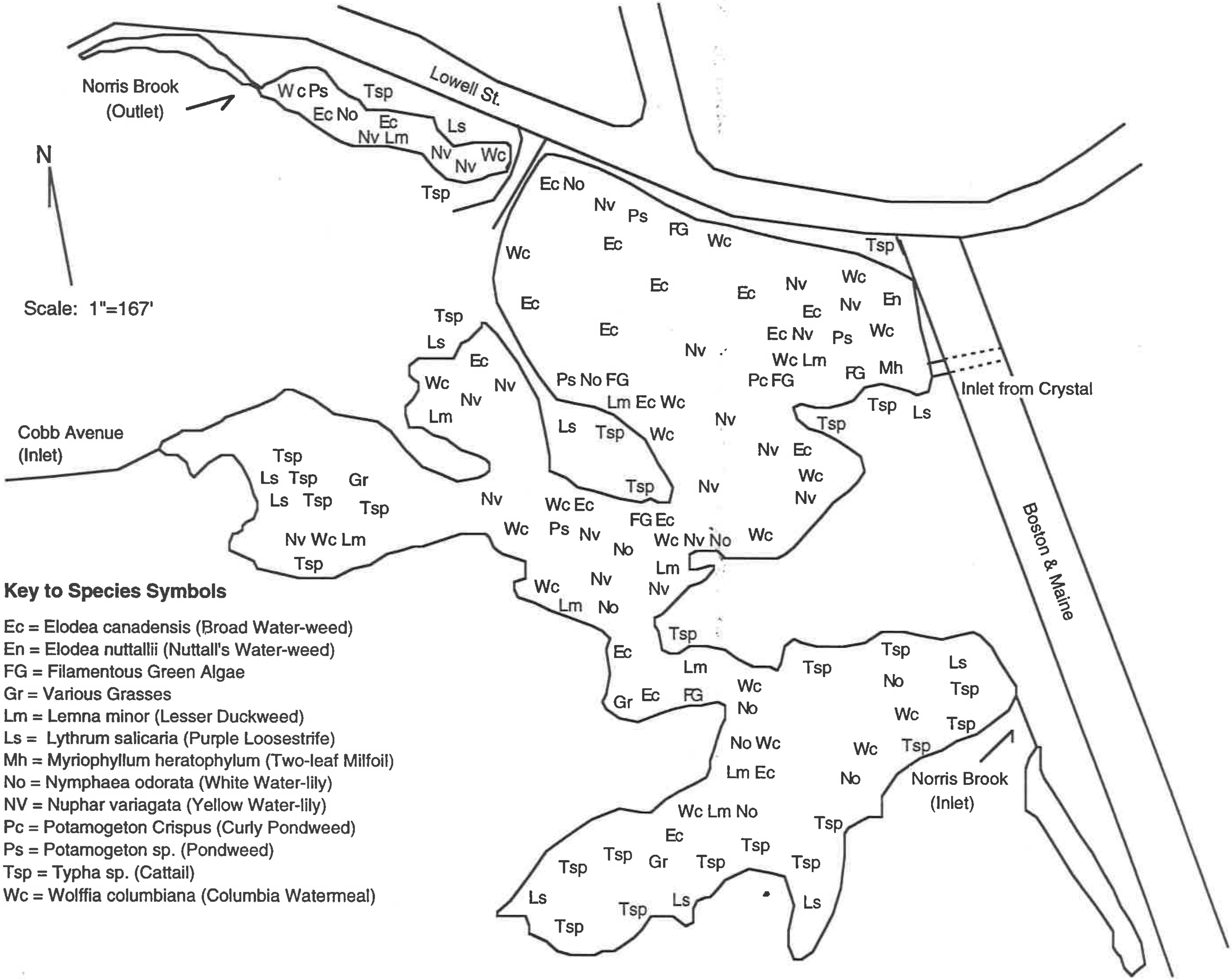

Key to Species Symbols

Ec = Elodea canadensis (Broad Water-weed)
En = Elodea nuttallii (Nuttall's Water-weed)
FG = Filamentous Green Algae
Gr = Various Grasses
Lm = Lemna minor (Lesser Duckweed)
Ls = Lythrum salicaria (Purple Loosestrife)
Mh = Myriophyllum heratophylum (Two-leaf Milfoil)
No = Nymphaea odorata (White Water-lily)
NV = Nuphar variagata (Yellow Water-lily)
Pc = Potamogeton Crispus (Curly Pondweed)
Ps = Potamogeton sp. (Pondweed)
Tsp = Typha sp. (Cattail)
Wc = Wolffia columbiana (Columbia Watermeal)

Figure 13. Dominant Aquatic Plant Distribution for Elginwood Pond - September 1995.

