to ensure uninterrupted performance.)

Meeting minutes from the City of Langford Parks, Recreation, Culture and Beautification Committee on September 29, 2014 reported that the aerators at both Langford and Glen Lakes "are continuing to achieve excellent conditions for fish habitat."[7]

St. Mary Lake on Salt Spring Island supplies potable water to the northern part of

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[3] Jim Zeeben, "Aerator getting replaced in Langford Lake" (25 July 2012), online: Goldstream Gazette <http://www.goldstreamgazette.com/news/163792626.html>.
[4] Charla Huber, "Officials: Stay out of Langford Lake" (15 January 2013), online: Goldstream Gazette <http://www.goldstreamgazette.com/news/187005661.html>.
[5] City of Langford, "Advisory Notice - Blue Green Algae Noted on Langford Lake" (13 January 2015) online: <http://www.cityoflangford.ca/EN/meta/whats-new/news-archives/2014-archive/advisory-notice-blue-green-algae-noted-on-langford-lake.html>.
[6] BC Ministry of Environment, *Glen Lake 1981-2009: Water Quality Monitoring Program* (April 2009) at 7-8, online: <http://www.env.gov.bc.ca/wat/wq/studies/glenlake-apr09.pdf>.
[7] City of Langford Parks, Recreation, Culture and Beautification Committee, *Agenda & Staff Report of September 29, 2014* at P4 (Adobe p 5), online: <http://www.cityoflangford.ca/assets/Agendas~and~Minutes/Parks~Recreation~Culture~and~Beautification~Committee/2014/20140929%20-%20Agenda%20Pkg.pdf>.

the island and is also regularly used for fishing and other recreational activities. There are over 200 residential structures on properties fully within the St. Mary Lake watershed and 32 more on properties partially within the watershed.[8] It has dealt with extensive, and at times toxic, algal blooms linked to the phosphorus levels in the lake. These high phosphorus levels had been previously caused by septic tank runoff, road building, and land clearing. Until recently, internal loading was believed to be the main source of phosphorus. The water quality at St. Mary's affects drinking water, recreational use, and fisheries productivity. An aerator was first installed in 1985, the largest one in Canada at the time. In 1992, a University of Victoria report found that the aerators enhanced fisheries habitat in St. Mary Lake.[9]

However, aerators installed in 2008, which operated from 2009-2012, ceased operation in 2013, as the aerators had not succeeded in improving water quality and limiting algal blooms. In 2014, the North Salt Spring Waterworks District (NSSWD) constituted a committee to study the aerators and the lake -- which determined that the aerators negatively affected water quality, "possibly by disturbing bottom sediments and lowering their capacity to bind phosphorus, which in turn increased phosphorus loading and algal growth."[10]

On December 1, 2012, an expert panel was held to discuss the concerns with St. Mary Lake, and Dr. Ken Ashley expressed an opinion that "temporary fixes" are a poor investment without complementing them with watershed management.[11]

The Salt Spring Island Watershed Protection Authority (SSIWPA) includes representatives from local and provincial government agencies, including the Ministry of the Environment, the Ministry of Health, the Capital Regional District, and others. Most recently, the SSIWPA produced a report, *St. Mary Lake Integrated Watershed Management Plan - 2015* (released October 23, 2015), which reviewed the existing aerators and found that they were not "candidates for a feasible management action" as they did not work to prevent algal blooms for two reasons: first, they probably stirred up sediments; and second, the magnitude of internal loading was less than previously thought, and the blooms are likely caused by runoff or rainfall, so the aerators address the wrong problem[12] (as they are a solution to internal loading, rather than a solution that addresses input management). The

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[8] Salt Spring Watershed Protection Authority, *St Mary Lake Integrated Watershed Management Plan – 2015* (released 23 October 2015) at 21, online: <http://ssiwatersheds.ca/wp-content/uploads/2015/10/INTEGRATED-WATERSHED-MANAGEMENT-PLAN-for-approval.pdf> ["*St Mary Lake Watershed Management Plan*"].
[9] Kevin Rieberger, University of Victoria Department of Biology, *The Effects of Hypolimnetic Aeration of the Fisheries Habitat of St. Mary Lake, B.C.* (Fall 1992) at 43, online: <http://www.env.gov.bc.ca/wat/wq/studies/stmaryfish92.pdf>.
[10] The North Salt Spring Waterworks, "The St. Mary Lake Aerators – Status Update" (15 September 2015), online: <http://www.northsaltspringwaterworks.ca/2015/the-st-mary-lake-aerators-status-update/>.
[11] Salt Spring Island Water Council, "Lake Water Quality and St. Mary Lake, Community Dialogue and Expert Panel, December 1, 2012 Final Report" (January 2013) at 3, online: <http://ssiwatercouncil.com/wp-content/uploads/2013/01/WCSoc-SML-Meeting-Final-Report-Dec.30.2012.pdf>.
[12] *St Mary Lake Watershed Management Plan*, *supra* note 8 at 8.

report has suggested next steps of:

1. Studying stormwater runoff (November 2015 – April 2016, approximate cost $5,000 – 10,000).
2. Confirm the 2014-2015 study results as they relate to septic outflow (the study finding that septic fields were not a significant contributing factor to excess phosphorus) (November 2015 – April 2016, approximate cost up to $10,000).
3. Confirm magnitude of internal loading (October 15, 2015 – March 2016, approximate cost $25,000).
4. Promote community engagement through a series of consultation efforts, workshops/presentations and educational initiatives (Fall – Winter 2015 and for some initiatives, ongoing; approximate cost $26,300).
5. Study agricultural runoff (Winter 2015, approximate cost $1,000).
6. Education on septic system use and maintenance (Winter 2015 and ongoing, approximate cost $2,000).
7. Study iron's role in controlling phosphorus (1 year duration, approximate cost $2,500 – 10,000).
8. Study agricultural runoff (duration to be determined, approximate cost $5,000).[13]

1.2 Dredging

Dredging is a technique that uses heavy equipment or specialized hydraulic dredges to remove accumulated lake sediments in order to increase depth and to decrease nutrient levels. By removing nutrient-rich sediment, dredging may improve water quality. Some potential concerns with dredging include release of sediments during the dredging operation and the temporary destruction of species habitat. Large-scale dredging is extremely expensive due to equipment costs, permitting issues, and disposal of the sediments that are removed. Due to costs, dredging is typically done on a limited scale. Although shallow lakes may benefit from this method, the expense limits its use in most water bodies.

Delavan Lake, in the Wisconsin area, started experiencing severe algal blooms in the 1980s due to residential and agricultural runoff. After studies were conducted (and wastewater collection sewers were installed to reduce septic runoff) during the 1980s, a comprehensive rehabilitation project was started in 1989 which included dredging Delavan Lake to remove sediment and increase the water depth, building ponds to help capture sediment coming from a feeding creek, building a peninsula to divert sediment-laden water from entering the lake, and building a dam to further help control inflow. The entire fish population in the lake was also eradicated and then restocked. This took three years and cost $7 million – one of the U.S.'s largest lake restoration efforts. It was considered a success, as by 1991, water clarity existed at a depth of 26 feet.

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[13] *St Mary Lake Watershed Management Plan*, *supra* note 8 at 34-40.

