Watershed Based Plan
East Pond, Maine

Prepared for the Maine Department of Environmental Protection, NPS Program

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Summary

The East Pond Watershed Based Plan serves the purpose of 1) fulfilling the U.S. Environmental Protection Agency (EPA) prerequisite for future federally funded work in this 303(d) listed waterbody, and 2) assisting the Maine Department of Environmental Protection (DEP) and the local watershed group with planning for efficient water quality improvement efforts.

Recovery of water quality in East Pond is impeded by several physical factors, especially the low flushing rate, lack of stream inlet, and high phosphorus load in the lake sediment. However, the lake is also the focus of a great deal of academic interest and research as well as two very active community volunteer groups. A strong history of non-point source (NPS) reduction through the 319 program also bodes well for eventual recovery of water quality. The 319 program will be in its third phase in East Pond in 2007.

A 10-year remediation strategy is recommended based on an assessment of past BMP work as well as several in-lake treatment approaches. The recommended strategy for phosphorus reduction in the coming years is a combination of 1) continued external load reduction through site work at existing sources, 2) local site development rules to prevent or reduce future loading, and 3) a significant internal load reduction achieved through an in-lake treatment. At this time aluminum treatment appears to be the most promising (or quantifiable) in-lake treatment. However, there is a growing body of research to support alternative in-lake treatments in East Pond, notably biomanipulation through fish removal and thermocline disruption through mixing/aeration. These alternative treatments should continue to be field-tested and should receive greater investment if and when they can produce quantifiable results for phosphorus reduction.

We estimate that the TMDL goal of phosphorus load reduction of 500 kg P/yr can be obtained within 10 years at a cost of $3,800,000 to $5,000,000. This would include costs for the primary in-lake treatment (one-time alum), implementation of best management practices at 250 priority sites (over 10 years), and continued education and outreach for both private landowners and town officials. Water quality recovery in East Pond will benefit from the coordination of the active and well-organized local constituency with academic and state expertise. Activity results should be periodically reviewed in order to modify the plan as needed over the next 10 years.

I. BACKGROUND

The purpose of the East Pond Watershed Based Plan is two-fold: 1) to fulfill the U.S. Environmental Protection Agency (EPA) prerequisite for future federally funded work in this 303(d) listed waterbody, and 2) to assist both the Maine Department of Environmental Protection (DEP) the local watershed group with planning for efficient water quality improvement efforts. Thus the intended audience for this report is the EPA, the Maine Department of Environmental Protection (DEP), and the local community.

This Watershed Based Plan includes a schedule of activities and goals for the next 10 years; however, it is not intended to be a static document but rather should evolve as new information becomes available. In accordance with EPA's own principles of Adaptive Management, the implementation strategy in this plan will be reviewed periodically and modified if necessary.

East Pond was placed on the 303(d) list by the Maine DEP due to failure to meet water quality standards of Secchi disc transparencies of 2 m or more and absence of nuisance blue-green algal blooms. East Pond has suffered persistent algal blooms since 1993. Phosphorus in excess quantities is the pollutant to be controlled in lakes affected by algal blooms, inasmuch as phosphorus is the limiting nutrient for algal growth. A Total Maximum Daily Load (TMDL) report for East Pond was submitted by the State and approved by EPA in 2001. Based on estimates of phosphorus load capacity of the lake and current loading, the *target* concentration of phosphorus was set at 15 ppb (= 0.015 mg/l). The *actual* phosphorus concentration has ranged from 18-22 ppb in the last ten years (see Table 1).

Since the year the TMDL was published, significantly more data has been collected concerning lake chemistry in East Pond. Although this report follows from the 2001 TMDL we will also make reference to the data collected by researchers at Colby College.

Two local watershed groups are active in East Pond, the Belgrade Regional Conservation Alliance (BRCA) and the East Pond Association. The BRCA has carried out several successful non-point source (NPS) projects, funded in large part by the Maine DEP '319' grants program. A NPS survey was carried out by the BRCA in 1999, followed by two 319 implementation projects, resulting in remediation of 36 sites. Pollutant load reductions were not estimated for the first 319 project. In the second project, the estimated sediment load reduction was 11.4 tons. The East Pond Association worked closely with the BRCA to identify sites and publicize the projects to the residents. Currently, the Kennebec Soil & Water Conservation District (Kennebec SWCD) is preparing to work with East Pond residents to implement the third phase of the 319 project, once this Watershed Based Plan is submitted.

Indicators of water quality are collected by the Maine DEP, the Colby College research program, and volunteer water quality monitors. From 1975 to 1992, the Secchi depth did not drop below 2 m (the defining transparency for algal blooms) except for one year (1987). Algae blooms have since persisted off and on since 1993. *Average* Secchi readings have varied between 2.3 and 4.8 meters over the last ten years and have reached a low point of 2 m or less for seven of those years.

Table 1. Ten-year summary of water quality in East Pond

Year	Algae bloom?	Secchi avrg. (m)	Secchi range (m)	Phosphorus in water column (ppb)	Trophic Index	Date of first bloom (Secchi <2 m)
1996	Yes	4.1	2-4.7			Aug. 10
1997	No	5.1	3.4-6.9	19	47	--
1998	Yes	3.0	0.9-5.9		76	Aug. 6
1999	Yes	3.5	1-5.5	22	68	Aug. 16
2000	No	3.8	2.3-6.2	18	63	--
2001	No	4.8	3.8-6.1	18		--
2002	Yes	3.9	1.5-5.6	18	62	Aug. 18
2003	Yes	2.3	1.3-4.4	19	19	Aug. 4
2004	Yes	3.8	1.6-7	18-22 (3 stns)	22	Sept. 3
2005	Yes	2.9	1 - 4.5			Sept. 1
2006	Yes					Aug. 12

Data sources: 2001 TMDL Report, PEARL database, Colby College data, East Pond Assocn. volunteers

Several physical characteristics of East Pond make it vulnerable to algae blooms. It is spring fed, with no permanent flowing inlet and only one outlet. It has a very low flushing rate of 0.25 (roughly once every four years) and occasionally backflushes at the outlet, Serpentine Stream. The pond is relatively small in surface area (1,716 acres) and relatively shallow (max depth of 27 ft), although the funnel-shaped bottom has a significant effect on lake chemistry.

The soils of the immediate shoreline (50 m in) are for the most part potentially highly erodible; whereas soils in the more upland areas are mostly not highly erodible. (See Table 2A-B, below). This rough cataloging of soils is not, however, an adequate determinant of risk to lake water quality. Areas of "potentially highly erodible" soils would need to be further assessed based on steepness and actual or planned development. A basic, GIS-aided erosion risk assessment is recommended.

Table 2A. Soils of the East Pond shoreline: defined here as water's edge to 50 m upland, a perimeter area of approximately 208 acres (excluding submerged lands) *Source: USDA digitized Soil Surveys, Kennebec & Somerset Counties*

Soil Series & Sub-Series	Erodibility	Prevalence: in acres and % of lake perimeter (excluding wetlands)
BuB2	Highly Erodible	1.0 acres (0.50 %)
RdA, ScA, RF, Pa, Sc, Lc, Bo	Potentially Highly Erodible	153.5 acres (73.8 %)
BkB, BkC, PkB, SkB, PdB, BhB, BuB, BhB, BuC2	Not Highly Erodible	53.5 acres (25.7 %)

Table 2B. Soils of the East Pond upland: defined as 50 to 300 m upland, a perimeter area of approx. 784 acres (excluding submerged land) *Source: USDA digitized Soil Surveys, Kennebec & Somerset Counties*

Soil Series & Sub-Series	Erodibility	Prevalence: in acres and % of lake perimeter (excluding wetlands)
BuB2, SkC2	Highly Erodible	13.4 acres (1.7 %)
RdA, Sc, ScA, RF, Pa, Lc, Bo, Wa	Potentially Highly Erodible	167.1 acres (21.3%)
BkB, BkC, PkB, SkB, PdB, BhB, BuB, BuC2, CnCm StB	Not Highly Erodible	616.9 acres (78.6%)

Nesbeda (2004) describes the lake bottom sediments:

East Pond bottom sediments can be characterized as an organic rich, moderately well-sorted silt. This is consistent with the lake's glacial formation and subsequent Holocene history. Both the grain sizes present and their distribution are to be expected in a hydrodynamically low energy system. Also, the results of the grain-size analysis correlate well to similar studies conducted on Messalonskee Lake, the terminal lake in the Belgrade Lakes chain. [...] The absence of clay-sized clasts in both the bottom sediments and suspended load of East Pond is unexpected, while also consistent with

> Messalonskee Lake. It is suspected that a miniscule clay fraction may exist in East Pond sediments; this clay fraction is too small to be represented in the small sample size analyzed by the LPC. Also, given that East Pond is the first lake in the chain, it is possible that clay-sized particles were flushed through and deposited further down-stream of the Belgrade Lakes. Sediment in the water column is likely re-suspended/entrained bottom sediments; the low concentration of suspended load in the water also reflects the low-energy within the lake.