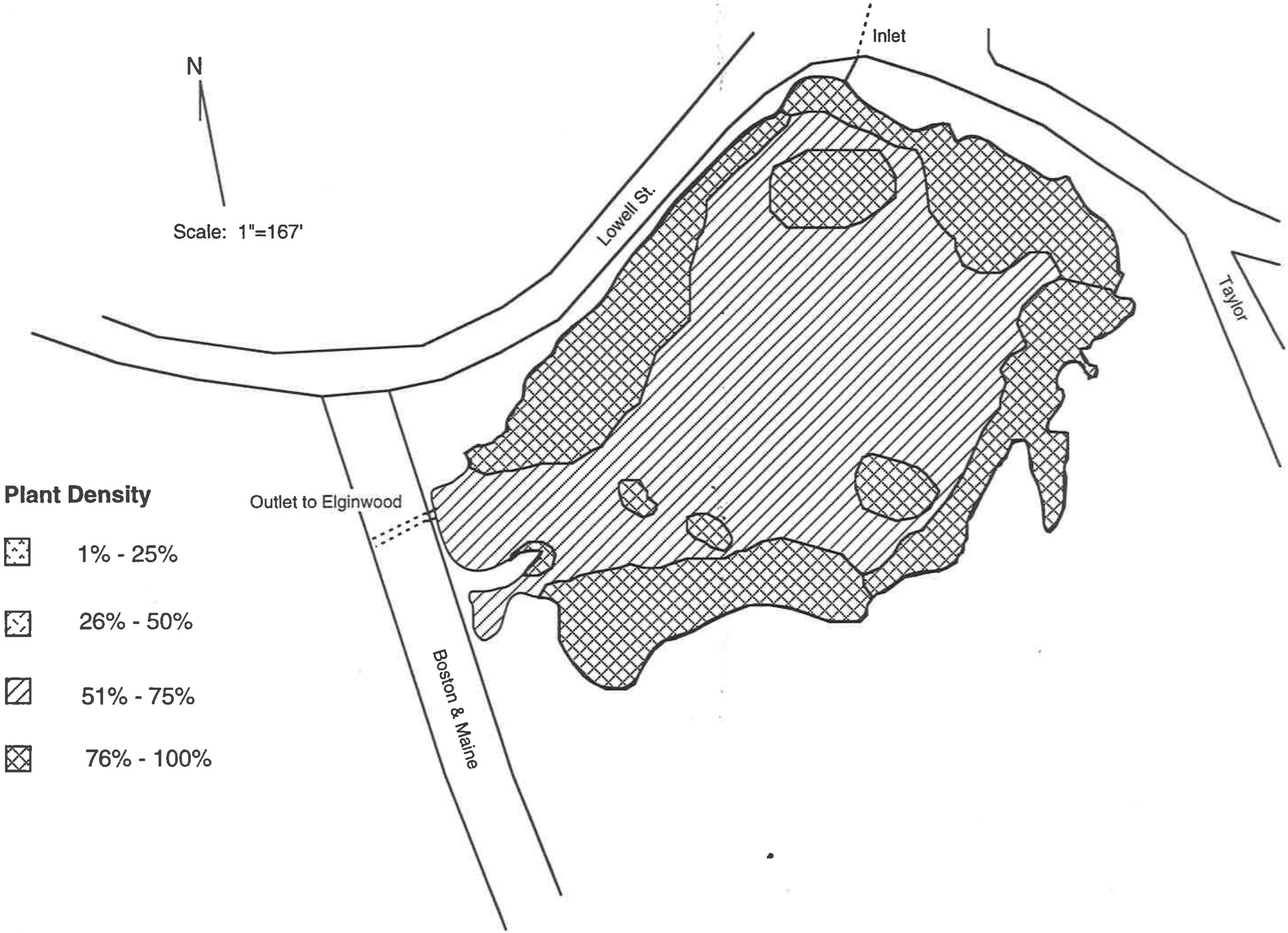

Figure 14. Aquatic Plant Density for Crystal Lake - September 1995.

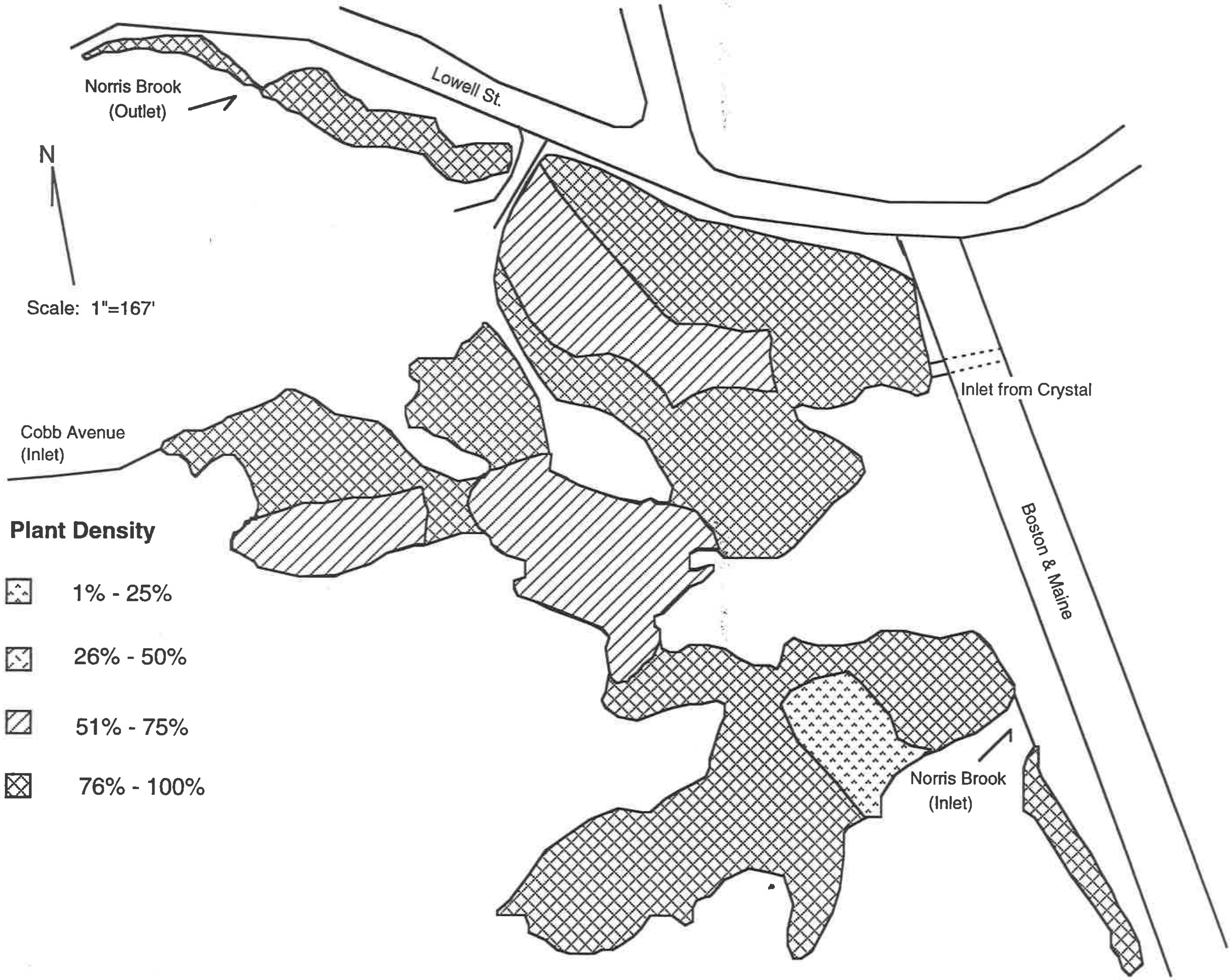

Figure 15. Plant Density Expressed as Percent Bottom Area Covered for Elginwood Pond - September 1995.

Table 10. Area of plant coverage for Crystal Lake and Elginwood Pond, September 1995.

Crystal Lake Area of lake = 414,272 ft.^2

Plant Density (%)	Area (acres)	Area (ft.^2)	% of Total (%)
76-100%	4.3	186,159	45
51-75%	5.3	228,773	55
0%	0.0	0	0

Elginwood Pond Area of pond = 495,936 ft.^2

Plant Density (%)	Area (acres)	Area (sq. ft.)	% of Total (%)
76-100%	8.1	352,071	71
51-75%	2.8	123,716	25
0%	0.5	20,136	4

Macroinvertebrate Review

A qualitative survey of the macroinvertebrate fauna of Crystal Lake and Elginwood Pond was conducted on 31 August 1995. The vegetation and sediments were swept with a dip net to dislodge attached fauna at several sites throughout the ponds. On a qualitative basis, the macroinvertebrate communities of the two ponds were very similar. The plants supported a greater diversity of macroinvertebrates than did the soft sediments. Usually associated with the plant community were snails (*Gastropoda*, 3 varieties), water striders (*Gerridae*), and water boatmen (*Corixidae*). The sediment in both ponds was a very soft sediment mixed with a large amount of fine detritus. Associated with this sediment matrix was a large number of midges (*Chironomidae*), scuds (*Amphipoda*) and small mussels (*Pelecypoda*, 2 varieties). The macroinvertebrate community of Crystal Lake and Elginwood Pond is not diverse; however, the fauna is comparable to that of other small eutrophic ponds with similar habitat.