In 2006, a small tributary was dredged at a cost of $150,000. In 2008, Delavan Lake Inlet (a wetland that filters sediment that flows into the lake) was dredged to increase its filtering ability, and two sedimentation ponds initially excavated during the 1989 project were dredged – all at a cost of $1.46 million (the majority of which is covered by the Town of Delavan's local taxes). After a 2005 study valuating the lake in economic terms,[14] the Chairman of the Delavan Town Board said that although the cost of dredging is very high, the cost of *not* dredging would be higher. The removed sediment was moved to a dedicated storage site. The 2008 dredging led to improved water flushing due to the increased water depth and was projected to prevent 50% of the phosphorus and sediment from entering the creek. The dredging was done in addition to alum treatment of the main lake body (discussed at section 1.3 below), and accompanied by a comprehensive water quality monitoring program. [15] As of 2011, it was expected that dredging would have to be done again in 10 – 15 years.[16]

Burnaby Lake in Burnaby, BC has also been dealing with years of contaminated runoff from its urban watershed. Its inputs come primarily from farming and construction,[17] as well as boating[18] and surface runoff into storm sewers.[19] The lake was dredged in 1972 in preparation for hosting a rowing event at the 1973 Canada Summer Games. Then in 1997 a study recommended running a pilot-scale dredging project to collect data and determine if a full-scale dredging project was feasible; this pilot was conducted in 1999.[20] Burnaby Lake was dredged and double turbidity barriers were used to contain mobile sediments resulting from the dredging, thereby dealing with the above-mentioned concern regarding the nutrient release into the lake during the dredging process. The removed sediment was recycled as subgrade for a nearby sports field. In addition, the main feeding stream was treated. The lake now has a deeper water column, which encourages oxygenation.[21] The

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[14] The study found that Delavan Lake generates about $77 million in local spending annually, along with 812 jobs and $17 million in direct labor income: "*Lake Geneva News, Delavan Lake*," *infra* note 15.

[15] Chris Schultz, "Delavan Lake Dredging Clears Natural Filter" (13 October 2011), online: Lake Geneva News <http://www.lakegenevanews.net/Articles-i-2011-10-13-245216.114135-Delavan-Lake-dredging-clears-natural-filter.html> ["*Lake Geneva News, Delavan Lake"*]. See also: GazetteXtra, "Saving Delavan Lake: A history of lake restoration (30 June 2011), online: <http://www.gazetteextra.com/article/20110630/ARTICLES/306309973> [*GazetteXtra, "Lake Delavan"*].

[16] "*Lake Geneva News, Delavan Lake"*, *supra* note 15.

[17] ENKON Environmental Ltd., *Environmental Assessment of the Burnaby Lake Rejuvenation Program: Sediment and Water Quality, Benthic Invertebrates and Plankton Studies Final Report* (January 2002) at 4-5, online: <http://burnaby.ironpointv7.net/AssetFactory.aspx?did=770> ["*ENKON EA of Burnaby Lake"*].

[18] *Ibid*, at 7-8.

[19] *Ibid*, at 4-41.

[20] IMS, "Burnaby Lake Pilot Dredging Project Proves Feasibility of Lake Dredging" (accessed 5 November 2015), online: < http://www.imsdredge.com/lake2.htm>.

[21] Association of Consulting Engineering Companies British Columbia, "Award of Merit Burnaby Lake Rejuvenation Project - Urban Jewel" (accessed 5 November 2015), online: <http://www.acec-bc.ca/media/5738/acecbcAwards12-2M.pdf>.

whole process cost $20 million and was split between the City of Burnaby and the provincial government.[22] In 2012, the Association of Consulting Engineers of BC gave the Burnaby Rejuvenation Project an award for its success.[23] However, shortly after the dredging project completed in 2011, milfoil weeds were still an issue for recreational users of the lake.[24] Media has reported that as of 2014, algae was still an annual issue at Burnaby Lake.[25]

The Chain of Lakes is a network of five lakes in Minneapolis, Minnesota that sit in a 1500-acre urban park.[26] By 1990, the lakes were suffering from elevated phosphorus levels and subsequent algal blooms due to a highly developed urban watershed and associated urban runoff. One of the lakes, Lake of the Isles, was dredged over time, but in 2002 was put on Minnesota's "Impaired Waters List," as it had not seen a reduction in phosphorus levels.[27] However, other measures proved to be successful for Lake of the Isles, as well as the other four lakes in the network, as discussed below in sections 1.3, 2.3 and 3 – and all but Lake of the Isles have stayed off the Impaired Waters List.

In St. Mary Lake's Watershed Management Plan, released in 2015 by the SSIWPA and described above in section 1.1, dredging was discouraged. The report stated, "the cost is likely to be extremely high, successful results are uncertain and the [BC Ministry of Environment] are concerned about impacts."[28]

1.3 Alum

A third in-lake treatment option is to add alum to the lake in order to inactivate phosphorus. When applied to water, aluminum sulfate ("alum") removes phosphorus and particulates (including algae) from the water column. The alum settles on the sediment where it forms a layer that acts as a barrier to phosphorus. Phosphorus that would be released from the sediments combines with the alum and is not released into the water to fuel algal blooms. The algal levels should decline after alum treatment as phosphorus levels in the water are reduced. Alum treatment

[22] http://www.canadianconsultingengineer.com/features/award-of-excellence-burnaby-lake-rejuvenation/

[23] http://www.burnabynow.com/news/burnaby-lake-dredging-project-wins-award-of-merit-from-engineering-association-1.410043

[24] http://www.burnabynow.com/news/newly-dredged-burnaby-lake-s-weed-problems-could-prevent-boating-competitions-1.1899335

[25] http://www.vancitybuzz.com/2014/07/massive-algae-bloom-turns-burrard-inlet-english-bay-waters-red-photos/

[26] LakeLubbers, "Minneapolis Chain of Lakes, Minnesota, USA" (accessed 25 October 2015), online: <http://www.lakelubbers.com/minneapolis-chain-of-lakes-2361/>. Note some sources include Twin Lakes in the Chain of Lakes, in which case it consists of *six* lakes, not five: see *US EPA, "Minneapolis Chain of Lakes"*, *infra* note 27.

[27] United States Environmental Protection Agency, "Minnesota: Minneapolis Chain of Lakes, Nutrient Concentrations Nearly Returned to Presettlement Conditions" (updated 6 March 2012), online: <http://water.epa.gov/polwaste/nps/success319/mn_chain.cfm> ["*US EPA, "Minneapolis Chain of Lakes"*].

[28] *St Mary Lake Watershed Management Plan*, *supra* note 8 at 9.

is a process that requires repeated applications. The length of treatment effectiveness varies with the amount of alum applied and the depth of the lake. Alum treatment for phosphorus inactivation in shallow lakes may last for eight or more years. In deeper lakes, alum treatment may last much longer.[29]

Green Lake is an urban lake in the Seattle area that receives an estimated 1 million visitors per year. Unfortunately, storm water runoff from septic systems and other facets of urbanization have caused phosphorus and algae bloom growth – intense algal blooms have been reported since 1916.[30] This is exacerbated by the fact that the lake is shallow, so doesn't stratify by temperature,[31] and there are no inflows or outflows from the lake to flush toxins (wetlands have dried up or been developed).[32] The algal blooms, foul odors, and swimmers itch have plagued lake visitors, prompting intervention. Internal phosphorus loading is now the largest contributor.[33]

Major efforts have been made to restore Green Lake. Alum treatment has been used twice in Green Lake: after the lake was listed as an "impaired and threatened water body" by the Department of Ecology in 1991, 180 tonnes of alum were added to the lake. This was considered a "limited dose," and reportedly had short-lived effects – it lasted 3 – 5 years,[34] despite the project's completion report recommending treating the lake every 5 – 8 years as maintenance.[35] Notably, other elements of the lake restoration project included: harvesting invasive weeds, treatment and diversion of stormwater inflow, dilution of the lake with excess drinking water, management of the resident Canada goose population (as animal feces is a source of phosphorus), public education, and fish management to control destructive fish populations (carp burrow in sediments, which releases phosphorus).[36]

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[29] Department of Ecology State of Washington, "Algae Control Program" (accessed 5 November 2015) at "Nutrient Inactivation" heading, online: <http://www.ecy.wa.gov/programs/wq/plants/algae/lakes/LakeRestoration.html>.
[30] Seattle Department of Parks and Recreation, "Technical Report: Green Lake Alum Treatment Study" (June 2003), online: <http://www.seattle.gov/parks/parkspaces/GreenLakePark/GreenLakeAlumStudy.pdf> ["*Seattle Green Lake Alum Study*"].
[31] Richard D Oxley, "Green Lake: When in doubt, stay out" (12 August 2015), online: My Northwest <http://mynorthwest.com/11/2794970/Green-Lake-When-in-doubt-stay-out>.
[32] Eric Scigliano, "Trouble in Green Lake" (9 October 2006), online: Seattle Weekly News <http://www.seattleweekly.com/2002-08-14/news/trouble-in-green-lake/> ["*Seattle Weekly Trouble in Green Lake*"].
[33] *Ibid*.
[34] Rob Zisette, "Green Lake Alum Treatment – Dose for a Dose for a Decade" (2008) at Adobe p 13, online: <https://digital.lib.washington.edu/researchworks/bitstream/handle/1773/16442/zisette.pdf?sequence=2> ["*Rob Zisette, "Green Lake Alum PPT*"].
[35] *Seattle Green Lake Alum Study*, *supra* note 30 at 2.
[36] *Ibid*, at 1.
More information on the dilution: City of Seattle, "News Release: Nickels Announces Strategy to Rid Green Lake of Algae Bloom" (14 August 2002), online: <http://www.seattle.gov/news/detail.asp?ID=2848&Dept=40>.