East Pond can be considered to have moderate to high habitat value compared to other lakes and ponds in Maine. It is home to at least 13 fish species (PEARL database), of which three might be considered to have moderate to high sensitivity to water quality: brown trout, rainbow smelt, and smallmouth bass. The pond is also habitat for American eel (*Anguilla rostrata*). Sedge wren (*Cistotharus platensis*), a State endangered species, has nested at a location on the west shore of East Pond. Another rare animal occurrence is on the east shore. The Serpentine Stream marsh at the pond's outlet is habitat for bald eagles, a federally endangered species. There were at least two pairs of eagles fishing in the stream in the winter of 2006 when the fast-flowing stream remained ice-free. The entire Serpentine Stream marsh is classified by the Maine Department of Inland Fisheries & Wildlife as Wading Bird and Waterfowl Habitat. DEP has regulated activities in, on or over these habitats to the extent these habitats were located *within* another protected natural resource, such as a freshwater or coastal wetland, since September 17, 2005. DEP has regulated activities in, on or over these habitats, located *outside* other protected natural resources, to the extent they meet criteria adopted in Chapter 305 since June 8, 2006.

The population of Oakland and Smithfield living within the watershed was estimated to be 1,142 in 2000 (Colby 2000 in TMDL 2001). Given that the population growth of these two towns has been 2 to 12% over six years, the current watershed population can be extrapolated to be 1,165 to 1,279. The majority of the lake population is summer residents; although more camps are being converted to year-round homes, as is the case throughout the state. Added to the resident population is the yearly flux of approximately 1,000 persons who are visitors or staff at the four large summer camps.

II. EPA - REQUIRED ELEMENTS

a) Pollutant load causes and sources

Sources of phosphorus in East Pond are both external or internal. *External loading* includes both natural and man-made sources external to the lake, i.e., atmospheric deposition and nutrient transport over land by stormwater flows and eroding soils. *Internal loading* is equated with release of phosphorus into the water column from lake sediments as organic matter decays. An internal phosphorus load accumulates in the lake bottom over time when inputs from the land exceed outflow and long-term burial in sediment (1 m or more). It is possible that the past agricultural history and watershed development of East Pond has led to an excess of phosphorus in the sediments. Continuing algal blooms may also increase the organic phosphorus content of the lake bottom over time (see explanation under Internal Loading).

An examination of the source of pollutants should be framed by the relative importance of internal vs. external phosphorus loading. The 2001 TMDL estimated that the relative internal and external loads were as follows: External phosphorus of 483 kg/yr + Internal phosphorus loading of 400 kg/yr = total phosphorus load of 883 kg/yr. This estimated total phosphorus load far exceeds the lake's estimated load capacity of 389 kg/yr.[1] The entire external phosphorus load (both natural and man-made) would have to be eliminated in order to reach the recommended phosphorus limit. Or, the equivalent of the entire internal load would have to be eliminated to reach the water quality target. The feasibility of addressing either the external or internal load (or both) will be discussed in Section III.

<u>Internal Loading</u>

The 2001 TMDL reported an estimated internal phosphorus load of 400 kg/yr. The internal load is due to past land uses (including agriculture) plus the accumulation of organic phosphorus in the lake bottom sediments as algae in the water column dies off and reaches the bottom. As organic matter in the lake bottom decays, the phosphorus is released into the water column. The

[1] The loading capacity of 389 kg P/yr was estimated based on a phosphorus retention model that links the target concentration of phosphorus for water quality (15 ppb) to a maximum phosphorus load based on watershed area, lake depth, flushing rate and a retention coefficient [see model description in 2001 TMDL]

more phosphorus available to the algae - either through release from the lake sediments or from polluted runoff - the more algae that will accumulate in the organic matter that finds its way to the lake bottom. Thus the internal load is determined both by the history of phosphorus concentrations in the lake and the continued deposition of phosphorus from either dying algae or runoff from land.

The Colby research team has studied possible contributors to algae blooms in East Pond since 2000. The research question can be summarized as: Are the observed algal blooms correlated with stratification and can this be accurately modeled? Factors studied include water and air temperature, wind direction and speed, cloud cover, precipitation, water visibility (light penetration), lake and stream hydraulics, and especially the nature and quantity of phosphorus in the sediment. The 2005 data[2] reveal that a thermocline forms between days 200 and 220 (July 18 - August 7) and inverts around day 225 (August 12). At that point phosphorus is released from the sediment and mixes in the water column, resulting in algae blooms. The phosphorus in the bottom has built up over many years. Chemical analysis of the lake bottom sediment indicates that the organic carbon is mostly algal-derived rather than from organic matter from land (Brown 1998 in Nesbeda 2004). The organic fraction of phosphorus is larger than the inorganic fraction, which also indicates that the internal phosphorus loading is from decaying organic matter.[3]

The seasonal release of sediment phosphorus into the upper water column - causing algal blooms - is thought to be brought on by inversion of the thermocline in late summer. Data collected by the Colby College research team supports this hypothesis. The average phosphorus content of the lake sediments is 0.048%, which can be characterized as high relative to other lakes in Maine that have been studied for sediment phosphorus. Nesbeda observes that "the high sediment concentration of phosphorus in the sediments of East Pond is sufficient to support algal blooms indefinitely." This high concentration of phosphorus in the lake sediment would not pose a problem for water quality if it were not for the seasonal stratification AND mixing. More precisely,

[2] 2006 data is similar, thermocline was longer in duration.

[3] Stochiometric analyses of the sediment, including the "Redfield ratio" are discussed in detail by Nesbeda (2004). **Note** that it is also possible that some of the organic P is P that was released and then recomplexed in the organic matter (R. Bouchard, pers. comm.)

> There are two key factors controlling East Pond's bloom dynamic. First, there is a precondition of water-column stratification that allows for phosphorus release from the sediments into the bottom water. Second, there is a trigger to vertically mix the water column and transport the P-rich bottom water to the lake surface. Both of these factors are needed for a bloom to occur. Without the precondition, the phosphorus would be trapped in the sediments. And, without the trigger there would be no vertical mixing trapping the lens of phosphorus-rich water at depth. (Nesbeda 2004)

The 'precondition' of stratification is caused by rising temperature in the early summer and increased oxygen demand in the lake bottom. Small-scale stratification is required as well. The 'trigger' that causes the inversion - or mixing - is the slow increase in bottom temperature combined with the rapid cooling of the surface water in late summer. Wind shifts and/or rain might hasten this cooling but are not thought to be necessary as a trigger (WKing, pers comm). The anoxia of the deepest waters results in an absence of the iron oxide block to phosphorus release into the water. Recent data (2006) from Colby reinforce this hypothesis and indicate that East Pond may in fact be experiencing a feedback loop, in which yearly algal blooms increase in severity as the sediment P load from decaying algae also increases.

There is uncertainty around the impact of backflushing from the outlet (Serpentine Stream) on water quality in the pond. Colby research in 1999 and 2000 reported conflicting results (as cited in the TMDL). On the one hand, backflushing following storms of greater than 2.5" over 6 hrs could increase nutrient loading vs. some evidence that the stream wetlands are absorbing phosphorus and therefore backflushing has a neutral or even beneficial impact on East Pond nutrient concentration. The effect - whether positive or negative - of the Serpentine Stream on water quality of the lake can probably be considered very small compared to the much larger internal and external loadings of the lake itself (R. Bouchard, pers. comm.).

External Loading

Under the TMDL methodology, external phosphorus loading is divided into "Cultural" or human-caused, and "Non-cultural" or mostly natural sources. These sources are detailed in the following two tables. For more information, refer to the 2001 TMDL Report. (Maine DEP Report #DEPLW 2001-10).