Fish Review

A qualitative survey of the fish community of Crystal Lake and Elginwood Pond was conducted on 31 August 1995. Fish data were collected through visual observation only, and consequently, only larger, open-water fish were observed. The ponds were observed to support populations of largemouth bass, chain pickerel and sunfish. Other game and non-game species typical of warmwater conditions are likely to be present.

Crystal Lake and Elginwood Pond are reported to offer some recreational fishing in the deeper, less plant-choked waters. Zooplankton data collected during this investigation, however, suggest that fishery resources are likely to be sub-optimal.

Phytoplankton

Phytoplankton samples from Crystal Lake and Elginwood Pond contained 6 of 8 algal divisions (Table 11+12). Taxonomic richness and biomass was greater in Elginwood Pond, resulting in Shannon-Weaver Diversity Index values which were moderate to high, with a well balanced species composition as indicated by the Evenness Index. Total algal biomass was very high for Elginwood Pond, indicating high nutrient inputs. Bluegreens (*Oscillatoria*) were numerically abundant in Elginwood Pond during August, but did not comprise much of the biomass. Algae providing the most biomass were edible forms valuable to the food web such as *Navicula, Pinnularia* and *Gomphonema*. However, Elginwood did have significant *Mougeotia* biomass, a filamentous green species which is not a preferred food choice. Algal species significantly contributing to biomass in Crystal Lake were *Dinobryon* and *Euglena*, both valuable to the food web. Lack of dominance by a few species or one algal division in these ponds is probably a function of the high flushing rate, which prevents stable conditions conducive to monospecific blooms from developing.

Table 11. Phytoplankton Density and Biomass for Crystal Lake, 1995.

TAXON	PHYTOPLANKTON DENSITY (CELLS/ML) Sample I.D. Crystal Lake 8/31/95	PHYTOPLANKTON BIOMASS (UG/L) Sample I.D. Crystal Lake 8/31/95
BACILLARIOPHYTA		
Achnanthes	6	0.6
Fragilaria	36	10.8
Melosira	48	14.4
Navicula	12	6.0
Nitzschia	12	9.6
Synedra	6	4.8
CHLOROPHYTA		
Closteriopsis	12	12.0
Scenedesmus	168	16.8
Sorastrum	48	9.6
Staurastrum	12	9.6
Tetraedron	6	15.0
CHRYSOPHYTA		
Dinobryon	600	1800.0
CRYPTOPHYTA		
Cryptomonas	636	396.0
EUGLENOPHYTA		
Euglena	30	603.0
Phacus	18	21.6
Trachelomonas	30	55.8
PYRRHOPHYTA		
Ceratium	3	282.0
Peridinium	6	270.0
SUMMARY STATISTICS		
	DENSITY (#/ML)	**BIOMASS (UG/L)**
BACILLARIOPHYTA	120	46.2
CHLOROPHYTA	246	63.0
CHRYSOPHYTA	600	1800.0
CRYPTOPHYTA	636	396.0
EUGLENOPHYTA	78	680.4
PYRRHOPHYTA	9	552.0
TOTAL PHYTOPLANKTON	1689	3537.6
	TAXONOMIC RICHNESS	
BACILLARIOPHYTA	6	
CHLOROPHYTA	5	
CHRYSOPHYTA	1	
CRYPTOPHYTA	1	
EUGLENOPHYTA	3	
PYRRHOPHYTA	2	
TOTAL PHYTOPLANKTON	18	
S-W DIVERSITY INDEX	0.73	
EVENNESS INDEX	0.58	

Table 12. Phytoplankton Density and Biomass for Elginwood Pond, 1995.

TAXON	PHYTOPLANKTON DENSITY (CELLS/ML) Sample I.D. Elginwood Pond 8/31/95	PHYTOPLANKTON BIOMASS (UG/L) Sample I.D. Elginwood Pond 8/31/95
BACILLARIOPHYTA		
Achnanthes	2304	230.4
Amphora	96	134.4
Cocconeis	288	115.2
Cyclotella	576	57.6
Cymbella	128	128.0
Eunotia	384	384.0
Fragilaria	768	230.4
Gomphonema	1824	2528.0
Gyrosigma	128	409.6
Meridion	128	38.4
Navicula	2528	4288.0
Nitzschia	576	1152.0
Pinnularia	320	3200.0
Stauroneis	128	243.2
Synedra	512	409.6
CHLOROPHYTA		
Ankistrodesmus	128	12.8
Chlamydomonas	384	38.4
Closterium	32	128.0
Mougeotia	1280	6924.8
Oedogonium	384	1792.0
Pandorina	384	192.0
Scenedesmus	512	51.2
Staurastrum	32	25.6
CHRYSOPHYTA		
Mallomonas	32	16.0
CRYPTOPHYTA		
Cryptomonas	2080	1984.0
CYANOPHYTA		
Oscillatoria	8960	89.6
EUGLENOPHYTA		
Trachelomonas	544	956.8
SUMMARY STATISTICS		
	DENSITY (#/ML)	**BIOMASS (UG/L)**
BACILLARIOPHYTA	10688	13548.8
CHLOROPHYTA	3136	9164.8
CHRYSOPHYTA	32	16.0
CRYPTOPHYTA	2080	1984.0
CYANOPHYTA	8960	89.6
EUGLENOPHYTA	544	956.8
TOTAL PHYTOPLANKTON	25440	25760.0
	TAXONOMIC RICHNESS	
BACILLARIOPHYTA	15	
CHLOROPHYTA	8	
CHRYSOPHYTA	1	
CRYPTOPHYTA	1	
CYANOPHYTA	1	
EUGLENOPHYTA	1	
TOTAL PHYTOPLANKTON	27	
S-W DIVERSITY INDEX	1.05	
EVENNESS INDEX	0.73	

Zooplankton

Both ponds had very low zooplankton density and biomass, probably resulting from the very high flushing rate for the system. Zooplankton samples included a range of types and sizes, with small-bodied Cladocerans the most abundant in Crystal Lake (Table 13) and no species evidently dominant in Elginwood Pond (Table 14). *Bosmina* was the most abundant species both numerically and with respect to biomass in Crystal Lake. Mean length of zooplankton individuals in the samples was very low in Crystal Lake (0.35 mm) and in Elginwood Pond (0.44 mm). Samples were indicative of limited grazing potential and inadequate food supply for small fish, and suggest a sub-optimum length distribution for fish in these ponds.