After serious algae problems in the summers of 1999, 2002[37] and 2003, a more comprehensive dose of alum (441,000 gallons[38]) was added in 2004.[39] This treatment was estimated to cost $1.5 million and was projected to last for ten years – until 2015.[40] The treatment did lead to improved water quality and a reduction in phosphorus, but for a period of four and seven years, rather than the expected ten. The reduction in phosphorus was greater, and lasted longer, than the application in 1991, due to a much larger quantity of alum being applied.[41] One remaining problem is the overpopulation of invasive carp species, which stir up the bottom sediments and lead to phosphorus release (efforts to address this problem is discussed in section 1.4, below). Additionally, the presence of algae actually *prevented* the growth of an invasive plant called milfoil, so the clearer waters allowed for that weed to flourish – which necessitates further intervention.[42]

2004 Alum Treatment at Green Lake. From: Rob Zisette, Herrera Environmental Consultants, "Green Lake Alum Treatment – Dose for a Decade" (for Water Center Seminars, 2008), at Adobe p 24, online: <https://digital.lib.washington.edu/researchworks/bitstream/handle/1773/16442/zisette.pdf?sequence=2>.

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[37] *Seattle Green Lake Alum Study*, *supra* note 30 at 2.
[38] City of Seattle, "News Advisory: Green Lake Alum Treatment is Doing its Job" (23 September 2008), online: <http://www.seattle.gov/news/detail.asp?ID=8866&Dept=14>.
[39] Jake Lynch, "The trouble with Green Lake" (30 April 2008), online: Crosscut <http://crosscut.com/2008/04/the-trouble-with-green-lake/> ["*Crosscut The Trouble with Green Lake*"].
[40] *Seattle Green Lake Alum Study*, *supra* note 30 at 39.
[41] Herrera Environmental Consultants, *Data Analysis Report: Green Lake Phytoplankton Study* (21 January 2015) at vi (Adobe p 10), online: <http://www.seattle.gov/parks/parkspaces/GreenLakePark/GreenLakeAlumStudy_2015.pdf> ["*Green Lake Alum Study 2015*"].
[42] Lynda V Mapes, "Algae-prone Green Lake is staying clean" (19 March 2008), online: <http://www.seattletimes.com/seattle-news/algae-prone-green-lake-is-staying-clean/>.

Starting in fall 2012, Green Lake again experienced annual closures (to wading, swimming and "wet-water boating") due to recurring algal blooms. Parks officials specifically cautioned dog owners not to let their dogs drink from the lake[43] - and cautioned people from eating fish caught in the lake "on a frequent basis."[44] Some sources suggest that there has been opposition to adding more chemicals to Green Lake. One former president of the Green Lake Community Council is reported to have queried: "If we go down the path of putting chemicals in the lake, where will it end? Right or wrong, officials have to make a better case for it."[45] In January 2015, a study by an environmental consultant was released, which recommended applying another treatment of alum as soon as possible, but to apply smaller, periodic treatments than the previous treatments.[46] It also recommended evaluating alternatives, such as aeration, dredging, dilution with clean water, developing a water quality monitoring plan and preparing a public education plan – as well as preparing a Lake Management Plan to continue to deal with weed management, fisheries management and stormwater management.[47] The City of Seattle allocated $300,000 in its 2015 budget in order to study water quality and obtain permits prior to applying another alum treatment,[48] which is expected to be completed by summer 2016.[49] Between $1.2 and 1.8 million has been allocated by the City for the upcoming alum treatment.[50]

Criticisms of the approach taken at Seattle's Green Lake centre around its reactive nature: some say a long-term lake management plan and budget must be

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[43] Seattle Parks and Recreation, "Toxic algae bloom closes Green Lake to some activities" (2 October 2012), online: <http://parkways.seattle.gov/2012/10/02/toxic-algae-bloom-closes-green-lake-to-some-activities/#sthash.gZGi3fGx.dpbs>.
Regarding the fall 2013 closure, see also: Coral Garnick, "Green Lake closed to swimming for people and pets" (13 September 2014), online: The Seattle Times <http://www.seattletimes.com/seattle-news/green-lake-closed-to-swimming-for-people-and-pets/>.
Regarding the fall 2014 closure and a suspected 2015 closure, see: online: Beena Raghavendran, "High temperatures, sunny skies could aggravate algal bloom in lakes" (2 July 2015), online: The Seattle Times <http://www.seattletimes.com/seattle-news/high-temperatures-sunny-skies-could-aggravate-algal-bloom-in-lakes/> ["*Seattle Times Algal Blooms in Lakes*"].
[44] Cathy McLain, "Toxic algae bloom in Seattle's Green Lake growing worse" (4 October 2012), online: The Seattle Times <http://www.seattletimes.com/seattle-news/toxic-algae-bloom-in-seattles-green-lake-growing-worse/>.
[45] *Seattle Weekly Trouble in Green Lake*, *supra* note 32.
[46] *Green Lake Alum Study 2015*, *supra* note 41 at viii (Adobe p 12).
[47] *Ibid*.
[48] City Living Seattle, "Council committee accelerates Green Lake cleanup" (20 November 2014), online: <http://citylivingseattle.com/Content/News/Healthy-Living/Article/Council-committee-accelerates-Green-Lake-algae-cleanup/22/170/90619>.
[49] Seattle City Council, "News Release: Councilmembers Godden, O'Brien Announce Accelerated Green Lake Algae Cleanup" (20 November 2014), online: <http://council.seattle.gov/2014/11/20/councilmembers-godden-obrien-announce-accelerated-green-lake-algae-cleanup/> ["*Seattle City Council Nov 20 News Release*"].
[50] $1.2 million reported: Seattle Parks and Recreation, "Green Lake Alum Treatment Project Information" (Spring 2015), online: <http://www.seattle.gov/parks/projects/green_lake/alum.htm>.
$1.8 million reported: *Seattle Times Algal Blooms in Lakes, supra* note 43.

established – the lake management plan currently in place was developed in the 1980s. These critics adopt some of the suggestions from the January 2015 report mentioned above, including controlling stormwater and managing fish.[51] In 2006, a local limnologist reportedly said "[t]here may not be a long-term solution for this lake."[52]

Alum treatment was also used in two of the lakes in the Chain of Lakes in Minneapolis in 1996 and 1997, and two more of the lakes in 2001. Combined with other measures, including public education measures to limit phosphorus inputs, those four lakes' water quality improved.[53]

As mentioned above, alum was added to Lake Delavan in Wisconsin in 1991 in order to trap phosphorus in the sediments. Initial assessments suggest that overall, the rehabilitation project has increased water clarity and eliminated algae blooms in the lake body. Water quality improved. However, during the maintenance dredging projects from 2006 – 2011, it was determined that further alum treatment on the tributary inlet would not be beneficial, as the high rate of sediment loading would result in it having low effectiveness, it is high cost, and it is close to a Wisconsin Department of Natural Resources (WDNR) Sensitive Area so would affect fish and other species.[54]

1.4 Harvesting Problematic Species

Certain fish species can influence the levels of nutrients in a lake. For example, they may stir up bottom sediments, releasing phosphorus into the lake, or eat phytoplankton that feed on problematic algae. Removing these fish from the lake may help reduce the nutrient load and subsequent algal blooms.