Table 3A. Cultural phosphorus exports in the East Pond watershed*. Phosphorus coefficients from literature cited in 2001 TMDL; output is summed here. Land use types are ranked from greatest to least contributor of phosphorus, regardless of percent land area. Farmland was considered negligible and not included.*

Land Type	**Total Area (hectares)**	**Phosphorus coefficient (kg/ha)**	**Phosphorus Export (kg)**	**Notes**
Shoreline Development	185 *	0.52 to 0.98, depending on land use sub-type	148	This land use class includes low-density residential, high-density residential, and summer camps; figures are averaged across these sub-types
Non-shoreline Development	102	ranges from 0.4 to 2.9	91	Includes land use types: low-density residential, timber harvesting, non-shoreline roads
Shoreline roads	14	3.9	55	
Septics (residential & commercial)	1	N/A	47	EP Model used
TOTAL	**302**		**341**	

**A comparison of aerial photographs from 1998 and 2003 indicate no significant increases in land clearing; therefore we proceed under the assumptions of the 2001 TMDL.*

Table 3B. Non-Cultural phosphorus exports in the East Pond watershed*. Source: 2001 TMDL.*

Land Type	**Total Area (hectares)**	**Phosphorus coefficient (kg/ha)**	**Phosphorus Export (kg)**
Forests	630	0.04	25
Wetlands	93	0.02	2
Scrub-Shrub	98	0.03	3
SUB-TOTAL	*821*	--	*30*
Atmospheric	698	0.16	112
TOTAL	**1519**	**--**	**142**

We can focus our attention on the first table for the reason that -from a management perspective- there is not much to be done about the "non-cultural" nutrient loading. First of all, the natural sources of phosphorus - forests and wetlands - are desirable in and of themselves; they are the 'given' in this problem. Secondly, the atmospheric deposition includes industrial pollution that can come from a large area at a great distance (out of state) and is thus more difficult to measure and control. The plausibility and legality of "policy BMPs" to control atmospheric deposition of aquatic pollutants was explored by the International Joint Commission for the Great Lakes (1999). Phosphorus is less suitable for this sort of regulation than is mercury, for example, because it comes from many more sources.

In summary, it appears that Shoreline Development is *at present* the priority category of concern for phosphorus loading in East Pond. However, as development moves upland into more available areas, erosion control practices must follow. This can be addressed with site work for existing sources and town regulation to limit or prevent future sources [see discussion below under Section e) *Phosphorus reduction measures*].

b) Load reduction estimates

We examined in some detail three different approaches to phosphorus load reductions in East Pond. These are:

1*) In-lake treatments to reduce internal loading.* The methods assessed were chemical treatment, dredging, mixing and/or aeration, hypolimnetic withdrawal, and biomanipulation. (This last approach is in fact underway in 2007).

2) *External load reductions through BMP work*, which in this case is mainly shoreline and camp road erosion control work, and

3) *A combination of in-lake treatment and BMP work*. BMP work should include both remediation of existing sites and regulation of new development; i.e., local policies need to be developed in time for new development in the immediate and near future.

Increasing the flushing rate of the lake is not a recommended option for East Pond (see *Appendix* for details).

Using the available data from the scientific and lake management literature, along with local knowledge and data collection, we estimated both the probable physical outcome of each approach and the costs. There appear to be very few technical reviews of lake treatments from a practical standpoint, i.e., review of enough projects of a similar type in order to derive an average efficacy and cost for lakes of a certain type. We have made assumptions and estimates based on the best available information from a wide variety of sources. More detailed descriptions of the candidate approaches and estimates of efficacy and cost in East Pond can be found in the *Appendix.*

Findings

In-lake methods. At least one of several possible in-lake treatments - dredging - can be easily eliminated in the case of East Pond. The cost of dredging is clearly prohibitive. Dredging would be a more desirable approach if the lake also needed deepening and/or there were toxic pollutants that needed to be removed. Physical factors of the lake also make both hypolimnetic withdrawal and bottom aeration unfavorable approaches in East Pond.

By a process of elimination alum treatment appears to be the most promising approach, given the success of past alum treatments in Maine and the relative lack of information on the other methods as applied to actual in-lake restoration projects. A decision to move forward with alum treatment should only be made based on a more detailed calculation of output and costs, using data from the site. Contractors can be requested to supply representative sediment cores and chemical analyses on which to base a cost estimate.

A diagnostic study is recommended for each of the remaining two alternative in-lake treatments - mid-depth air-mixing and biomanipulation. A field trial of biomanipulation will in fact be underway in 2007. As well, the Colby College lake research team is utilizing a numerical model that will help determine the feasibility and cost of mixing devices (both mechanical and air-mixers) to disrupt stratification.[4] This approach appears promising in terms of the actual effects on lake chemistry and air-mixing presents less of a logistical problem and cost than do the mechanical mixers. In the overall planning budget for East Pond, funds should be allocated for these diagnostic studies.

BMP approach. A third-phase of the '319' non-point source reduction projects will begin in the East Pond watershed the spring of 2007. Typical priority sites are eroding or failing camp roads, miscellaneous property erosion near the lake and eroding or overly exposed shoreline. Best management practices (BMPs) that have been proven effective in past projects include culvert replacement and armoring, road rebuilding (with added protection such as rock-lined ditches and

[4] Determination of best vertical placement of a mixer or bubbler device is key to success. See Appendix for details

basins), and rock armoring of eroded shoreline in combination with buffer plantings. Work is carried out through cost-share agreements with the landowners.

According to the loading estimates of the TMDL and the data from recent 319 projects (both at East Pond and elsewhere in Kennebec County), site-based BMP work alone is not a realistic strategy for effectively reducing the phosphorus load to acceptable levels in East Pond. It is estimated that a total investment of $2 to $3 million would halve the external load (from approx. 480 kg P/yr to 240 kg P/yr) after ten years**.** It is assumed that this reduction in the external load would also lead to a reduction in the internal load but this would be difficult to estimate. The 240 kg P/yr estimate of external load reduction approximates one-half of the total annual load reduction recommended by the TMDL (500 kg/yr). Therefore, in order to reach the goal of lake recovery, the internal load would also need to be significantly reduced - from 400 kg P/yr to 140 to 150 kg/yr. The progress made in external load reductions would also have to be maintained.

c) Phosphorus reduction measures (including NPS management)

Based on the available data at this time (2006) we can recommend a combined approach of in-lake treatment of a large area of East Pond (area of highest P concentration) coupled with continued erosion control work in the immediate drainage as described above under Section b). In-lake treatment can substantially or almost entirely eliminate the internal P load in East Pond. However, the long-term success of this approach depends on continued control of external P sources. If external loading grows to such an extent that the increase in external load approaches the original internal load, the gains made from in-lake treatment will be lost. Septics are also a significant but poorly quantified external source of phosphorus and should be assessed by the towns. A simple calculation of number of dwellings less the number of updated systems (data available at the town office) will indicate the number of households that may need assistance in updating their septic systems.

It appears, based on the TMDL and local knowledge, that Shoreline Development is *at present* the category of concern for phosphorus loading in East Pond. However, as development moves upland into more available areas, erosion control practices must follow. This can be addressed with site work for existing sources and town regulation to limit or prevent future sources.

It is recommended that the towns of Smithfield, Rome, and Oakland work towards adoption of a phosphorus control ordinance. Each town can require - through revisions to its subdivision ordinance - that a developer perform a phosphorus load estimation based on Maine DEP's standard methodology (Maine DEP 2002). The project should also submit a site erosion control plan devised by a neutral party. Commercial projects should also fall under the same requirement. If a proposed development exceeds the recommended per-acre phosphorus allocation the developer should be required to implement BMPs on site to address the excess P loading or mitigate within the direct drainage of East Pond. The overall goal is to reduce the contribution of P by new development by 0.5 ppb. The total P load contributed by future development can be estimated based on a "build-out" model of the watershed.

Numerous unregulated single-lot developments can have as great an impact on water quality as regulated subdivisions. The East Pond towns can look at ways to monitor single lot development through the building permit process and ensure that adequate BMPs are in place before, during, and after construction. This can be combined with regular education and enforcement around existing shoreland zoning. The role of the Code Enforcement Officer could be more oriented towards technical assistance to landowners and builders before building instead of assigning fines after the fact. Raising funds to pay for this staff time will be a challenge - some of the cost can be captured in permit fees, both for subdivisions and single lot developments.

Although phosphorus control ordinances exist in several Maine towns in the southern counties, their adoption has been resisted in other communities. To prepare for an ordinance that makes sense for the East Pond communities, the water quality problems need to be presented to the town officials. Simplified model ordinances can in time be presented. It should be clear to everyone who will be affected by the ordinance and under what circumstances. The overall benefit should be quantified as much as the data will allow; for example, it is estimated that phosphorus ordinances can reduce the phosphorus load by as much as 30 to 50 %. The local lake associations (BRCA and East Pond) have an important role to play in advocacy and education. As town officials come and go over time, there needs to be the institutional knowledge and momentum for restoring water quality through town policy.

Table 4. Summary of key elements of the watershed-based plan for East Pond.