DIAGNOSTIC CONCLUSIONS

- Watershed size is much greater than pond area, with >50% of watershed developed; this pre-disposes the ponds to eutrophication problems.
- Volume of soft sediment in Crystal Lake and Elginwood Pond combined is nearly 105,000 cubic yards, representing a large portion of original lake volume in each case.
- Sediments are very mucky and fairly deep with high organic content. Decomposition and nutrient release from mucks is likely to be a threat to water quality.
- Physical and chemical analysis of sediments revealed acceptable levels of contamination in both ponds as relates to disposal of any dredged material. These sediments had >80% moisture content, indicating greatly reduced volume upon drying.
- Storm water runoff is a major influence on pond water quality; input quality is generally poor, but high flushing rate limits detention and impact manifestation.
- Nutrient load analysis indicates that nutrient levels in the ponds are well above desirable levels for both phosphorus and nitrate. No major changes in the pond water quality are expected as a result of increased detention time due to possible dredging.
- Plant densities are high, impeding recreational use and impairing overall habitat value.
- Plant species tend to be native varieties; there is currently no serious threat from invasive non-native submergent plants. There is some threat by emergent non-native forms (Purple Loosestrife), although these are not yet dominant.
- The phytoplankton community includes a variety of species at moderate to high biomass. Zooplankton richness, biomass and mean size are low. High flushing rate appears to greatly influence plankton assemblage features.
- A variety of insects and related invertebrates tolerant of eutrophic conditions were observed.
- A visual survey of the fish community indicates that the ponds appear to be typical of other warm water eutrophic ponds with minimal management; a variety of warm-water species are present, but the size distribution is likely to be sub-optimal.

Table 13. Zooplankton Density and Biomass for Crystal Lake, 1995.

TAXON	ZOOPLANKTON DENSITY (#/L) Sample I.D. Crystal Lake 8/31/95	ZOOPLANKTON BIOMASS (UG/L) Sample I.D. Crystal Lake 8/31/95
ROTIFERA		
Asplanchna	0.8	0.8
COPEPODA		
Copepoda-Cyclopoida		
Cyclops	1.2	2.9
Mesocyclops	0.4	0.5
Other Copepoda-Nauplii	3.2	8.5
CLADOCERA		
Bosmina	19.2	18.8
Ceriodaphnia	4.4	11.4

SUMMARY STATISTICS	DENSITY (#/L)	BIOMASS (UG/L)
ROTIFERA	0.8	0.8
COPEPODA	4.8	11.9
CLADOCERA	23.6	30.3
TOTAL ZOOPLANKTON	29.2	43.0
	TAXONOMIC RICHNESS	
ROTIFERA	1	
COPEPODA	3	
CLADOCERA	2	
TOTAL ZOOPLANKTON	6	
MEAN LENGTH: ALL FORMS	0.35	
MEAN LENGTH: CRUSTACEANS	0.35	
S-W DIVERSITY INDEX	0.47	
EVENNESS INDEX	0.61	

Table 14. Zooplankton Density and Biomass for Elginwood Pond, 1995.

TAXON	ZOOPLANKTON DENSITY (#/L) Sample I.D. Elginwood Pond 8/31/95	ZOOPLANKTON BIOMASS (UG/L) Sample I.D. Elginwood Pond 8/31/95
ROTIFERA		
Asplanchna	2.2	2.2
COPEPODA		
Copepoda-Cyclopoida		
Cyclops	2.2	5.4
Mesocyclops	1.1	1.4
CLADOCERA		
Bosmina	2.2	2.2

SUMMARY STATISTICS

	DENSITY (#/L)	BIOMASS (UG/L)
ROTIFERA	2.2	2.2
COPEPODA	3.3	6.7
CLADOCERA	2.2	2.2
TOTAL ZOOPLANKTON	7.7	11.1

	TAXONOMIC RICHNESS
ROTIFERA	1
COPEPODA	2
CLADOCERA	1
TOTAL ZOOPLANKTON	4
MEAN LENGTH: ALL FORMS	0.44
MEAN LENGTH: CRUSTACEANS	0.50
S-W DIVERSITY INDEX	0.59
EVENNESS INDEX	0.98

MANAGEMENT OBJECTIVES

Actual goals for the management of Crystal Lake and Elginwood Pond depend upon their intended uses. It is our understanding that their is no impetus for establishing an active, contact recreational facility or water supply system at either pond, and that aesthetics, overall habitat value, fishing, skating and possibly non-motorized boating comprise the range of desired uses. Officials of the City of Peabody should prioritize desired uses before accepting the management recommendations of this report, which are based on the impressions of Fugro personnel, not the people of Peabody.

With these assumed goals in mind, it would seem that the specific goals of management should include:

1. Eliminate nutrient-rich and oxygen-demanding sediments which have accumulated, restoring the original depth to each water body.
2. Control rooted aquatic plant growths in a manner which increases open water and overall habitat diversity.
3. Improve the quality of pond water to the extent necessary to prevent rapid sedimentation in the ponds and reduce fertility to a level which does not support extensive growths of floating aquatic plants or algae.

MANAGEMENT OPTIONS AND CONSTRAINTS

Management options for lakes and their watersheds are described briefly in Table 15, while approaches dealing specifically with rooted aquatic plants are outlined more fully in Table 16. Based on what is now known of this aquatic system, the following management options warrant discussion with respect to technical feasibility, potential effectiveness, cost and regulatory requirements:

Dredging

Since a major focus of this study was to examine the possibility of increasing pond depth to remove plants and increase recreational potential, it has been assumed that dredging would provide desirable conditions in the pond. In terms of increasing pond depth and controlling emergent growths, this is certainly true. Both ponds are in an advanced stage of eutrophication (aging and increased fertility), and transition into an emergent wetland is underway. Based on the desired pond uses assumed above, dredging will be a necessary component of any comprehensive management program. Only dredging will provide the means to completely restructure the physical and biological components of each system. Some improvement in water quality may be expected, but sufficient alteration of water quality in accordance with management objectives will depend upon additional management actions aimed at storm water.

Table 15. Lake restoration and management options

Technique	Descriptive Notes
Watershed Level	**Approaches applied to the drainage area of a water body.**
1. Agricultural Best Management Practices	Application of techniques in forestry, animal, and crop science intended to minimize adverse impacts.
2. Bank and Slope Stabilization	Erosion control to reduce inputs of sediment and related substances.
3. Behavioral Modifications	Actions by individuals.
a. Use of Non-Phosphate Detergents	Elimination of a major wastewater phosphorus source.
b. Eliminate Garbage Grinders	Reduce load to treatment system.
c. Limit Lawn Fertilization	Reduce potential for nutrient loading to water body.
d. Limit Motorboat Activity	Reduce wave action, vertical mixing, and sediment resuspension.
e. Eliminate Illegal Dumping	Reduce organic pollution, sediment loads and potentially toxic inputs to a water body.
4. Detention or Infiltration Basin Use and Maintenance	Lengthening of time of travel for pollutant flows and facilitation of natural purification processes.
5. Increased Street Sweeping and Catch Basin Cleaning	Removal of potential runoff pollutants from roads and drainage systems.
6. Maintenance and Upgrade of On-site Disposal Systems	Proper operation of localized systems and maximal treatment of waste water to remove pollutants.
7. Provision of Sanitary Sewers	Community level collection and treatment of waste water to remove pollutants.
8. Storm Water or Waste Water Diversion	Routing of pollutant flows away from a target water body.
9. Zoning and Land Use Planning	Management of land to minimize deleterious impacts on water.
10. Treatment of Runoff or Stream Flows	Inactivation of nutrients or other treatments to chemically alter inflows.