Lake George is a lake with a small drainage area along the St. Johns River in Florida. It supplies drinking water to many homes and is a sport-fishing river.[55] It is located within a highly urbanized Florida area and experiences pollution from approximately 1.8 million pounds of phosphorus in an average year. Treated wastewater is the largest contributing factor, as partially treated sewage from wastewater facilities is pumped into the river for disposal. Farm runoff and storm water runoff also contribute. The elevated phosphorus levels produce algal blooms, which are occasionally toxic.

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[51] *Crosscut The Trouble with Green Lake*, *supra* note 39.
[52] *Seattle Weekly Trouble in Green Lake*, *supra* note 32.
[53] *US EPA, "Minneapolis Chain of Lakes"*, *supra* note 27.
[54] Peter Berrini, "Delavan Lake North Inlet Dredging Project Summary of Project Benefits and Future Actions" (no date) at 1-2, online: <http://townofdelavan.com/wp-content/uploads/2015/07/Summary-of-Project-Benefits-and-Future-Actions.pdf>.
[55] George Earl, "Decline of Lake George" (19 April 2012), online: Adirondack Explorer <http://www.adirondackexplorer.org/stories/decline-of-lake-george> ["*Adirondack Explorer, Lake George*"].

Normally gizzard shad, a fish species native to Florida lakes, make up 5 – 20% of fish in a lake, but in high phosphorus lakes they can make up to 90% of the population (so sport fish are significantly fewer). They feed on the bottom level of the lake, which stirs up the sediments, releasing stored phosphorus into the lake. Their excrete nutrients back into the water, so it's a cycle that keeps the lake nutrient-rich and high in algae. Further, the shad eat zooplankton, which feed on algae. Scientists in the 1990s discovered that harvesting the shad could reduce phosphorus levels in lakes (Lake Denham and Lake Apopka were successful in reducing phosphorus levels by harvesting shad – though Lake Apopka also reduced phosphorus inputs to the lake).[56] Using $1.7 million[57] in legislative appropriations from 2013 to 2014,[58] gizzard shad were harvested in Lake George to remove approximately 20,000 pounds of phosphorus from the lake (and 2.56 million pounds of fish). However, despite implementing 58 overall water quality related projects (outlined in section 2.1 below, and including waste water and stormwater initiatives) from 1993 to 2007, and another 47 projects anticipated from 2008 – 2012 (32 of these projects estimated to cost more than $17 million),[59] algal blooms continued to be reported during the summers of 2014 and 2015.[60] A summer shad harvest was conducted again during the summer of 2015,[61] for a cost of $861,000.[62] The results of this latest harvest are not available at the time of writing.

As mentioned, Green Lake in Seattle had an invasive carp population that contributed to the lake's water quality issues. This is because carp disturb the deep lake sediment, releasing phosphorus that is stored in it. Since carp thrive in a nutrient-rich environment, it is a destructive cycle. One of the techniques used in 2000 to address the carp overpopulation was stocking the lake with sterile tiger musky – however, a 2003 study indicated that the carp were still the dominant species,[63] and an overpopulation of carp is still an issue facing Green Lake today.[64]

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[56] St. John River Water Management District, "Shad Harvesting" (updated on 14 October 2013), online: <http://floridaswater.com/waterbodies/harvestingshad.html> ["*SJRWMD Shad Harvesting*".
[57] *Ibid*.
[58] Dinah Voyles Pulver, "Lake George gizzard shad harvest aims to help clean up lake" (6 November 2015), online: Orlando Sentinel <http://www.orlandosentinel.com/features/os-ap-lake-george-gizzard-shad-20150725-story.html>.
[59] Lower St. Johns River Water Management District, "Surface Water Improvement and Management Plan Update 2008" (August 2008),at iii (Adobe p 7), online: <http://floridaswater.com/SWIMplans/2008_LSJRB_SWIM_Plan_Update.pdf> ["*Lower St. Johns River, Management Plan Update 2008*"].
[60] St. Johns River Water Management District, "News: Lower basin water quality" (accessed 27 October 2015) at *May 29, 2015: Algal blooms observed at various locations* heading, online: <http://floridaswater.com/lbwqnews/>.
[61] St. Johns River Water Management District, "News Release: Gizzard shad harvest removes nutrients from Lake George, helps improve lower St. Johns River water quality" (10 July 2015), online: <http://webapub.sjrwmd.com/agws10/news_release/ViewNews.aspx?nrd=nr15-070>.
[62] *SJRWMD Shad Harvesting*, *supra* note 56.
[63] *Seattle Green Lake Alum Study*, *supra* note 30 at 8-9.
[64] Seattle Greenlaker, "Green Lake's Elusive Carp" (10 July 2014), online: <http://www.seattlegreenlaker.com/2014/07/green-lakes-elusive-carp/>.

1.5 Summary and Recommendations – Technical In-Lake Solutions

In determining the ideal technical in-lake solutions for Elk and Beaver Lakes, it should be noted that:

(1) Aeration can improve habitat and fish populations by improving their food supply by providing more oxygenated waters. While several local lakes have experienced improved water quality after the installation of an aerator, aerators remain expensive to operate, must abide by strict schedules and may not be successful in all cases (proper calibration is required to ensure the aerator can meet the rate of oxygenation of the sediments). It can also be difficult to supply adequate oxygen without *stirring up* the bottom sediments, which can cause subsequent algal blooms.

(2) Due to costs, dredging is typically done on a limited scale. It also can affect sensitive ecosystems and habitat. For example, dredging might just be considered for the smaller O'Donnell Creek water body or for other limited areas, if an expert assessment determines it's feasible.

(3) Alum treatment is a process that often requires repeated applications. The length of treatment effectiveness varies with the amount of alum applied and the depth of the lake. However, it has worked to improve water quality and fish habitat in other lakes.

(4) If there are problematic fish species (and there are carp in Elk/Beaver Lakes), a predator fish species may be stocked, or a large harvest of the problematic fish may be planned for.

(5) Finally, a fulsome analysis by lake experts is imperative prior to attempting restoration techniques. For example, the magnitude of phosphorus loading within St. Mary Lake was overestimated, and therefore an inappropriate (and expensive) solution was implemented. Further, monitoring should be rigorous and analyses should be updated frequently, as the sources of phosphorus can change over time. The restoration plan should be flexible, and allow for changes if it appears the techniques initially adopted are not working.

2. Input Management: Waste Water, Changing Behaviours, Wetlands

External nutrient sources such as fertilizers, pet waste, storm water runoff, septic system effluent, agriculture, and even rainfall can contribute nutrients to a lake. Proper lake management requires the removal or modification of as many of these nutrient sources as possible, especially those sources shown to be contributing the greatest nutrient load to the water body. In addition to in-lake measures, there should be appropriate long-term input management to control sediments, nutrients, and toxic inputs. A successful lake restoration program should strive to manage both external *and* internal nutrient sources.