Treatment type	Specific action	Expected P reduction at end of 10 yrs	Estimated cost
Primary In-lake treatment	▪ One-time alum treatment of 1,300 acres (75% lake bottom area)	320 kg P/yr	$1,000,000 to 2,000,000
Secondary In-lake treatment	▪ Biomanipulation (perch removal) and/or destratification through air-mixing	(pending)*	(pending)*
BMP: remediate priority erosion sites	▪ 250 priority erosion sites fixed over 10 years	240 kg/yr	$2,800,000 to $3,000,000
BMP: local land use policy & enforcement	▪ Site development rules; more enforcement ▪ Assistance and/or enforcement of septic replacement	**	**
TOTAL		**560 kg/yr**	**$3,800,000 to $5,000,000**

** efficacy and cost estimates are pending assessments underway in 2007-2009*
*** DEP model phosphorus standards could be used with land use assessment to calculate phosphorus load abatement; cost of policy is considered non-quantifiable, carried out by residents, volunteers, town officials*

d) Technical & Financial Resources Needed

The estimated total cost of implementation is between $3,800,000 and $5,000,000. This total includes actual cost of practice implementation, i.e., alum treatment cost, BMP implementation cost, as well as some of the attendant cost of project publicity, public education, and project administration. A more definite cost could be obtained once a contractor's estimate is requested for the alum treatment, and once the 2007 round of NPS site work is completed and reported to Maine DEP. Note that the total estimated cost is cash expenditure only and does not include significant volunteer time of the community (as water quality monitors, stewards, and educators) and the professional time of the Maine DEP staff and researchers at Colby College and the University of Maine. We have not attempted to quantify the total of this in-kind assistance.

The following are potential funding sources to support the actions listed in the 10-year implementation plan:

- Maine DEP 319 program. The 319 program for non-point source (NPS) remediation and prevention is partly funded through Section 319 of the Federal Clean Water Act. The federal program is managed by the EPA and an annual fund is allocated to the states, which administer a competitive grant program. Site work is accomplished through cost-share agreements with private and public landowners. Education and outreach is also a major component of 319 work. A third phase of the 319 program in East Pond is set to begin in the spring of 2007.
- Maine DEP SEP program. Payments from consent agreements are matched with cost of proposed environmental projects.
- EPA grants: various grant programs under the Office of Watershed Management.
- Maine Institute of Technology (innovative technology such as rigging the aerator)
- Maine Outdoor Heritage Fund (biomanipulation). Proposals are usually invited every March and September.
- The Funds to Preserve East Pond is a funded by community member contributions and is managed by the East Pond Association. Funds are ear-marked for water quality research and restoration. Out of this fund the Association has been able to give some support to the Colby College lake chemistry research on East Pond and collection of water quality data used by the Maine DEP.

e) Public Information & Education

Public information and education around NPS and other water quality issues will be carried out by the following groups:

- Maine DEP - through, for example, the public education around the perch removal project, and Lake Smart landowner education program.

- Belgrade Region Conservation Alliance (BRCA) through the new BRCA Lakes Trust (described below),
- Kennebec County Soil & Water Conservation District - through 319 work, and
- the continued outreach work of the East Pond Association volunteers.

The East Pond Association is an unusually active and energetic lake association. In addition to all the community outreach work typically undertaken by a lake association, this small but dedicated community group has committed time and money to support the research and monitoring programs of much larger organizations. They were also one of the first lake associations in the region to develop and deploy a youth conservation corps. The Association became a 501(c)(3) non-profit corporation in 1997, and the membership has grown to 160 households in the watershed. The Association organizes itself into a number of Task Forces to take on specific activities: Camp Roads, Buffers, Septic Systems, Water Quality, and Milfoil Prevention. The Association is funded through voluntary donations from community members and annual requests for support to the towns of Oakland and Smithfield. The Association Board members approached Colby College to initiate what is now a well-developed research partnership and have also had contact with the University of Maine to further the data collection in East Pond and diagnostic studies of phosphorus control methods.

The Belgrade Region Conservation Association (BRCA), a well-established land trust in the area, has been involved in lake water quality for some time, including management of '319' non-point source projects. In early 2007, this movement culminated in the formation of the BRCA Lakes Trust. Leaders from each of the seven lakes, including East Pond, have committed to working within the structure of the BRCA to achieve shared goals for water quality. The three goals of the Lakes Trust are:

1. *Water quality restoration,* which includes 319 and non-319 erosion control projects, strengthening of local code enforcement, and support of the local Conservation Corps.

2. *Building lake association capacity,* including technical ability and personnel. BRCA will provide fundraising leadership and assist individual lake associations through business and membership services.

3. *Creating public support to fund water quality protection*, which includes an annual capital campaign and funding for long-range strategic planning. BRCA will convene a Watershed

Working Group comprised of local officials, water quality professionals, and public stakeholders.

Membership in the BRCA Lakes Trust does not preclude the lake associations from taking the initiative in their own lakes; rather, the Lakes Trust is intended to assist the lake associations in their organizational growth and development. It is expected that the newly formed BRCA Lakes Trust and the East Pond Association will work closely together in the coming years.

The East Pond Association and the BRCA Lakes Trust have reviewed this Watershed Based Plan and will use it to inform their decisions on support and funding of different efforts.

f) Implementation Schedule (including NPS measures)

A combined approach of alum treatment plus continued BMP work (both at existing problem sites and to curtail loading from future development) is recommended to address both the internal and external P loading in East Pond. (See previous section for details of expected treatment results and costs). The following implementation schedule is proposed for the ten-year period 2007 - 2017.

East Pond Ten-Year Plan for Water Quality Improvement

Goal: TMDL target for annual phosphorus reduction (500 kg/yr) is reached within 10 years

Year 1
2007

- East Pond Watershed Based Plan is released
- BRCA has reported results of East Pond Phase II 319 project
- Colby College: feasibility and cost assessment of air-destratification ("mid-depth bubbler") based on numerical modeling
- DEP/East Pond: first year of trial perch removal project
- DEP: using existing or new core data, request for estimates on alum treatment
- Kennebec SWCD/East Pond: first year of two-year Phase III 319 project
- East Pond/DEP/BRCA: use 319 and regular meetings to begin devising simple P ordinances to propose to towns
- Colby/East Pond/VLMP: continue water quality monitoring

Year 2

- DEP/East Pond: second year of 3-yr trial of perch removal project

2008

- Kennebec SWCD/EAst Pond: second year of two-year Phase III 319 project
- Colby/East Pond/VLMP: continue water quality monitoring
- DEP: based on 2007 studies and cost estimate, write proposal for alum treatment, find funding (in coordination with East Pond, BRCA)
- First phosphorus control proposal presented to town officials
- East Pond/BRCA: depending on results of a new site survey, write proposal for final East Pond 319 project

Year 3

2009

- Final Report of East Pond Phase III is due.
- East Pond/BRCA: w/Kennebec and/or Somerset SWCDs: begin implementing phase final East Pond 319 project (if funded); renewed emphasis on site controls and assistance for new development (i.e., 'old' sites will have been more or less addressed at this point)
- Colby/East Pond/VLMP: continue water quality monitoring
- Third year of 3-year field trial perch removal
-

Year 4

2010

at this point RESULTS are available for:

- 3-yr perch removal project
- 2-yr 319 phase III project (BMP work) + 1st year of final 319 project
- town response to proposed phosphorus control standards last two years
- alum treatment proposal finalized, funding secured?
- field trial of mixers/aerators

East Pond Lake Assocn. and BRCA to convene a **technical conference** to review these results and decide on appropriate in-lake treatment: whether to proceed with alum or continue with biomanipulation and/or mixing. *IF* alternative approach(es) can estimate a quantity of phosphorus reduced and if this quantity is equal or greater than amount estimated from proposed alum treatment than alternatives to alum could be recommended.

Group to write a follow-up to the 2007 Watershed Based Plan

- Colby/East Pond/VLMP: continue water quality monitoring

Year 5

2011

- Funding secured for in-lake treatment(s) recommended from previous year
- **Implementation of the chosen in-lake treatment (alum or alternative)**
- Final Report for Final East Pond Phase 319 project
- Colby/East Pond/VLMP: continue water quality monitoring

Year 6

2012

- Continue lake water quality monitoring
- Continue education to towns and landowners

Year 7

2013

at this point, cumulative RESULTS are available for:

- diagnostic studies from 2010 and technical groups' recommendation
- estimated phosphorus quantities and actual costs from three 319 cycles from 2004 through 2011

- estimated phosphorus quantities and actual costs from the in-lake treatment

- **Technical group** to reconvene and compare results with projections from 2007 Watershed Based Plan, make modifications as necessary.