Table 15. (cont.) Lake restoration and management options.

Technique	Descriptive Notes
In -Lake Level	**Actions performed within a water body.**
1. Aeration and/or Destratification	Mechanical maintenance of oxygen levels and prevention of stagnation.
2. Biocidal Chemical Treatment	Addition of inhibitory substances intended to eliminate target species.
3. Biomanipulation or Habitat Management	Facilitation of biological interactions to alter ecosystem processes.
4. Bottom Sealing	Physical obstruction of rooted plant growths and/or sediment-water interaction.
5. Chemical Sediment Treatment	Addition of compounds which alter sediment features to limit plant growths or control chemical exchange reactions.
6. Dilution and/or Flushing	Increased flow to minimize retention of undesirable materials.
7. Dredging	Removal of sediments under wet or dry conditions.
8. Dye Addition	Introduction of suspended pigments to create light inhibition of plant growths.
9. Hydroraking and Rotovation	Disturbance of sediments, often with removal of plants, to disrupt growth.
10. Hypolimnetic Withdrawal	Removal of oxygen-poor, nutrient-rich bottom waters.
11. Macrophyte Harvesting	Removal of plants by mechanical means.
12. Nutrient Inactivation	Chemical complexing and precipitation of undesirable dissolved substances.
13. Water Level Control	Flooding or drying of target areas to aid or eliminate target species.

Table 16. Management options for control of rooted aquatic plants

Option	Mode of Action	Positive Impacts	Negative Impacts
Drawdown	♦ Lowering of water over winter period allows desiccation, freezing, and physical disruption of plants, roots and seed beds ♦ Duration of exposure and degree of dewatering of exposed areas are important ♦ Variable species tolerance to drawdown; emergent species and seed-bearers are less affected ♦ Most effective on annual to once/3 yr. basis	♦ Control with some flexibility ♦ Opportunity for shoreline clean-up/structure repair. ♦ Flood control utility	♦ Possible impacts on contiguous emergent wetlands ♦ Possible impairment of well production ♦ Reduction in potential water supply and fire fighting capacity ♦ Alteration of downstream flows ♦ Possible overwinter water level variation ♦ Possible effects on overwintering reptiles or amphibians
Chemical treatment	♦ Liquid or pelletized herbicides applied to target area or to plants directly ♦ Contact or systemic poisons kill plants or limit growth ♦ Typically requires application every 1-5 yrs	♦ Wide range of control is possible ♦ May be able to selectively eliminate species ♦ May achieve some algae control as well	♦ Possible toxicity to non-target species of plants/animals ♦ Possible downstream impacts; may affect non-target areas within pond ♦ Restrictions of water use for varying time after treatment ♦ Increased oxygen demand from decaying vegetation ♦ Possible recycling of nutrients to allow other growths
Harvesting/ hydroraking/ rototilling	♦ Plants directly removed by mechanical means, possibly with disturbance of soils ♦ Collected plants placed on shore for composting or other disposal ♦ Wide range of techniques employed, from manual to highly mechanized ♦ Application once or twice/yr. usually needed	♦ Highly flexible control May remove other debris ♦ Can balance habitat and recreational needs	♦ Possible impacts on aquatic fauna ♦ Non-selective removal of plants in treated area ♦ Possible spread of undesirable species by fragmentation ♦ Possible generation of turbidity

Table 16. (cont.) Management options for control of rooted aquatic plants

Option	Mode of Action	Positive Impacts	Negative Impacts
Benthic barriers	♦ Mat of variable composition laid on bottom of target area, preventing plant growth ♦ Can cover area for as little as several months or permanently ♦ Maintenance improves effectiveness ♦ Not really intended for use in large areas, usually applied around docks, boating lanes, and in swimming areas	♦ Highly flexible control ♦ Reduces turbidity from soft bottoms ♦ Can cover undesirable substrate ♦ Often improves fish habitat	♦ May cause anoxia at sediment-water interface ♦ May limit benthic invertebrates ♦ Non-selective interference with plants in target area ♦ May inhibit spawning/feeding by some fish species
Dredging	♦ Sediment is physically removed by wet or dry excavation, with deposition in a containment area for dewatering ♦ Dredging can be applied on a limited basis, but is most often a major restructuring of a severely impacted system ♦ Plants are removed and regrowth can be limited by light and/or substrate limitation	♦ Plant removal with some flexibility ♦ Increases water depth ♦ Can reduce pollutant reserves ♦ Can reduce sediment oxygen demand ♦ Can improve spawning habitat for many fish species ♦ Allows complete renovation of aquatic ecosystem	♦ Temporarily removes benthic invertebrates ♦ May create turbidity ♦ May eliminate fish community (complete dry dredging only) ♦ Possible impacts from containment area discharge ♦ Possible impacts from dredged material disposal ♦ Interference with recreation or other uses during dredging
Dyes	♦ Water-soluble dye is mixed with lake water, thereby limiting light penetration and inhibiting plant growth ♦ Dyes remain in solution until washed out of system.	♦ Light limit on plant growth without high turbidity or great depth ♦ May achieve some control of algae as well ♦ May achieve some selectivity for species tolerant of low light	♦ May not control peripheral or shallow water rooted plants ♦ May cause thermal stratification in shallow ponds ♦ May facilitate anoxia at sediment interface with water
Biological controls	♦ Fish, insects or pathogens which feed on or parasitize plants are added to system to affect control ♦ The most commonly used organism is the grass carp, but the larvae of several insects have been used more recently, and viruses are being tested	♦ Provides potentially continuing control with one treatment ♦ Harnesses nature to produce desired conditions ♦ May produce potentially useful fish biomass as an end product	♦ Typically involves introduction of exotic species ♦ Effects may not be controllable ♦ Plant selectivity may not match desired target species ♦ May adversely affect indigenous species

Dredging is among the most complicated of lake management techniques, with a very large number of considerations to be addressed in the planning and permitting stage. Although this investigation is not a design level project, the information gathered provides much of what will be needed to address those considerations. A template for dredging feasibility assessment, filled out as existing information allows and suitable for filing as part of any permit application, is included in Appendix A. Some key points are summarized below.

For dredging to be an effective plant control measure, a depth (low light) or substrate (unfavorable bottom material) limitation must be created. Removal of all muck sediment or achievement of at least 8 ft. of water depth would be necessary in this case. Dredging also will remove nutrient reserves and oxygen-demanding substances which are stored in pond sediments. The removal of these sediments can reduce sediment oxygen demand, thereby increasing the likelihood of creating a desirable fishery. Removal of nutrient reserves will limit internal recycling of key plant nutrients, although in this system it is external inputs which control fertility at this time. Although partial dredging is an option if only partial utility is acceptable, the condition of these ponds warrants a complete dredging.