2.1 Waste Water (Septic)

Lake Washington, near Seattle, is perhaps the most widely recognized example of a lake that solved its algae problem by input management – in this case, by diverting sewage runoff. It's the earliest success story of reversing lake eutrophication. The lake became the subject of public attention in the 1950s, when a concerned academic, W. Thomas Edmondson of the University of Washington, noticed the lake water was looking cloudy. The city of Seattle had discharged raw sewage into the lake from 1900-1941. From 1941-1953, ten sewage treatment plants were built around the lake, and the lake received secondary treated sewage.[65] Despite worrisome 1956 research from Mr. Edmondson, it wasn't until 1968 before the effluents were diverted from the waste treatment plants near the lake to new plants near Puget Sound, and then discharged into the ocean – in what was the most expensive pollution control effort in the U.S. at the time (it cost $140 million).[66] Lake quality stopped deteriorating after this, and by about 1976, blue-green algae was insignificant. The lake's water quality steadily improved into the 1990s, with transparency depth at an all-time high of 25 feet in 1993.[67] However, in 2007, algal blooms were reported again, and in January 2015, the lake experienced a *toxic* algal bloom,[68] forcing lake closure in April 2015.[69] One expert attributed this to more days with higher temperatures, leading to warmer waters and increased nutrients coming into the lake.[70]

In the Canadian Okanagan Basin (which includes six lakes),[71] water quality issues began to be noted in the 1960s. It's an urbanized watershed and its tributary systems cannot be relied on to flush pollutants as it experiences extreme variations in flows. The cause of these issues included poorly treated sewage, agricultural runoff, and insecticides – which led to algal blooms and toxicity.[72] The pollution was the motivation for the founding of the Okanagan Basin Water Board (OBWB) in 1970, which commissioned a study that ran from 1970 to 1974 and identified that municipal sewer outfalls were the primary source of excess nutrients in Okanagan

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65 King County, "The Lake Washington Story" (updated 5 October 2015), online; <http://www.kingcounty.gov/environment/water-and-land/lakes/lakes-of-king-county/lake-washington/lake-washington-story.aspx>.
66 *Ibid*.
67 *Ibid*.
68 *Seattle Times Algal Blooms in Lakes*, *supra* note 43.
69 Cathy McLain, "Toxic algae found at Kirkland's Waverly Beach" (8 April 2015), online: The Seattle Times <http://www.seattletimes.com/seattle-news/health/toxic-algae-found-at-kirklands-waverly-beach/>.
70 *Seattle Times Algal Blooms in Lakes*, *supra* note 43.
71 These lakes are: Okanagan, Kalamalka, Wood, Skaha, Vaseux and Osoyoos (Okanagan Basin Water Board, "The Okanagan Basin" (accessed 6 November 2015), online: <http://www.obwb.ca/wsd/about/state-of-the-basin>).
72 Okanagan Basin Water Board, "Water Quality Improvement" (accessed 6 November 2015), online: <http://www.obwb.ca/overview/water-quality-improvement/>.

Lake. Interestingly, the study attempted to quantify social and environmental benefits incurred by the lake in economic terms.[73] The OBWB lobbied the Province to implement special regulations requiring tighter controls on wastewater treatment and release into the lakes. The Board established Sewage Facilities Grants, which matched federal dollars to help pay local communities for upgrades. Septic tank systems were also a major problem and the extension of community sewers to these properties became another focus of the OBWB. Septic control efforts throughout the 1980s and 90s focused on identifying problem septic areas and formulation of sewering options through a formal Waste Management Plan with local governments. Collection systems were expanded to gather sewage from problem areas and new systems were put in place in other areas. Since 1990, there have been significant sewer extensions or new sewer systems to priority septic loading areas. Sewage infrastructure upgrades led to a 90% reduction in phosphorus over 20 years.

At Langford Lake, in addition to aeration, a centralized sewer service in the watershed was implemented in 2006 to improve water quality by switching residents from a septic to a sewer system. Connection is not mandatory for existing homes but is required for all new construction.[74] At Glen Lake, there are approximately 58 lakefront properties, all of which previously relied on private septic systems for sewage disposal. From 2005 to 2009, 48 of these properties were connected to the City of Langford sewer system. A City Bylaw, adopted in 2007, made it mandatory for all lakefront properties to be connected to the City sewer infrastructure. As the bylaw provides for some allowances, 12 properties have yet to be connected to the City sewer – but the majority are now connected, which alleviates the nutrient input to the lake (in addition to the aerator, described at section 1.1, above). As mentioned, as of fall 2014, Langford and Glen Lakes have reportedly excellent conditions for fish habitat.

In Wisconsin, the Delavan Lake Sanitary District formed and oversaw installation of wastewater collection sewers around the lake in the 1980s at a cost of $50 million.[75] This helped reduce discharge from residential septic systems into the lake, and was followed-up with an extensive restoration project that involved dredging and alum treatment. Overall, the restoration has been successful, as described above.

For Lake George in Florida, a citywide no net-gain goal was implemented for septic tanks. The St. Joseph River Watershed Initiative provides cost-share funding to local partners on projects that reduce nutrient loading to the river. The reduction of nutrient input has been the target of the St. Johns River Water Management District

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[73] Canadian British Columbia Okanagan Basin Agreement, *Summary Report of the Consultative Board* (March 1974) at Adobe p 9, online: <http://www.obwb.ca/fileadmin/docs/1974_Basin_Study_Summary_Report.pdf>.

[74] Science and Information Branch, Water Stewardship Division, Ministry of Environment, "Water Quality Assessment and Objectives for Langford Lake" (20 August 2007), at 3 (Adobe p 13), online: <http://www.env.gov.bc.ca/wat/wq/objectives/langford_lake/langford_tech07.pdf>.

[75] *GazetteXtra, "Lake Delavan," supra* note 15.

with the understanding that this will reduce the occurrence and frequency of harmful algal blooms. Projects for nutrient reduction have included re-directing wastewater discharges from water bodies, stormwater collection and retention improvements, sanitary sewer collection improvements, and repairing or removing malfunctioning septic tanks. Parallel with this, the District encourages best management practices and has constructed regional stormwater treatment areas to reduce nutrient runoff from agricultural areas.[76] As mentioned, despite these efforts, algal blooms continue to be reported during the summer of 2015.

Finally, it should be noted that Lake Capacity Models have been used in Ontario in the past.[77] These involve establishing the loading capacity of a lake, and not allowing for further septic permits, for example, after that threshold is met.

2.2 Changing Behaviours (through Public Education or Regulation)

A Washington State law was enacted in 2011 that bans fertilizers containing phosphorus – intended to reduce nutrient inputs to lakes like Green Lake in Seattle (discussed in section 1.3, above).[78] Green Lake's restoration efforts have also included a stormwater monitoring program.[79] Specific measures taken include removing a wood chip pile that was contributing to phosphorus runoff entering the lake.[80] A presentation by the environmental consultancy working on the restoration project recommended converting dirt soccer fields to turf, paving unpaved parking lot, and plugging a catch basin at an off-leash dog park as well.[81] It is not clear whether these actions were taken.

At Lake George in Florida, regulations were proposed that would impose a 50-foot riparian area where tree cutting would be prohibited and a 100-foot stream corridor where development would be restricted – these proved to be very contentious. There were conflicting opinions among business owners and "property-rights advocates" on the one hand (for example, the Lake George Property Owners' Association), and other landowners and concerned citizens on the other (for example, the Lake George Association – LGA - and the Fund for Lake George). A weakened version of the proposed regulations was passed by the Warren County Board of Supervisors,[82] but they have not been adopted by local governments – so as

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[76] St. Johns River Water Management District, "Regional stormwater treatment areas" (accessed 6 November 2015), online: <http://floridaswater.com/lowerstjohnsriver/regionalstormwater.html> ["*St. Johns River, Regional stormwater treatment*"].
[77] Personal communication between Dr. Rick Nordin and Erin Gray, October 26, 2015.
[78] *Seattle City Council Nov 20 News Release*, *supra* note 49.
[79] *Rob Zisette, "Green Lake Alum PPT*, *supra* note 34 at Adobe pp 33-38.
[80] Craig Welch, "Keeping Green Lake clean" (8 September 2005), online: The Seattle Times <http://www.seattletimes.com/seattle-news/keeping-green-lake-clean/>.
[81] *Rob Zisette, "Green Lake Alum PPT*, *supra* note 34 at Adobe p 43.
[82] The Chairman of the County Board asserts that the State of Florida should change its highway practices, rather than any regulations be imposed on landowners around the Lake.

of 2012, no stream rules applied.[83]

Public Education

In the absence of support for regulation, and in hopes of garnering support for regulation, the LGA and the Fund for Lake George turned their attention to public education.[84] In 2011, 2,000 people went aboard the LGA's Floating Classroom, a retrofitted pontoon boat, to learn about lake protection and ecology.[85] The St. Johns River Water Management District launched a public education initiative and has presented to homeowners, civic and school groups and elected officials on the St. Johns River's quality as well as providing media tours of the river, resulting in much media coverage of the water quality issues surrounding the Basin.[86]

Any community or environmental improvement project initiated by a local community should harness the power of public concern. Particularly, given the popularity of Elk Lake as a recreational spot for many local people, community support for a clean-up project should be channeled to assist in the efforts. Additionally, educating the public on the water quality issues involved may lead to improved household practices and greater knowledge and implementation of individual steps that may be taken to work towards healthier lakes.