Year 8
2014
- Continue lake water quality monitoring
- Continue education to towns and landowners

Year 9
2015
- Continue lake water quality monitoring
- Continue education to towns and landowners

Year 10
2016
at this point, cumulative RESULTS are available for:
- 10 years of water quality data since Watershed Based Plan first published
- 4 years of water quality data since completion of 319 cycle (3 phases)
- 9 years (possibly) of water quality data since inception of annual perch removal activity
- 4 years of water quality data since in-lake treatment
- 9 years of advocacy to strengthen town planning and land use ordinances
- data assessment and recommendations from two technical conferences (2010 and 2013)

g) Measures of Success - Implementation

The different elements of the Watershed Based Plan can be assessed for completion and effectiveness by using the following performance indicators:

Indicator G-1a: *Annual and total number of sites completed*

This information is reported by project implementors to Maine DEP semi-annually and at the completion of 319 projects. Progress is measured against the goal of 250 sites total from 2007 through 2016 or 25 sites per year on average. Actual site costs are reported. Average cost per site and per pound of phosphorus will also be assessed. Party to assess progress: DEP 319 administrators in co-ordination with 319 project partners.

Indicator G-1b: *Cost effectiveness of external load reduction* ($/kg P)

This is readily obtained from regular 319 project reporting to the Maine DEP. Site reports show cost of implementation and estimated quantity (lbs) of P reduced. An average and median unit-cost of a kg of P can be obtained. *Party to assess progress*: Maine DEP and 319 implementors

Indicator G-2a: *Implementation of primary lake treatment*

Benchmarks towards actual implementation of the alum treatment will be devised by DEP staff.

Indicator G-2b: *Cost effectiveness of internal load reduction* ($/kg P).

This can be calculated for alum treatment once complete, possibly for biomanipulation once complete, and possibly for mixing/aeration if this is pursued. *Party to assess progress*: Maine DEP and Colby College w/ assistance from East Pond Assocn. & BRCA

Indicator G-3: *Assessment of secondary lake treatments*

Further assessment of efficacy and feasibility of the two candidate alternative treatments: biomanipulation through fish removal, and water column mixing. DEP technical staff will carry out the assessment of biomanipulation, in coordination with academic partners (UMaine, Colby College). Colby College will report to lake group the results of mixing assessment.

Indicator G-4: *Local policy adoption* (benchmarks)

The community groups (BRCA, East Pond Assocn.) can yearly or biannually assess progress in each of the three towns with simple benchmarks, e.g., presentations are made to towns, a draft ordinance is reviewed, ordinance is ready for town vote, ordinance is approved, ordinance is adequately enforced, increased awareness and compliance among landowners and developers.

h) Measures of Success - Water Quality

Indicator H-1: *Total estimated phosphorus load reduction* (kg P/yr).

External load reductions from BMP work is regularly reported in the 319 projects. Any additional, non-319 work could be collected by the East Pond Association and compared with typical 319 work. This total can be added to the total load reduction from the in-lake treatment, once it is executed. Alum treatment results are readily quantified. Perch removal may also result in quantifiable results. The total should be compared annually to the goal of 500 kg P/yr (the reduction goal set in the TMDL). *Party to assess progress*: Maine DEP and 319 implementors

Indicator H-2: *Actual phosphorus concentration* (ppb)
Water column phosphorus concentration is recorded each year by the Volunteer Lake Monitoring Program and Maine DEP. Annual results should be compared against the goal of 15 ppb. *Party to assess progress*: Maine DEP in coordination with VLMP and East Pond Assocn.

i) Monitoring Progress of the Plan

Both the parties responsible and the method for monitoring progress in implementing the different elements of this watershed based plan - and corresponding pollutant load reduction - have been listed under the different performance indicators above.

REFERENCES

Maine DEP 2001. East Pond (Somerset & Kennebec Counties) Total Maximum Daily (Annual) Load. Final Lakes TMDL Report # DEPLW 2001-10. September 6, 2001.

Maine DEP 2002. Nutrient Criteria Adoption Plan. February 2002.

Nesbeda, Robin, 2004. Sedimentological and geochemical characterization of East Pond, Belgrade Lakes watershed, central Maine. (M.S. Thesis, Colby College)

PEARL database. University of Maine source for environmental information in Maine. [http://pearl.spatial.maine.edu/]

Personal communications: Maine DEP: Roy Bouchard, David Halliwell, Melissa Laser; East Pond Association: Jerry Tipper; Colby College: Whitney King, PhD.

APPENDIX to East Pond Watershed Based Plan

Lake Stats in Brief

Name of Waterbody: East Pond
Intermediate drainage: Messalonskee Stream (HUC-10# 0103000310)
Larger drainage: Kennebec River (HUC-8# 01030003)
Location: west of the Kennebec River, borders Kennebec and Somerset Counties, Maine covers part of towns of Oakland, Rome, and Smithfield

Watershed area: 4,450 acres
Waterbody surface area: 1,716 acres = 694 ha.
Lake volume: 26 million m^3 (6,868,473,361 ga)
Maximum depth: 7.3 m
Flushing rate: 0.25 (once/4 yrs)

Analysis of Candidate Approaches to Load Reduction

We examined in some detail three different approaches to phosphorus load reductions in East Pond. These are:

1*) In-lake treatments to reduce internal loading*

2) *External load reductions through BMP work*, and

3) *A combination of in-lake treatment and BMP work*. BMP work should include both remediation of existing sites and regulation of new development; i.e., local policies need to be developed in time for new development in the immediate and near future.

Still another approach would be to increase the flushing rate of the lake - replacing nutrient-rich water with water of lower nutrient concentrations. We have not examined this option as closely as the others for the following reasons. Seasonal flow diversion from a nearby stream (as recommended, for example, in the Toothaker Pond 2004

TMDL) requires a ready input of fresh water near the lake, which is not the case in East Pond. Increasing the flushing rate through water level management at the outlet (Coffin dam) is not expected to have much effect in disrupting the annual cycle of thermocline formation and inversion. According to Jerry Tipper, Chair of the East Pond Water Quality Task Force,

> An initial review of the impact of water flow over the dam to reduce the phosphorus in the lake reveals that the way the dam is presently constructed, the largest flow possible makes only a nominal (albeit positive) impact on removing lake phosphorus. More evaluation is planned for next summer. (East Pond News, winter 2006)

APPROACH #1

In-lake treatments to reduce the internal load

The 2001 TMDL reported internal loading estimate but did not recommend manipulation. The East Pond Association, a local community group committed to improving water quality, has researched methods for delaying or reducing the seasonal phosphorus release from the sediments through an alum treatment (aluminum sulfate) and other in-lake treatments such as mechanical mixing or biomanipulation by removal of fish. The Association has enlisted the help of researchers at Colby College, the University of Maine, and the technical staff of the Maine DEP to help them understand how these methods works and the likely efficacy and cost.

1. Chemical Treatment: Aluminum

Description: Aluminum sulfate [$Al_2(SO_4)_3xH_20$] or "alum" is used to treat wastewater and stormwater before it is discharged to a lake or other water body. It has also been used to treat algae-prone lakes. Good candidate lakes are those that have had external phosphorus loads reduced to an acceptable (or achievable) level and that have a high internal P load from lake bottom sediments and low to moderate flushing. It is also recommended that alum be used on lakes with good pH buffering (Wagner 2004) or be used in buffered combinations. In Maine, four lakes have been treated with alum - Cochnewagan, Annabessacook, Chickawaukie, and Threemile - and three of these are considered successes (Toothaker TMDL). In each of the Maine lakes, alum was buffered to avoid toxic conditions.

The buffered aluminum forms particles which bind with phosphorus and other pollutants, causing them to come out of solution and remain in an inactive form in the sediment. The result is an "immediate" improvement in water clarity and quality and benefits to the benthic community in the receiving waters. The benthic community is benefited by better oxygen conditions in situations where extensive anoxia develops . This is due to lower production of oxygen-robbing organic matter and typically takes several years.

Efficacy: Actual efficacy of this treatment is estimated to be 80 to 90% (Welch & Cooke 1999). Therefore, estimated load reduction from this treatment alone is (0.8) 400 kg P/yr = 320 kg P/yr for the life of the treatment, which is expected to be 10 to 15 years. Factors that can jeopardize success of the alum treatment are: inadequate reduction of external loads, inadequate alum dosing or application, and disruption of the treatment by bio-turbation or wind re-suspension. Another limiting factor is the toxicity of Al to fish, which can be decreased or eliminated if pH is balanced properly to avoid high levels of ionic aluminum. A concentration of 50 ug Al/L or less is considered safe (Wagner 2004).

Cost:

A. Cost estimates based on project literature.. Actual costs in lakes average \$500 or more per acre (Welch and Cooke 1999, Wagner 2004). The average cost was \$500/acre; For a treatment area of 1,300 acres (roughly two-thirds of lake bottom area) the cost would be \$650,000+. Alternatively, Alum costs \$140/ton. Application requires 2.5 tons/acre = \$350/acre. Taking the higher estimate of \$500/acre; an alum treatment of East Pond would be over \$650,000 for a one-time treatment of two-thirds of the lake bottom.