Although Crystal Lake may be amenable to a hydraulic dredging approach, Elginwood Pond is not, and both could be dredged by conventional, dry methodology. It will be necessary to control incoming surface and ground water, which may be difficult during storm events. Some means of partitioning each lake into workable, sequestered units which can be dewatered and dredged may be necessary. Alternatively, storm water could be diverted around the ponds (or through them); this option has merit as a nutrient input control strategy as well and will be addressed further later in this report.

Although dewatering and management of throughflow are critical technical aspects of any dredging project, containment area and ultimate disposal arrangements are perhaps the most important factors. With over 100,000 cu. yds. of material to be handled, a large area will be needed if the project is to be completed within the shortest possible time frame. Organic material dries best if not piled more than 3 ft deep and when deposited on sandy soils well above the ground water table. In this case, this would call for no excavation below ground surface, as the water table is close to the lake surface level, and an area of approximately 20 acres if all material is to be placed there before any is removed for use or disposal elsewhere. The dredged material will be useful as a soil amendment or fill material once dried, so ultimate disposal is less a consideration than initial containment and dewatering. If a large enough area is not available, it will be necessary to accomplish the dredging in stages, with periodic removal of dried accumulations. This complicates the whole process, but is a common occurrence in lake dredging.

Dredging costs can vary widely as a function of site conditions and containment capacity, and are best estimated through consideration of each element of the project during the design phase. However, a rough cost of $6-10/cu. yd. can be assumed for most dry dredging jobs. This equates to a cost of $630,000 to $1.2 million to remove roughly 105,000 cu. yds. from both ponds. The costs of removal of the dredged material would be minimized if a disposal site could be located close to the ponds, or if the dredged material could be sold to offset costs. Dredging is almost never a "break-even" proposition, however, and $600,000 is the expected lower limit of the cost for dredging these two lakes. A higher value up to 1,000,000 is likely, unless a nearby containment area or party interested in acquiring the dredged material can be found.

Permits would be necessary under the Wetlands Protection Act (local Conservation Commission with review by the MA DEP) and under Sections 401 (MA DEP) and 404 (Army Corps of Engineers) of the Federal Clean Water Act. It may also be necessary to apply for a Chapter 91 Waterways License (MA DEP), which deals with structural alterations in Great Ponds. Crystal Lake is under the 10 acre lower limit for Great Ponds under Chapter 91, but Elginwood Pond is not. However, Elginwood Pond does not appear to be natural, and may not be on the Commonwealth's list of Great Ponds, in which case the Chapter 91 License would be unnecessary. Based on the information gained to date, there should be no serious difficulty in obtaining the necessary permits. However, open water is not a favored habitat under the current regulatory climate, and cumulative impacts to more than 1 acre of area require an individual permit under Section 404. Expect about one year of review, hearings and additional submittals in the permitting process.

Dredging, if conducted, could satisfy the first two management objectives, dealing with depth restoration and rooted plant control. It could provide a desirable start toward improved in-lake water quality, but would be insufficient to maintain desirable water quality without additional management activities at the watershed level.

Other Plant Control Options

The remaining methods of plant control include drawdown, benthic barriers, dyes, biological controls, chemical treatment, and harvesting (Table 16). None of these would afford the benefit of increased depth to the ponds. Drawdown is not appropriate for these ponds, as emergent growths are already dense in some areas and would probably expand. Some impact on submergent species is possible, but the necessary drying or freezing is likely to be incomplete in the deep, soft, organic sediments. Dyes will be ineffective in these shallow, low detention time systems. There are no legal biological control methods applicable to the situation in Crystal Lake or Elginwood Pond. There is not enough water depth in most areas of these ponds to use available harvesting equipment, and even hand harvesting would be hampered by inadequate access to target areas. Chemical treatment could be effective if detention time was increased, but may not even be permittable under current high flushing rates. Benthic barriers could be used to control submergent growths, but are expensive on a large scale (about $15,000-20,000/acre) and will not adequately control emergent growths such as cattails or loosestrife. In short, while some of these management tools may be effective in extending the benefits of a dredging program or in controlling plants for aesthetic purposes in the absence of a dredging program, none are suitable substitutes for dredging.

Land Use Controls

A lake is a reflection of its watershed, which in this case is currently moderately developed. Further development will be limited by protection of wetlands within the watershed. Nevertheless, the percentage of watershed which has been converted to residential use is high enough to pose a threat to water quality, especially during storm events. The use of buffer zones, while highly desirable from a water quality perspective, may be difficult to implement in this watershed as a "retrofit" action. Certainly controls intended to minimize runoff and contaminant transport should be imposed on all new development, but this will not improve existing conditions. In effect, the time has already passed during which land use controls would have been effective in preventing pollution of the ponds.

Source Control

With development already beyond the stage at which land use controls would be sufficient to control pollution, meeting the third management objective (improved water quality) would be optimally accomplished through elimination or reduction of input sources. This is far easier said than done in an urban area, but successful lake management does often depend upon minimizing those sources. In this case, runoff from residential areas appears to be a primary source, and the inputs to that runoff are likely to be related to lawn fertilizers, pets and urban wildlife, various household chemicals, and possibly sewage disposal practices. The quality of the tested runoff places at least some of it among the most fertile of samples collected across the United States; improved residential land management is clearly in order.

Key areas of possible control include limiting lawn fertilization to those cases with demonstrated need, as evidenced by recent soil testing. Only new lawns require much phosphorus, yet most lawn services and many commercially available fertilizers employ elevated phosphorus dosage to ensure success. Chemicals used outdoors should be used only as needed and in a manner consistent with minimizing transport from the property. Lawn wastes should be properly composted or bagged for hauling to an approved disposal area. Pet wastes should be collected and processes with other solid waste. Sewer connections should be tested for leaks or faulty connections which allow linkage to the storm water drainage system. Maintenance of catch basins was intended by the designers of such appurtenances as at least a semi-annual action, yet many communities clean catch basins only rarely. As a consequence, road sand fills sumps and overflows into the outlet pipe with many other undesirable contaminants

There is relatively little tangible cost associated with most of these control options, but most are also difficult to enforce. Volunteer cooperation often generates a detectable change in loading, but in this case, where a very large reduction is necessary, voluntary cooperation cannot be counted upon to provide the necessary level of input reduction. Unless bylaws are passed and enforcement mechanisms are developed, further actions which mitigate the transport of pollutants or their impact in the ponds are clearly needed.

Storm Water Diversion
This option should be considered in conjunction with any dredging activity to maintain the post-dredging volume of the ponds and reduce nutrient loading. A storm water diversion plan would enable water with high sediment and/or nutrient loads to be routed around the ponds. The accumulated sediments in these ponds are a consequence of past erosion in the watershed, road sanding during winter, and plant production fueled by nutrient inputs from an urbanized watershed. As the amount of water flowing through the ponds is already quite high relative to existing or even proposed (post-dredging) volume, it would be advantageous to divert any water of poor quality away from the ponds.