Some examples of good educational tools include a guide produced for the Canadian Okanagan Basin called *Slow it. Spread it. Sink it! An Okanagan Homeowners' Guide to Using Rain as a Resource*, which is full of information on best practices for rainwater runoff, capture, and collection. The Okanagan Basin Water Board's "Don't Move a Mussel" campaign educated the public about invasive mussels' contribution to promoting toxic blue-green algae.[87]

Another good document was produced as part of the Langford Lake cleanup effort: this was a cartoon illustrating what happens to city runoff called 'Down the Drain.'

Public education was key in the improvement of the water quality at Fork Lake, in Highlands, near Victoria, BC. A big part of the improvement was as a result of banning motorized boats through a CRD bylaw. The bylaw was successfully passed in large part because local residents were educated about the role that motorized boats were playing in churning up bottom sediments and nutrients. After this became common knowledge, the residents supported passing the bylaw.

At St. Mary's Lake, local groups have worked to hold community events such as the SSI Water Fair on World Water Day, March 22, 2015 to build awareness and skills

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[83] *Adirondack Explorer, Lake George*, *supra* note 55.
[84] *Ibid*.
[85] *Ibid*.
[86] *Lower St. Johns River, Management Plan Update 2008*, *supra* note 59 at v (Adobe p 9).
[87] Don't Move a Mussel, "What Mussels?" (accessed 6 November 2015), online: <http://www.dontmoveamussel.ca/mussels>.

for watershed health management. Concepts presented to local residents included the importance of annual maintenance of septic system and landscaping that guards against runoff,

Additionally, filtering urban runoff through gravel can improve water quality and subsequently fish habitat.[88]

At the Chain of Lakes in Minneapolis, public education efforts began in 1993 and continue to present day. The Clean Water Partnership (CWP) used bookmarks, table tents and paper place mats for restaurants, utility bill inserts, pet waste posters, billboards, newspaper articles, and lawn care mailings that were distributed throughout the watershed. They promote voluntary adoption of best management practices and watershed awareness of the drainage into the Chain of Lakes, the importance of the proper use of fertilizers and the availability of non-phosphorus lawn fertilizers, and the importance of keeping leaves and grass clippings away from hard surfaces, which drain into the storm sewer system.[89] Education and awareness efforts appeared to have paid off quickly, as a 50% reduction in pesticides in residential stormwater runoff has led to a significant in-stream reduction of phosphorus and a measurable phosphorus reduction in some of the lakes.[90]

2.3 Constructed Wetlands

A third possible nutrient input management technique is building constructed wetlands. This technique involves constructing an artificial wetland at the source of nutrient input to a water body. The wetland can efficiently filter out nutrients.

For example, in 2012 the Nature Conservancy of Canada and the Quamichan Watershed Stewardship Society built or restored seven wetlands near streams that flow into the Quamichan Lake, which is in the Cowichan Watershed on Vancouver Island, BC.[91] The new wetlands help to remove nutrients from run-off that would enter the lake.[92]

In 2002, the St. Johns River Water Management District began designing two regional stormwater treatment areas to reduce the amount of nutrients from flowing into the St. John's River (and subsequently into Lake George and other lakes). The Deep Creek West Regional Stormwater Treatment Area consists of a 15-

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[88] Sandi Doughton, "Toxic road runoff kills adult coho salmon in hours, study finds" (8 October 2015), online: The Seattle Times <http://www.seattletimes.com/seattle-news/environment/whats-killing-coho-study-points-to-urban-road-runoff/>.
[89] Louis N Smith, *et al*, A *Watershed Approach to Lake Restoration* (no date) at Adobe p 4, <http://www.minnehahacreek.org/sites/minnehahacreek.org/files/watershedapproach.pdf>.
[90] *US EPA, "Minneapolis Chain of Lakes"*, *supra* note 27.
[91] Quamichan Stewards, "The Quamichan watershed has seven new wetlands (node 204)" (accessed 6 November 2015), online: <http://quamichanlake.ca/node/204>.
[92] Katy Fulton, "Volunteers lending a hand to protect the Quamichan wetlands" (3 February 2014), online: Nature Conservancy of Canada <http://www.natureconservancy.ca/en/blog/volunteers-lending-a-hand-to.html?referrer=https://www.google.ca/#.Vj0TDLerTcs>.

acre wet detention pond and a 38-acre treatment wetland. The Edgefield Regional Stormwater Treatment Area consists of a 25-acre wet detention pond and a 56-acre treatment wetland. The projects each cost approximately $3.8 million to complete.[93]

The restoration efforts at the Chain of Lakes in Minneapolis used constructed wetlands to intercept urban stormwater and capture nutrients, in addition to alum treatment, described at section 1.3 above, and public education, described above at section 2.2. Restoration efforts also included constructing sedimentation basins and wet detention ponds, which sought to achieve the same goal as the wetlands. Overall, the restoration efforts were successful, as the U.S. Environmental Protection Agency (EPA) has documented measureable improvements in water quality throughout the Chain of Lakes.[94] Specifically, stormwater treatment ponds have ranged from a 25–66% percent removal rate.[95]

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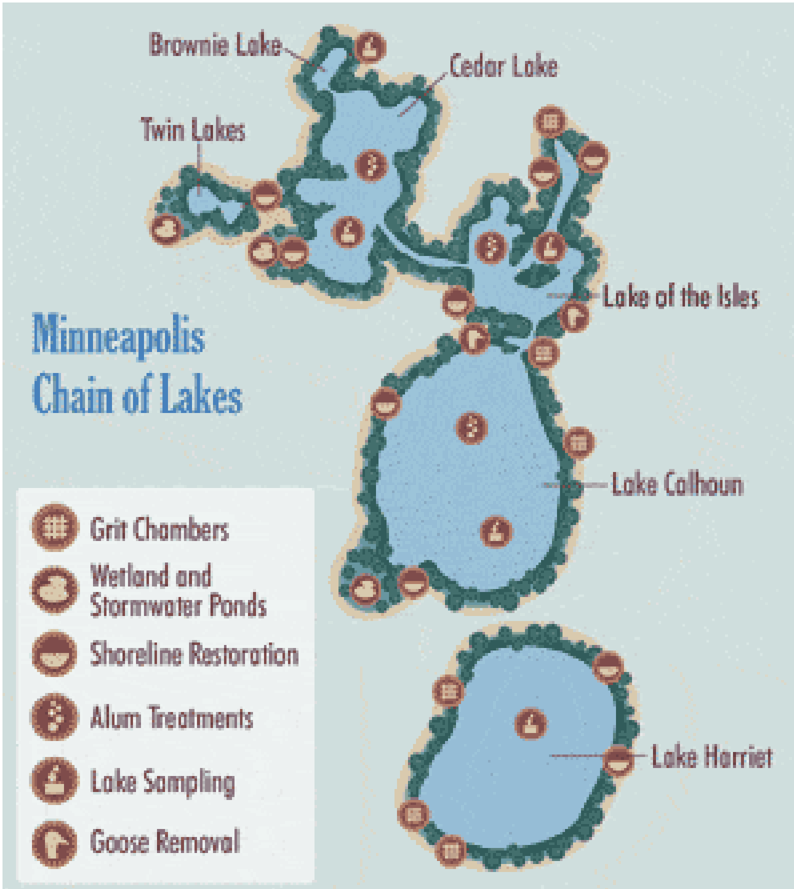
[93] *St. Johns River, Regional stormwater treatment*, *supra* note 76.

[94] *US EPA, "Minneapolis Chain of Lakes"*, *supra* note 27. See, for example, the Lake Nokomis Wetland Settling Project: Minnehaha Creek Watershed District, "Lake Nokomis Wetland Settling Ponds" (accessed 25 October 2015), online: <http://www.minnehahacreek.org/project/lake-nokomis-wetland-settling-ponds>. See also, the Pamela Park Wetland Restoration Project: Minnehaha Creek Watershed District, "Pamela Park Wetland Restoration Project" (accessed 25 October 2015), online: <http://www.minnehahacreek.org/projects/capital-projects/past-projects/pamela-park-wetland-restoration-project>.