B. Cost estimate based on Toothaker TMDL procedure. A more accurate estimate of the cost for alum treatment in East Pond can be obtained by following the method of alum dose estimation as described in the Toothaker TMDL (2004), which follows the method of Rydin and Welch (1998). Assuming that a similar dose of 40 g Al/m2 is required in East Pond (to be confirmed with a sediment analysis) and accounting for inflation since the 2004 estimate, the cost of an alum treatment in East Pond would be from $1,000,000 to $2,000,000 (R. Bouchard, pers. comm.). In this estimate the area treated is roughly 1,300 acres, which is the area of 9.5 feet depth or deeper. The expected longevity of the treatment is 10 to 15 years.

Other chemical treatments

There are a number of other chemical treatments that have not been used as widely as alum. Calcium hydroxide, calcium nitrate, and iron additions generally lack sufficient field data or are difficult to handle (see descriptions in Toothaker TMDL 2004, Wagner 2004). In the case of the calcium treatments, Maine waters are too low in pH to make these chemical treatments effective. Copper sulfate and peroxide have been widely used to provide short term or 'contact' control of algae during a bloom. Copper sulfate can be toxic to nontarget aquatic organisms and peroxide application is very expensive.

2. Dredging

Description: Dredging has been pursued as a phosphorus remediation in some lakes. The overall advantage of dredging over chemical treatments is that there is no introduction of foreign material. Dredging may in fact increase benthic diversity (Peterson, in Klein 97). A drawback is the need for a suitable dumping site. The three types of wet-dredging equipment used are: grab bucket, hydraulic, and pneumatic. Klein (1997) and Wagner (2004) reviewed each of these methods and reported the following advantages and disadvantage.:

Grab bucket: operates from shore or from a barge. Advantage: able to work in a confined area; least costly of dredging methods. Disadvantage: generates high turbidity, leaves uneven bottom contour. Downstream areas (in this case, Serpentine Stream and wetland)

must be protected from sediment flow. *Hydraulic*: a more complex equipment, sediments are removed by suction. Advantage: minimal shoreline disturbance and reduced turbidity *if operated properly.* Disadvantage: more costly than basic excavation (grab bucket); requires more containment area for dewatering the sediment. *Pneumatic*: similar to hydraulic but uses hydrostatic pressure to pump the sediment. Advantage: powerful enough to remove sediments with high solids content
Disadvantage: more expensive.

Efficacy: In order to be effective, an adequate number of sediment cores would need to be examined to determine the necessary depth of sediment to dredge. Even so, reduction of P in treated area will always be less than 100% because of turbidity, some spillage and runoff back into pond.

Cost: The cost of wet-dredging is between \$15 and \$25/cubic yard, including disposal (Wagner 2004). If the area of 1,064,930 m2 (center of lake) is dredged to a depth of 20 cm (0.2 m); then the total volume of sediment treated is 212,986 m^3 or approximately 278,575 cubic yards. The expected cost of dredging East Pond is therefore over \$4 million. This is within the range of actual costs of dredging projects reviewed in the literature.

3. Mixing: Mechanical (e.g., SolarBee®) and Air-Mixing ("Bubblers")

Description: Mixing ("artificial circulation") can be achieved by a variety of mechanisms in a lake this size, including layer aeration with or without heat transfer, diffusion bubblers, and physical entrainment/water movement through low velocity lifting mechanisms such as SolarBee®. It is estimated that between 5 to 20 SolarBee® units would be needed to mix a sufficient water volume in East Pond to prevent the seasonal thermocline and inversion (W. King, pers comm). Air-mixing is another method for destratification. An off-shore pump delivers oxygen through an underwater pipe to a bubbler unit. In either case, the mixing units should operate from ice-out (April) to winter (Dec).

Efficacy:. The mixing could result in near-total elimination of seasonal release of phosphorus from the sediments or it could have moderate to no impact. A numerical model currently being developed at Colby College will be able to estimate the volume of water that needs to be mixed in order to disrupt thermocline formation. Notwithstanding the cost of set-up, the surface-placed mixing units (e.g., SolarBee) would need annual placement and maintenance, may be prone to vandalism, and could draw complaints of being unsightly or a hazard to boaters. Air-mixing or "bubblers" would be more appropriate to the locale. There are few reports of efficacy; one air destratifier in an Australian reservoir reduced internal phosphorus by 85%. EPA reports highly variable results. In the case of East Pond the bubbler probably should not be set on the lake bottom because the substrate is 'gelatinous' in texture and easily disturbed. Bottom-set bubblers would be more appropriate for water bodies with more solid substrates and thicker thermoclines. A bubbler with an outlet hose positioned mid-depth would be more suitable. The Colby model should be able to report best vertical positioning.[5] As the maximum depth is only a little over 7 m, the system would not require a very large pump to deliver high pressure (not more than 1 atm). Control over air flow rate and proper vertical positioning will increase efficiency. In addition to de-stratification and subsequent disruption of the algae bloom cycle, bubblers give the added benefit of oxygenating the water.

Cost:

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[5] DYRESM is a one-dimensional hydrodynamics model for predicting the vertical distribution of temperature, salinity and density in lakes and reservoirs. It is assumed that the water bodies comply with the one-dimensional approximation in that the destabilising forcing variables (wind, surface cooling, and plunging inflows) do not act over prolonged periods of time. DYRESM has been used for simulation periods extending from weeks to decades. Thus the model provides a means of predicting seasonal and inter-annual variation in lakes and reservoirs, as well as sensitivity testing to long term changes in environmental factors or watershed properties.

Mechanical Mixers: Assuming that surface-placed mixing units are not needed throughout the lake but only in the lake center, the number of units needed is estimated to be anywhere from 5 to 20. Initial cost: purchase and set-up = $25,000 each X 5 to 20 = $125,000 to $10,000,000 (does not include replacement cost in the event of damage or theft). Annual operating costs are unknown and may be considerable. Operational costs (not including replacement cost of the machinery) should include labor to place and remove the units each spring and winter, storage, periodic inspection and repair. The units will also have to be lit for boaters' safety at night.
Bubbler(s): No average costs found.

4. Bio-Manipulation: Perch Removal

Description: Fish reduction or biomanipulation is a relatively simple technique which has had some success in restoring water quality in Europe and the U.S. Midwest. The introduced game species white perch (*Morone americana*) was found to be the dominant consumer of zooplankton in East Pond (Maine DEP 2005). The removal of perch and other planktivores (yellow perch, black crappie, landlocked alewife) is expected to alleviate predation on the zooplankton population and thus allow the zooplankton (Cladocera) to injest more plankton and head off the seasonal algal blooms. The perch harvest being organized by the East Pond Association and Maine DEP in 2007 will be carried out by trained technicians. Adult fish will be live-trapped in the spring and juveniles in the summer. Transporting the harvested perch to a place suitable for composting is the major cost item. In its trial phase, the project is limited to one disposal location for permitting reasons, which eliminates the ability to recover costs of transportation by asking farmers to pay for the fish compost or haul it themselves.

Efficacy: On the plus side, fish can be considered easier to manage than direct manipulation of the water and sediment chemistry. Additionally, the perch removal will not permanently alter the current biological balance of the aquatic community. Perch populations are known to rebound after chemical eradication efforts. On the negative side, it is very difficult to tease out the effect of biomanipulation of a single species from the many other factors in the food chain. Longevity of the results is untested. While drastic removal of fish is more likely to deliver clear water, at high nutrient concentrations the algae may return (Lammens 1999). Gradual and continued fish manipulation may be more useful as a supplement to another treatment measure. The goal for the East Pond demonstration project is not total elimination of the algae blooms; rather, the goal is to bring the food chain to a balance that could be maintained with continued perch removal as sport fishery (D. Halliwell, pers. comm.)

According to the strategy set out by Jeppesen & Sammalkorpi (2002), East Pond would seem to be a good candidate for biomanipulation. The P concentration is rarely higher than 0.02 mg/l (20 ppb), the ratio of chlorophyl a to TP is high, and the lake is dominated by plankti-benthivorous fish. Successful management (removal) of juveniles as well as adults is needed.

Olin (2004) estimated that fish removal of 200 to 400 kg/ha every 3 years would "decrease considerably" the population of cyanobacteria. Jeppesen (2002) reported two different formula that estimate fish biomass correlated with TPP, based on actual fish sampling in European lakes. For a lake the size of East Pond (surface area 1,716 acres), these formulae estimate a planktivore fish biomass of 15,000 to 52,000 kg/ha/yr. Given that these formulae are derived from a set of lakes that are much more enriched than lakes in Maine (the Jeppessen data set includes lakes with TP of 20 ug/l and up - as high as 160 ug/l), we can expect that these recipes for fish removal are probably more drastic than what is required in East Pond. However, the East Pond perch removal project managers are projecting a trial removal of as many as 50,000 to 100,000 perch or enough to account for 75% of the perch biomass over 3 years. Fish will be caught by DEP technicians using a live trap-net. This allows for selective removal of species. Most of the catch is expected to be white and yellow perch adults.