This approach has two shortcomings, one philosophical and one practical. On a philosophical level, diverting poor quality water does not address the cause of the problem, the actual sources of contamination of that storm water. Diversion passes the problem downstream, although in reality the short detention time in these ponds is not providing much pollutant attenuation capacity (i.e., the pollutants are moving downstream already). Just the same, it would be desirable to attack the sources of pollution, not merely relocate the impact. The practical problem is simply the expense associated with diversion of storm flows. Leaping weirs must be installed in storm water drainage systems and streams, a piping system must be laid around or through the ponds to pass the water downstream, and downstream piping and channels may need to be adjusted to handle increased velocities. A detailed assessment of costs can not be conducted without far greater knowledge of the configuration of the storm water drainage system, but the simplest case of 1500 ft of new piping and associated weirs would cost about $150,000.

Storm Water Treatment
An alternative to diverting storm water around the ponds entirely would be to divert storm water through a detention basin or other treatment facility upstream of the ponds to allow deposition of sediment and removal of a portion of the nutrient load. Ideally, such a facility would be capable of holding the runoff from at least a two-year storm (a storm of a magnitude which occurs once every two years), which would be about 10 million cubic feet. As this volume is much greater than the combined volume of Crystal Lake and Elginwood Pond, this is not a very feasible option. However, the ponds in the largest sub-watershed (#1, Figure 3) do provide substantial capacity, and it may be possible to capture and hold runoff from a much smaller portion of the watershed closer to the ponds. Even then, the detention facility capacity is likely to approach that of the two ponds, suggesting that in order to improve Crystal Lake or Elginwood Pond, one or more ponds of similar total capacity must be built and sacrificed.

Another approach to storm water treatment involves the use of many small treatment systems placed near contributing sources. Although this does not constitute source reduction in the traditional sense, a decentralized approach does allow management on a source by source or land parcel by land parcel basis. Smaller detention or infiltration basins can be used in association with small developments, and a number of innovative treatment modules have been developed recently for use in existing storm water drainage systems. Some are "in-line" systems, in which all storm water passes through and is treated in inverse proportion to the volume handled (that is, smaller storms receive greater treatment). Others are "off-line" systems, in which the first flush or some other defined portion of a storm (possibly all of the runoff from a small event) is diverted from the drainage system, treated in some manner, then released back into the drainage flow. Off-line systems could be very useful in this watershed, as high flushing rate increases the importance of the last water entering the ponds after a storm. If an amount of water equal to the volume of the ponds can be treated in this manner and released near the end of each storm event, the quality of water in the ponds between storms would improve substantially

The most applicable off-line treatment systems for this watershed include catch basin or manhole inserts which allow diversion of some portion of the incoming runoff into a holding chamber, after which some form of passive treatment is applied. Settling or filtration are the two processes used most often; these should be effective in this case, but may require frequent maintenance as solids are likely to build up rapidly. Aside from maintenance needs, the major drawback of this approach is cost. Capital costs for localized treatment of runoff will tend to range from $5,000 to $10,000 per acre of watershed area treated, even for seemingly simple systems. Cost per acre will usually be much less for a centralized treatment system, if feasible.

If runoff cannot be sufficiently detained for treatment by natural processes, either in a centralized or decentralized system, it would be possible to treat the runoff to remove contaminants under a more limited detention scenario. The use of a smaller detention area in conjunction with an alum treatment could remove up to 90% of the key contaminants in this system. Such an approach could even be used within the ponds themselves, although this would increase the rate of infilling unless a forebay for settling was created at each inlet and cleaned periodically. Ongoing operational costs of such treatment would be substantial, at around $50,000 per year, once the initial capital expenditure of at least $100,000 was invested to set up the treatment sites. Costs could be reduced by treating only the first flush of runoff, but as this water passes through the ponds so quickly during a storm event, the first flush may be considerably less important than in most systems. It may be more appropriate to treat only the last portion of the storm water to enter the ponds, greatly reducing operational costs and purifying the water which will reside in the ponds the longest. Sediment loading may not be adequately controlled in this manner, but the impact of nutrient loads on the ponds would be appreciably lessened. Unfortunately, background (dry weather) loading of nutrients to the ponds is also substantial, so more regular treatments would probably be necessary to maintain low nutrient levels within the ponds.

It appears certain that some form of storm water management will be needed to meet the third management objective (improvement of pond water quality), but just what form this management should take is less certain. Some further study of watershed inputs is warranted before large expenditures are made in this regard, as our analysis is based on very limited data.

Monitoring and Documentation

Informed management depends upon reliable information. A special study of watershed inputs is needed, one which defines sources and allows priorities for watershed management to be set. Beyond this additional investigation, water quality at the inlets and in the ponds should be assessed at least once in the spring and monthly between June and August, more frequently if at all possible, with emphasis on phosphorus and nitrogen levels. Plankton should be sampled along with water quality and annual plant surveys should be conducted. If fishing is an important pond use, assess the fish community at least once every five years. Keep records of management activities, results and costs, which will vary over time and for different components of the program.

The watershed source investigation could be expected to cost around $10,000, with an annual program of routine monitoring costing on the order of $6,000. Such a program is an integral part of watershed and lake management, allowing the program to be evaluated and fine tuned as it progresses. Managing urban lakes for even a moderate level of utility is a difficult and expensive endeavor, and should not be undertaken without substantial local commitment.

RECOMMENDED MANAGEMENT PLAN

Given the stated management objectives and what is now known about Crystal Lake, Elginwood Pond and their watershed, it appears that watershed management should focus on identifying sediment and nutrient sources and reducing their inputs by any means feasible, while in-lake efforts should center on removing accumulated sediments. The combined effect of these actions would improve incoming water quality, increase pond depth, control plant growth, improve habitat quality, and restore recreational utility. To this end, the following steps are recommended:

1. Prioritize lake uses and re-evaluate the management objectives assumed in this study (no tangible cost).
2. If the management objectives remain the same, initiate the design and permitting phase for a dredging project involving both ponds (estimated cost = $50,000).
3. Dredge the ponds in a sequential fashion, phasing the project as necessary to make it affordable (estimated cost = $636,000-$1,060,000, best guess = $750,000)
4. Conduct an investigation of watershed nutrient and sediment sources to determine what source controls are most appropriate and feasible (estimated cost = $10,000 for study only; actual source control costs will depend on chosen approach, but are not likely to be large).
5. Assuming that pollution sources are widespread and that source controls will be insufficient by themselves to improve water quality in the ponds to the desired level, either divert storm water around the ponds or establish off-line storm water treatment systems which will provide water of acceptable quality at the end of each storm event (estimated cost = $150,000 capital expense; maintenance costs depend on chosen approach).
6. Continue a monitoring program which supports the restoration process, providing information necessary to evaluating progress and additional needs (estimated cost = $6000 annually).