[95] Minnesota Pollution Control Agency, "Minneapolis Chain of Lakes – a stormwater treatment train approach to improving lake water quality" (modified 20 March 2013), online: <http://stormwater.pca.state.mn.us/index.php/Minneapolis_Chain_of_Lakes_-_a_stormwater_treatment_train_approach_to_improving_lake_water_quality>.



Restoration efforts at Minneapolis Chain of Lakes (note this diagram includes Twin Lakes). From: United States Environmental Protection Agency, "Minnesota: Minneapolis Chain of Lakes, Nutrient Concentrations Nearly Returned to Presettlement Conditions" (updated 6 March 2012), online: <http://water.epa.gov/polwaste/nps/success319/mn_chain.cfm>.

2.4 Summary and Recommendations – Input Management

In determining what input management strategies should be adopted for Elk and Beaver Lakes, it should be noted that:

(1) Proper lake management requires the removal or modification of as nutrient sources as possible, especially those sources shown to be contributing the greatest nutrient load to the water body. These may include: septic, lawn fertilizer, agricultural and stormwater run-off;

(2) Changing residents' behaviour in relation to these external nutrient sources can occur through regulation or education;

(3) Traditionally septic has been a large issue for other lakes, so specific regulation or public education materials around septic may be appropriate (depending on what expert analysis finds in relation to current septic use around Elk and Beaver Lakes);

(4) Consider producing creative educational materials (these may include pictures and cartoons to pique interest, promote comprehension and increase retention) around best practices that residents can implement at

home to reduce nutrient run-off into storm drains; and

(5) Host community events that incorporate education around water quality issues and what people can do;

(6) Lake Capacity Models may be considered to provide the lake with a phosphorus "budget," which determines the amount, type and source of nutrients that are permitted to enter the Lake; and

(7) Well-placed constructed wetlands can greatly reduce the amount of nutrients entering a lake.

3. Collaborative Governance over Lake Problems

Lake management is complicated, is often costly and requires a coordinated effort by community groups, individuals, landowners, and government. Assessing who will play a role in the process is important to the overall effort. A major clean-up effort must consider who will be the key players, how to bring important stakeholders to the table, and how to handle the potentially sensitive multi-jurisdictional issues that may be at play.

In 2008, after mounting concern from residents and business owners as to the water quality of St. Mary's Lake on Salt Spring Island, the Salt Spring Island Watershed Protection Authority (SSIWPA, formerly the St. Mary Lake Watershed Working Group) was established. The SSIWPA consists of a Steering Committee, a Technical Advisory Committee, and a Public Advisory Committee. The Steering Committee is the main decision-making body. The Technical Advisory Committee provides science-based technical advice. The Public Advisory Committee advises the Steering Committee from the perspective of local values. Its members are representatives from local and provincial government agencies that collaborate to achieve a system of watershed governance and undertake to protect and manage Salt Spring's watershed. Members of the Steering Committee include the Ministry of the Environment, the Ministry of Health, the Capital Regional District, and others. The agencies began cooperating in 2012, at which point they sought formal delegated powers to enable coordinated management, which was granted by the Islands Trust Council in June 2013. Most recently, the SSIWPA produced a report, *St. Mary Lake Integrated Watershed Management Plan - 2015* (released October 23, 2015 and described above).

In the Canadian Okanagan Basin, a tax was levied on properties within the watershed to fund restoration and maintenance of water quality generally. Over the past 20 years this tax has assisted ten communities and provided more than $40 million in funding. The Okanagan Basin Water Board (OBWB) was instituted in 1970 as a collaboration of the three Okanagan regional districts to identify and resolve critical water issues in the Okanagan watershed. The Board of Directors includes representatives from the three Okanagan regional districts, the Okanagan Nation Alliance, the Water Supply Association of BC and the Okanagan Water Stewardship Council – a multi-stakeholder group established by the Board to provide independent science-based advice on water issues.

The Langford Lakes and Area Protection Society (LLAPS, incorporated in 1995) provides stewardship for the lake and also works with residents, government, and other societies. The society engages in public education about how best to protect water quality.

Somenos and Quamichan Lakes are sister lakes located in the Cowichan Watershed. Both lakes are suffering from a common set of problems including excessive nutrient loading from surrounding farm and residential runoff, insufficient water flushing in the summer, increased plant growth and algae blooms, reduced oxygen levels, and intensified warming.[96] Both lakes now have stewardship organizations that have formed in response to the pressures they face.

The Somenos Marsh Wildlife Society formed in 1986 to protect surrounding wetlands from development pressures. The Somenos Marsh is a renowned bird sanctuary and was designated as a "globally significant" Important Bird Area (IBA) in 2000 by Bird Life International.[97] In 2001, the Somenos Management Plan was developed, and the Somenos Management Committee was subsequently formed to provide oversight on the undeveloped lands surrounding the lake.[98] In 2006, the area was declared the Somenos Marsh Conservation Area. The 2001 management plan has been updated to a more recent "5 Year Strategic Plan: 2012-2017."[99]

The Quamichan Watershed Stewardship Society (Quamichan Stewards) was formed in the spring of 2006 in response to the continually declining health of Quamichan Lake.[100] After two years of initial research and investigation, the Quamichan Stewards prepared a Watershed Management Plan. The Plan presents a road map for restoring the Quamichan Watershed to a healthy state.[101] It was funded by the federal EcoAction Community Funding Program the Pacific Salmon Foundation and substantial in-kind and cash donations from the community, and was developed in partnership with a wide variety of stakeholders including the Department of Fisheries and Oceans, the B.C. Ministries of Environment and Agriculture, the Municipality of North Cowichan, local farmers, and residents of the watershed. In 2010, the Quamichan Stewards received a new grant from the federal Environment Canada EcoAction Community Funding Program to begin implementing the

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[96] Cowichan Watershed Board *Quamichan and Somenos Lakes* (accessed 5 November 2015) online: <http://www.cowichanwatershedboard.ca/content/quamichan-and-somenos-lakes>.
[97] Somenos March Wildlife Society, "Home" (accessed 5 November 2015), online: <http://www.somenosmarsh.com/>.
[98] *Ibid*, at 90.
[99] Somenos Marsh Wildlife Society, *5 year Strategic Plan 2012-2017* (2009), online: <http://somenosmarsh.com/files/3414/1382/4269/SMWS_Strategic_Plan_9-2014-reduced.pdf>.
[100] Quamichan Stewards, *About Quamichan Stewards* (accessed 5 November 2015), online: <http://www.quamichanlake.ca/>.
[101] Quamichan Watershed Working Group, *Quamichan Watershed Management Plan* (2009), online: <http://quamichanlake.ca/sites/default/files/QuamichanWatershedManagementPlanFinal-October2009.pdf>.

Management Plan. To kick this off, the Quamichan Stewards and the Somenos Marsh Wildlife Society co-hosted the BC Lake Stewardship Society (BCLSS) 2010 Community Forum. The BCLSS Community Forum is an annual event for information sharing, networking, and comprehension of issues, products and services relating to the health of BC's lakes and water supplies.[102] The theme for the conference was "Sustainable Approaches to Healthy Watersheds." It was made possible with the addition of other funding from TD Friends of the Environment Foundation, Nature Trust, Pacific Salmon Foundation and Sea Spring Salmon Farm. Other projects completed as part of the 2010 EcoAction grant included:

- Developing the Quamichan Watershed Public Access Strategy to increase the visibility of the Quamichan Watershed and promote recreation and educational activities;
- Reducing non-source nutrient input from land and water activities in the Quamichan Watershed by promoting septic field education through creating a brochure, working with the District of North Cowichan to lead conversions from septic to sewer, and identifying the feasibility of building wetlands near streams that flow into the lake;
- Hosting a community fishing derby to use and promote the watershed as a venue for recreation, education and wildlife events. [103]

In the District of Highlands on the Saanich peninsula on Vancouver Island, the Friends of Fork Lake stewardship group was established in 1996 with the goal of protecting the water quality of Fork Lake, ensuring safe drinking water and maintaining property values.[104] Between 1997-2003, the group implemented a volunteer water quality monitoring program to establish baseline date base at Fork Lake and five other Highlands lakes. From 2000-2006, the Highlands Stewardship Society and the BC Lake Stewardship Society partnered with the Ministry of Environment to implement the BC Lake Stewardship and Monitoring Program at Fork Lake. The monitoring program resulted in a water quality assessment report.[105] The report notes the ban on motorized boats on the lake (by the unanimous consent of residents as well as a local government bylaw) and includes a public education document, *Tips to Keep Fork Lake Healthy*, which includes guidelines for yard maintenance, agriculture, sewage systems, auto maintenance, boating, and public involvement.