Direct phosphorus removal is modest. The value in fish harvesting is the disruption or elimination of the algae bloom cycle, which contributes to the phosphorus load and is a nuisance in and of itself. We did not find any estimates of actual quantity of algae reduced corresponding to a fish harvest weight. The results of a fish removal experiment by Lammens (1999) indicate that 250 kg fish/hectare over five years resulted in 0.1 g P/m2; although this may not be entirely caused by the fish removal.

Fish removal coupled with aeration may have the added benefit of providing refuge for the zooplankton, as they can migrate to deeper waters (now oxygenated) to escape sight predation from the fish. (SWCSMH 2006).

Cost: In the case of East Pond, the catching of the fish is expected to be carried out either by DEP staff or volunteers. Thus the only other cost, besides planning and assessment, is disposal of the fish. Trucking to an area farm for composting is expected to cost between $2,000 to $4,000 per year. If proven successful in East Pond, the perch removals could in future years be carried out by contractors (such as bait dealers) and cost roughly $10,000 to $20,000 per year.

Biomanipulation equations

	Muller & Jensen	Jeppessen
Formula to estimate total fish biomass (kg/ha); TP in ug/l (=ppb)	9.42 TP ^0.62	
Formula to estimate biomass of plankti-benthivores only (kg/ha); TP in ug/l (=ppb)	**1.46 TP ^0.93**	**16.9 TP ^0.52**
Location	lakes in Denmark	lakes in Finland, Scandinavia, Holland
Lake condition	shallow, eutrophic	nutrient rich, cyprinid-dominated, successfully restored

Using the Muller & Jensen formula for planktivores, **1.46 TP ^0.93,** the required catch/year in East Pond would be: 1.46 (18 ^ 0.93) = **21.5 kg/ha**
Given a lake area of 1,716 acres = 694 ha, the catch in kg would be: **14,921 kg/yr**

Using the Jeppessen formula, with a much higher coefficient, **16.9 TP ^0.52,** the required catch/year in East Pond would be: **76.0 kg/ha**
Given a lake area of 1,716 acres = 694 ha, the catch in kg would be: **52,744 kg/yr**

5. Aeration

Description: Apart from their mixing ability, aerator devices can be set at any depth to increase the oxygen content of the water. Sondergaard et al (2002) reviews studies of hypolimnetic oxygenation, i.e., the delivery of oxygen to the hypolimnion - the deepest layer of water in a lake. In iron-rich lake bottoms (and this is the case in East Pond) the newly oxidized iron is again able to bind with phosphorus, preventing its release into the water column. Long-term oxygenation may eventually decrease the organic oxygen demand in the uppermost sediment as well as improving conditions for cold water species such as trout. In some cases the aerator treatment has been combined with iron addition to boost the phosphorus precipitation in the sediment. Lake bottom aerators have been in use and their efficacy studied since the early 90s. (See Cooke 93 in Sondergaard 2002). The oxygen can be delivered from the oxygen tank via a shore or raft-based compressor and hose system to the aerator at the lake bottom. To prevent damage from ice scour, the system must be removed in late fall or the shore components adequately protected.

Efficacy: Sondergaard (2002) cautions that more oxygen may be needed than what is initially estimated because sediment oxygen demand often increases when the oxygen is delivered. Also, if the phosphorus retention of the lake bottom is already near capacity, increasing oxidized iron will have little effect. In the case of East Pond, placement of a bottom aerator presents a problem. The layer of water that is anoxic (just above lake bottom) is not very thick, thus the bubbling would have to be on or very near the bottom. Bottom-placement of a bubbler presents a problem because of the unstable and gelatinous lake bottom, which would make it difficult to set the equipment properly and would also lead to resuspension of the phosphorus-laden sediment. US EPA also recommends against using this method in shallow lakes without a large hypolimnion. In the case of

East Pond, bubblers are better used as a way to mix the water column at mid-depth, and only secondarily as a way to oxygenate.

Cost: No comparable estimates found.

6. Hypolimnetic Withdrawal

Description: Phosphorus-rich water is withdrawn from the lake bottom via suction and discharged at the lake's outlet or elsewhere. The withdrawal requires a powerful pump on shore.

This method of phosphorus reduction had been practiced in Europe since the 1960s and in North America since the 1980s. If the volume of water withdrawn causes a noticeable drop in lake level this may be a concern for the community. Discharge of the withdrawn water may also be an issue for downstream water quality, because of the potentially high phosphorus and metals concentration, low oxygen, and occasionally hydrogen sulfide (in waters with extensive anoxic hypolimnia).

Efficacy: Withdrawal is most effective in lakes that experience sustained stratification, thus isolating the volume of phosphorus-rich water. In the case of East Pond, there are some doubts of the stability of stratification and the efficacy of discharging P due to the relatively low top- to -bottom gradient and the limited anoxic volume. Also, plumbing to achieve such a discharge is a real issue. Hypolimnetic withdrawal is usually done where the target water is close by and either the dam gate is bottom discharged or piping is minimal.

Cost: As with other in-lake treatments, cost of this approach is very site dependent. Length of pipe, flow rate and thus size of pumping unit, and management of the effluent would have to be estimated by an engineer. Average cost from projects cited in the literature ranges from $4,000 to $7,000 per hectare of lake area. East Pond cost could be $2 million or more.

Summary of In-Lake Treatments. Total cost assumes practice life of 10 years.

Treatment	**General Efficacy & Longevity (under suitable conditions)**	**Cost : assume 10-yr life**	**Critical Factors**	**Recommend for East Pond?**
1. Alum	Very high (up to 90% P reduction)	$400,000 to $1,600,000+	Depends on adequate dosage (determined from sediment chemistry) and area of application	**Yes**
2. Dredging	Very high	$4,000,000+	Control of turbidity and protection of downstream areas	**No**
3. Mixing (by mid-depth bubbler(s))	*Potentially* very high	?	For air-destratification, efficiency depends on adequate volume of air delivered and correct vertical placement.	(Yes, pending result of Colby model and engineer's cost estimate)
4. Biomanipulation	Highly variable	$6,000+	Trophic relations thoroughly researched; effect of age-class changes are controlled	Yes (first year of trial is underway, re-examine after 3 years)
5. Bottom Aeration	**?**	?	Most suitable for small impoundments; untested on lakes	**No**
6. Withdrawal	**?**	$2,000,000+	Requires stable stratification to isolate targeted volume of water; cost depends on lake volume, more economical for small lakes.	**No**

In treatment 1, target area is roughly one-half to two-thirds the surface area of the lake bottom, In treatments 3 and 5, target area is deep center of lake, 1,064,930 m^2

Treatment recommendation

At least one of the six possible treatments - dredging - can be easily eliminated in the case of East Pond. The cost of dredging is clearly prohibitive. Dredging would be a more desirable approach if the lake also needed deepening and/or there were toxic pollutants that needed to be removed. Hypolimnetic withdrawal would give some phosphorus withdrawal but is too dependent on the stability of the stratification. Physical factors are not favorable. The issue of polluted water discharge (whether into the Serpentine marsh or off-site) is also a significant obstacle. Bottom aeration is also not suited for the lake bottom in East Pond.

Alum treatment appears to be the most promising approach, given the success of past alum treatments in Maine and the relative lack of information on the other methods as applied to actual in-lake restoration projects. A decision to move forward with alum treatment should only be made based on a more detailed calculation of output and costs, using data from the site. Contractors can be requested to supply representative sediment cores and chemical analyses on which to base a cost estimate.

A diagnostic study is recommended for each of the remaining two alternative treatments - air-mixing and biomanipulation. A field trial of biomanipulation will in fact be underway in 2007. Colby College is conducting a numerical model that will help determine the feasibility and cost of mixing devices (both mechanical and air-mixers) to disrupt stratification. This approach appears promising in terms of the actual effects on lake chemistry and air-mixing presents less of a logistical problem and cost than do the mechanical mixers. In the overall planning budget for East Pond, funds should be allocated for these diagnostic studies.

APPROACH #2

External load reductions through BMP work

Actual load reductions in past years.