Implementation of all of the above management actions could result in a cost of over $1,000,000, so it may take multiple years to conduct the management program if outside funding is not available. Even then, a substantial commitment on the part of the people and leaders of Peabody will be essential to successful restoration and management of Crystal Lake and Elginwood Pond. Over time, the management plan should be fine tuned to continue those elements of pollution source and plant control which are most cost-effective, continue monitoring at a reduced level which provides early warning of possible problems, and incorporate expanded watershed efforts in accordance with what wet weather and in-lake monitoring indicate as problem areas. Once the lakes are restored, management becomes a matter of prevention, which tends to be much less expensive than restoration. However, where treatment of substantial urban runoff is involved, maintenance and operational costs are not likely to become insignificant.

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APPENDIX A

TEMPLATE FOR DREDGING EVALUATION

Reasons For Dredging:

- Increased depth/access which will enhance the quality of most recreational activities
- The removal of soft, organically rich, sediments decreases the nutrients available to be internally recycled within the ponds
- Control of aquatic vegetation achieved by removing current crop of plants and soft sediments
- Alteration of bottom composition can be achieved to increase biological diversity
- Habitat enhancement by providing a variety of depths throughout the system
- Reduction in oxygen demand through the removal of organically rich sediments

Existing and Proposed Bathymetry:

- Existing mean depth is 0.63 m in Crystal Lake and 0.26 m in Elginwood Pond
- Existing maximum depth is 1.2 m in Crystal Lake and Elginwood Pond
- Proposed mean depth is 1.97 m in Crystal Lake and 0.90 m in Elginwood Pond
- Proposed maximum depth is 3.2 m in Crystal Lake and 2.6 m in Elginwood Pond

Volume Of Material To Be Removed:

- In-situ volume to be removed from both ponds is 105,878 cu. yds.
- Sediment types were similar throughout both ponds, consisting of sand, silt and clay (Table 7)
- The greatest portion of sediment volume occurred in Crystal Lake (67,121 cu. yds.) and was evenly distributed throughout the area of the pond. The sediment volume in Elginwood Pond varied among the sub-basins, the basin adjacent to Lowell St. having the greatest volume.
- Bulked volume (see below)
- Dried volume (see below)

Physical Nature of Material To Be Removed:

- Sediment grain size distribution, solids content, organic content and % moisture are listed in Table 7
- These variables will affect settling rate, bulking factor, drying factor of the dredged material as well as the extent of any residual turbidity associated with the dredging operation.
- Bulking factor not determined empirically, but is expected to be on the order of 1.7-2.0 for mucks of the organic content encountered
- Drying factor also not determined empirically, but could be as low as 0.3 - expect 0.5-0.6 for planning purposes

Chemical Nature of Material To Be Removed:

- The sediments of these ponds had acceptable metals levels, organic contaminant levels and oil and grease content with respect to dredging (Table 7)
- Nutrient levels within the sediments were not measured, however, the extremely high level of total volatile solids (75%) measured in Crystal Lake and moderately high level (28%) measured in Elginwood Pond, is a strong indication that nutrient levels would be substantial.

Nature of Underlying Material To Be Exposed:

- Sand is most likely the dominant substrate to be exposed in both ponds, however, the sand was packed and impermeable to a probing rod without considerable effort

Protected Resource Areas:

- Wetlands
- No endangered species were encountered in biological survey of plants, benthic invertebrates of fish
- Habitats of special concern
- No species of special concern were identified during this study, all were typical of small northeastern warmwater ponds
- Regulatory resource classifications from National Heritage Program do show protected vernal pools in the Crystal Lake watershed, however, these are not expected to be impacted by dredging activity

Dewatering Capacity of Sediments:

- Dewatering potential of sediments is considerable, with >80% moisture content, but may be difficult due to high organic content
- Dewatering timeframe is dependent on the area and location of the selected dewatering/disposal site - expect at least 3 weeks to 1 month to dry material piled less than 3 feet high
- Since dry dredging is the likely method to be employed, initial (pre-excavation) dewatering will greatly affect efficiency of dredging

Flow Management:

System hydrology

- Possible peak flows which could be encountered are unknown at this time due to brevity of study, however, flows of >250 cfs could be encountered during large storm events.
- Expected mean flows during dry weather are <2 cfs, during rainfall up to 53 cfs
- Each pond has a flow retention devise located at its outlet which could provide a method for controlling water level during dredging operation

Equipment Access:

- Possible input and output points would need to be evaluated as relates to property issues and operational feasibility.
- Land slopes should not be a major consideration in the accessibility of these ponds by equipment, the perimeter of each pond is surrounded by gently sloping land.

Relationship To Lake Uses:

- Impact on existing uses during project is expected to be associated with disruption of recreation (fishing and wildlife viewing)
- The type of wildlife associated with the ponds could be altered after dredging as a result of increased recreational activity
- The access points provided by the dredging operation should create a suitable site/s for small watercraft deployment (canoes and rowboats).

Potential Disposal Sites:

- Possible containment sites need to be considered with respect to soil conditions, necessary site preparation, volumetric capacity, property issues and long term disposal options.
- Soil conditions at the site should be permeable to allow sufficient dewatering of dredged material
- The site must be large enough to contain the entire volume of dewatered sediment to be dredged if chosen as the permanent disposal site or a portion of the dredged material until sufficient dewatering allows the material to be sold or transported to a permanent disposal site.

Dredging Methodologies:

- Hydraulic dredging is marginally possible in Crystal Lake since it has a considerable volume of water, however this is not an alternative in Elginwood Pond.
- Wet excavation is not a possibility for either pond due to shallow water depth and excessive muck depth
- Dry excavation could be achieved through flow management in either pond and is the most operationally feasible option

Applicable Regulatory Processes:

- General Federal or State review (NEPA or state equivalent) - possible
- Environmental impact reporting - possible
- Wetlands protection statutes through local Conservation Commission with review by the Massachusetts Department of Environmental Protection (MA DEP) - necessary
- Chapter 91 Waterways License (MA DEP) for water diversion/use permits - possible for Elginwood Pond
- Clean Water Act Section 401 (Water quality certification with MA DEP) - necessary
- Clean Water Act Section 404 (US Army Corps of Engineers) - necessary
- Dam safety/alteration permits - possible

Removal Costs:

- Engineering and permitting costs at approximately $1/cu. yd.
- Construction of containment area at approximately $1/cu. yd.
- Equipment purchases - contract excavation expected
- Operational costs - contract excavation expected
- Contract dredging costs -$3-$5/cu. yd.
- Ultimate disposal costs - $1-$3/cu. yd.
- Total cost for volume to be removed - $636,000 - $1,060,000

Uses Or Sale Of Dredged Material:

- Possible uses - construction fill
- Possible sale - to offset transportation cost
- Target markets - development

Other Mitigating Factors:

- Necessary watershed management to protect investment
- Ancillary project impacts - possible impacts of truck traffic on roads
- Economic setting - large expense
- Political setting - is City of Peabody committed to lake management?
- Sociological setting - perceived need for project