At Delavan Lake in Wisconsin, a "Lake Committee" was formed to address the algal blooms in the 1980s. The committee included the City of Delavan, Walworth County, the U.S. Geological Survey, the U.S. EPA, the U.S. Army Corps of Engineers, the Department of Natural Resources, the Southeastern Wisconsin Regional Planning

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[102] BC Lake Stewardship Society, *2010 Community Forum Booth Registration Form* (2010), online: <http://www.bclss.org/images/stories/conference/conf_2010.html>.
[103] *Ibid*, at 91
[104] Kevin Rieberger, *Highlands Lakes Water Quality Assessment 1997-2003* (November 2009) at 3 (Adobe p 7), online: <http://www.env.gov.bc.ca/wat/wq/highlands_lakes/highlakes_wq.pdf>.
[105] BC Lake Stewardship Society, *Fork Lake: 2000-2006* (accessed 5 November 2015), online: <http://www.bclss.org/library/library/doc_download/7-fork-lake-2000-2006.html>.

Commission, the University of Wisconsin's Department of Civil and Environmental Engineering and The Nelson Institute for Environmental Studies. This group, along with the Southeastern Wisconsin Regional Planning Commission, released a Lake Management Plan in 2002.[106] The Delavan Watershed Initiative Network (WIN) was established in 2010 as a coalition of.11 municipalities and organizations. WIN focuses on input management – including from industrial, agricultural and stormwater runoff.[107] It has completed input management projects such as grassed waterways (which absorb runoff from agricultural fields), cover crops (which protect agricultural fields from erosion, which allows better absorption of runoff), and grass waterways (which include channels to collect and divert runoff water).[108] A Delavan Lake Watershed Implementation Plan is currently being developed, which will address input management.[109] Further, a comprehensive economic impact study was published by the Delavan Lake Improvement Association and the University of Wisconsin entitled, *What is the Value of a Clean and Healthy Lake to a Local Community?* The study calculated that $77 million dollars are generated annually as a result of Delavan Lake and its improved water quality. The economic analysis estimated that 812 jobs were generated, the average value of lake shoreline property appreciated $177,000, and the aggregate land value increased $99 million. This study was used as a basis to justify the high cost of the restoration projects that started in 1989 and are ongoing.

The City of Burnaby and other governments, academics, and community organizations formed the Brunette Basin Task Group, which developed the Brunette Basin Watershed Management Plan, which was released in 2001.[110] The Plan's goal is to "protect or enhance the integrity of the aquatic and terrestrial ecosystems and the human populations they support in a manner that accommodates growth."[111] The Plan included actions to reduce contaminants entering the lake. The outcome of the dredging project is outlined above, at section 1.2.

Minnesota, USA, in the late 1980s and early 1990s saw the formation of partnerships between citizen advocacy groups and state government seeking the restoration of the Minneapolis Chain of Lakes. This partnership is named the Minneapolis Chain of Lakes Clean Water Partnership (CWP) and continues engages

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[106] Walworth County Wisconsin, *A Lake Management Plan for Delavan Lake* (May 2002), online: <http://www.sewrpc.org/SEWRPCFiles/Publications/CAPR/capr-253_lake_management_plan_delavan_lake.pdf?>.
[107] Julia Riley, "Delavan lake restoration efforts deliver" (April 2012), online: Wisconsin Natural Resources magazine <http://dnr.wi.gov/wnrmag/2012/04/lake.htm>.
[108] Kettle Moraine Land Trust, "What is the Delavan Lake Watershed Initiative Network?" (no date) at Adobe p 3, online: <http://kmlandtrust.org/pdf/Delavan%20Lake%20WIN%20Narrative_030712.pdf>.
[109] Town of Delavan, "Watershed Plan" (accessed 25 October 2015), online: <http://townofdelavan.com/lake/watershed-plan/>.
[110] Brunette Basin Coordinating Committee, "Water Ways: Still Creek/Brunette River Watershed" (Spring/Summer 2001) at 2, online: Waterbucket <http://www.waterbucket.ca/gi/sites/wbcgi/documents/media/149.pdf>.
[111] *ENKON EA of Burnaby Lake*, *supra* note 17 at 1-1.

with public education and advocacy campaigns and on-the-ground restoration activities.[112] The CWP's restoration projects have cost $12.4 million, the majority of which was funded by local and regional partners, with assistance from the U.S. Environmental Protection Agency [113]

In northwestern USA, concerned citizens of Seattle formed the "Friends of Green Lake," after a string of toxic algal blooms in the 1990s and a finding by the Department of Ecology that fish from Green Lake exceeded criteria for the protection of human health.[114] Volunteers from the group study the lake extensively (for example, near-daily shoreline observations in 2014[115]), communicate with the public and lobby government for solutions to the lake's problems.

Lake George in Florida, USA, was considered a basin separate from the Middle and Lower St. Johns River basins, up until 2008, when the St. Johns River Water Management District started including the lake in its Surface Water Improvement and Management (SWIM) Plan.[116] Lake George was included in the SWIM because of the impaired water quality in the lake and because it had been found that improving and maintaining the water quality in the lake was important for the health of the nearby Middle and Lower St Johns River basins. The 2008 SWIM Plan demonstrates the need to practice a watershed management approach in order to maintain regional lake and river water quality.

3.1 Summary and Recommendations

In determining which stakeholders should be involved in the restoration of Elk and Beaver Lakes, and in what capacity, it should be noted that:

1) An economic study of the lake might be considered to help justify the costs of restoration (and allow for a traditional cost-benefit analysis);
2) Involving as many interested parties as possible (including all relevant government departments and all key non-government actors) increases chances of successful restoration;
3) Some of the stakeholders should anticipate being responsible for long-term management activities and expenses;
4) Taxes may be levied against residents in the watershed or on the lakefront to fund restoration efforts;

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112 *US EPA, "Minneapolis Chain of Lakes*, *supra* note 27.
113 Minnesota Pollution Control Agency, *Minneapolis Chain of Lakes – a stormwater treatment train approach to improving lake water quality* (accessed 5 November 2015), online: <http://stormwater.pca.state.mn.us/index.php/Minneapolis_Chain_of_Lakes_-_a_stormwater_treatment_train_approach_to_improving_lake_water_quality>.
114 *Crosscut The Trouble with Green Lake*, *supra* note 39.
115 Washington State Lake Protection Association, "Waterline – Green Lake toxic algae blooms significant in 2014" (March 2015), online: <http://www.walpa.org/waterline/march-2015/green-lake-toxic-algae-blooms-significant-in-2014/>.
116 *Lower St. Johns River, Management Plan Update 2008*, *supra* note 59 – see generally, and at vi (Adobe p 10) specifically.

IV. Summary/Next Steps

In reviewing the above case studies, it is important to keep in mind that every lake is different. This necessitates fulsome study prior to implementing any restoration activities.

Lessons from the above examples indicate that a comprehensive, long-term management approach (including required funding) is necessary to avoid ad hoc, reactionary actions. Continuous study and monitoring is required, as factors and environments change – the group managing the restoration must be flexible and ready to change course as needed.

We must emphasize the importance of bringing as many groups with an interest in the lake together, along with all the appropriate levels and agencies of government, to find a solution that considers everyone's interests.