From 2001 to 2002 the BRCA implemented a NPS reduction project through the Maine DEP "319" program. The first phase of the project did not report pollutant load reductions - as this was not part of regular 319 project reporting at the time the grant was awarded. From 2003 to 2006, the BRCA continued the NPS work in a second phase. East Pond Phase 2 reported a total sediment load reduction of 11.4 tons from 19 sites. This represents approximately 4.6 pounds/yr of phosphorus. We combined these results with pollutant load reporting from similar 319 projects in Kennebec County (having similar topography, soils, and rainfall). From these multiple projects we can estimate the average sediment and phosphorus load reduction achieved from typical 319 site work (camp road repairs, culverts, moderate property erosion, lakefront stabilization).

319 projects include other site work besides road repairs. Miscellaneous property erosion that can be modeled as "gully" erosion is sometimes addressed. There are also numerous shorefront stabilization sites; however, we have yet to find a model for estimating sediment load reductions from this kind of work. (The difficulty lies in modeling wave action from wind and boat traffic). If, however, we use the pollutant load reductions from the 56 road sites and treat this data as the cost efficiency of typical BMPs in this geographic area (similar rainfall, soil type, topography, costs of material and labor), we have an average BMP site cost of $3,959, which results in an average sediment load reduction of 1.1 tons/yr/site and an average phosphorus load reduction of 1.1 lbs/yr/site[6]. The **"unit cost"** of a pound of phosphorus abated is on average **$4,412** +/- 2,191. Attempting to reach the TMDL goal of a reduction of 500 kg/yr of phosphorus could not be done solely through BMP site work for two reasons:

1) overall cost

[6] The apparent similarity between figure for sediment load and figure for phosphorus load is due to the fact that the phosphorus concentration in soil is approximately 0.0005. Soil type correction factors for four soil types vary from 0.85 to 1.0 (i.e., are close to 1 on average) The 0.0005 phosphorus figure is coincidentally equal to the conversion factor from tons to pounds. Hence 1 ton of sediment often translates to 1 pound of phosphorus, with small variations depending on the soil type conversion factor.

2) finding a large enough number of sites.

Table. A*verage pollutant load reductions and cost of road NPS work in East Pond and similar projects in Kennebec County, 2003 - 2006. Source: project Final Reports*

Project	Cost: Total and Per Site (**1**)	Number sites	Sediment reduction per site (tons/yr/site) (**2**)	Unit cost of sediment reduction ($/ton-yr) (**3**)	Phosphorus reduction per site (lbs/yr/site) (**2**)	Unit cost of P reduction ($/lb-yr)	
East Pond	$74,393 $3,915	19	0.6	6,526	0.6	6,526	
Maranacook	$57,201 $7,150	8	0.65	11,000	0.67	10,672	
Togus	$42,498 $2,500	17	1.4	1,786	1.38	1,812	
Salmon-McGrath	$47,591 $3,966	12	1.8	2,203	1.85	2,144	
Straight Averages (N=4 projects)	$4,383	1966	1.11	$5,379	1.13	$5,288	
Weighted Averages (N = 4, weighted by # sites in each)	$3,959		1.11	$4,800	1.11	$4,748	
Average Alone (unit cost uses the weighted average outputs)	**$3,959**		1.11	**$4,383**	**1.11**	**$4,412**	+/- 2,191

(1) Source: project report. Total cost is for BMP construction only and = grant + landowner payment

(2) Source: project report. Reduction amounts for individual sites summed and averaged

(3) BMP functional life of 10 years or longer is assumed. "unit cost" is a one-time purchase of a continuing pollutant abatement for the life of the BMP.

1) Cost of the BMP approach

If the TMDL goal of 500 kg were to be attempted, the cost would be an estimated seven an a half million dollars. Because of the variability in BMP efficacy (see S.D., Table 2), the cost could vary by as much as four million dollars.

500 kg = 1,102 lbs

cost = $4,412 (+/- 2,191) X 1,102 lbs = **$4,862,024** (+/-) $2,414,482

Because of the inherent high variation in BMP efficacy reported from the projects the estimated cost is more correctly reported as a range. The range is from $2,447,542 to $7,276,506. Assuming that costs will be 80% of the 'worst case' scenario ($7,276,506) then we can conservatively plan on an expenditure of **$5,821,205**.

If the sites were treated in 319-type projects, we would want to include the cost of the attendant project activities, such as landowner contact, public education, partner coordination and grant management. The site work would not occur at all without some of this project support. Furthermore, the success at individual sites is bolstered by educating the landowner on long-term maintenance of the practice as well as encouraging others to adopt the practices (given that new sites are constantly being born as old ones are retired - although we can hope to control the recruitment rate somewhat.) The ratio of site to non-site costs in a typical 319 project is 75:25 [7]Therefore an investment of approximately $5,800,000 for site work over ten years would need to have added to it $1,933,000.

2) *Finding enough sites*

If the TMDL goal of 500 kg/yr is to be reached solely through site work (as opposed to treating the sediment or somehow addressing atmospheric deposition) then the number of sites we would have to find and treat could be as much as

500 kg = 1,102 lbs

1,102 lbs / 1.1 lbs/site (from Table 2) = **1,002 sites**

[7] Approx. ratio of construction to non-construction expenses in 319 projects (includes all monies, grant and match): East Pond Phase II: 62:38, Maranacook II: 79:33, Togus 65:35, Echo Lake 85:15

Even over 10 years it seems highly unlikely that program managers could identify and treat as many as 100 sites per year. As projects progress through multi-year phases, both the number of priority sites and number of willing landowners diminishes. It is also doubtful that there are even that many problem sites in the watershed. This is not surprising, considering that the TMDL goal of 500 kg is in fact larger than the total estimated external load, 483 kg/yr (because the goal was intended to reduce internal as well as external loading to bring the load back down within the lake's capacity).

Even if we revise our goal and cost a BMP program that addresses the total external load only (483 kg/yr), we would need to address

483 kg = 1,063 lbs
1,063 lbs / 1.1 lbs/site = **966 sites**

If we halve this goal AND if we assume maximum efficacy of the BMPs (1.8 kg/site, the upper range from the project data), we reach a realistic number of sites .

242 kg = 531 lbs
531 lbs / 1.8 lbs/site = **295 sites**

If the equivalent of 25 to 30 sites per year are fixed and remain fixed over the 10-year period than by the end of this period some 250 to 300 sites are fixed and the annual phosphorus load could be 242 kg/yr less than at the start of the ten-year program.

The cost of this approach is estimated to be
531 lbs X $4,412/lb-yr (+/- $2,191) = **$2,342,772 $/lb-yr** +/- ($1,163,421)
Bearing in mind the variation in the estimate, the conservative figure (80% of worst case) would be **$2,804,955** or roughly $280,000/yr over ten years.
Attendant project costs (management, landowner contact, public education) should be added to the estimate.

If we halve the TMDL goal AND if we assume maximum efficacy of the BMPs (1.8 kg/site, the upper range from the project data), we reach a realistic number of sites, 295. If the equivalent of 25 to 30 sites per year are fixed and remain fixed over the 10-year period then by the end of this period some 250 to 300 sites are fixed and the annual phosphorus load could be 242 kg/yr less than at the start of the ten-year program. Bearing in mind the variation in the estimate, the conservative figure for total cost would be **$2,804,955** or roughly $280,000/yr over ten years.
Attendant project costs (management, landowner contact, public education) should be added to the estimate.

If we combine earthwork BMPs with work on reducing or eliminating septic discharges, we increase the efficacy of the BMP approach but also the cost. We do not have sufficient data on the number of failing septics or the load reductions that can be expected from fixing or eliminating these. One simple way to estimate the number of septic systems that may need replacing - short of doing site by site visits - is to take the total number of dwellings around the lake, subtract the number of updated septic systems (recorded by the towns), leaving the number of older systems in need of inspection and/or replacement. The East Pond Association, using information available from the towns, could estimate this number. The two towns should be encouraged to either provide more assistance to the homeowners (e.g., through the State's revolving fund for septics).

Summary of the BMP approach

According to the loading estimates of the TMDL and the data from recent 319 projects, site-based BMP work alone is not a realistic strategy for effectively reducing the phosphorus load to acceptable levels in East Pond. **A total investment of $2 to $3 million would only halve the external load after ten years.** It is assumed that this reduction in the external load would also lead to a reduction in the internal load but this would be difficult to estimate. If, conservatively, we assume that the internal load remains the same, then the new annual phosphorus load in East Pond after 10 years would be

external load reduction = 483 kg P/yr - 242 kg P/yr = 241 kg P/yr

+ internal load (assume this is static) of 400 kg P/yr = 641 kg P/yr.

The difference between this new loading and the lake's capacity (389 kg P/yr) is 252 kg/yr. Thus, to reach the goal of lake recovery, the internal load would also need to be significantly reduced - from 400 kg P/yr to 148 kg/yr. The progress made in external load reductions would also have to be maintained.

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