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## Appendix A. Scope of Services

**Martins Pond – Assessment & Remediation**

### I. Purpose

Martins Pond, a Great Pond of the Commonwealth, is highly eutrophic, exhibits very high levels of phosphorus, and is on DEP's Year 2002 Integrated List of Waters as impaired by turbidity, noxious aquatic plants, metals, and exotic species. The Town of North Reading, in collaboration with DEP, the Martins Pond Association, Merrimack College, and Malcolm Pirnie Inc has initiated a program to conduct assessments of water quality, wetlands, and hydraulic conditions and to develop recommendations to address identified problems. The work of this project will build upon the work completed in Martins Pond Assessment Study by Merrimack College and Malcolm Pirnie Inc (March 2003).

The General Court of the Commonwealth has directed the Department of Environmental Protection, hereafter called DEP, through Chapter 352 of the Acts and Resolves of 2004, Section 78, to expend $300,000 toward the assessment and remediation of Martins Pond. The Town of North Reading, hereinafter the Town, agrees to use funds received from DEP specifically for the purpose of water quality problem identification and mitigation.

### II. Scope of Services

The Scope of Services for this Contract shall consist of the following tasks.

1) The Town will continue water quality assessment work conducted on Martins Pond by towards the goal of completing a new Diagnostic/Feasibility Study for Martins Pond and an assessment of potential Nonpoint source pollution in the Martins Pond Watershed. A D/F study conducted in 1985 by Anderson Nichols and Lycott reported low levels of total phosphorus and N/P ratios exceeding 35 that indicated phosphorus limitation. Recently collected data by Merrimack College and DEP indicate that Martins Pond has extremely high total phosphorus in some years and moderately high total phosphorus in other years which appear to be related to the color of the water. Such high levels of phosphorus suggest phosphorus is not limiting. The D/F study should focus on resolving why the tributaries and pond vary from year to year in total phosphorus and other parameters and if the high levels are due to a natural source such as wetlands or due to anthropogenic pollution.

   The ten-month Diagnostic/Feasibility study will include:
   a) An introduction summarizing past studies and outlining current problems in the pond.
   b) Preparation of a Quality Assurance Project Plan (QAPP) for DEP approval that outlines sampling sites, sampling procedures, and analysis of samples.
   c) Bi-monthly (every other month) sampling from an in-lake station, and a minimum of six upstream tributary stations and at least 2 wetland sites. In addition to monthly sampling collect sets of samples during three storm events at the tributary and wetland sites. The monitoring should include nutrients (ortho and Total phosphorus, nitrate+nitrite, ammonia and TKN (or TN), TSS, turbidity, true color (PCU), Secchi transparency, chlorophyll a, and E. coli bacteria; Sampling should include a quality assurance plan with field blanks, duplicates and lab spike samples. If non-state certified laboratories are used, at least 10 percent of samples should be duplicated by a certified laboratory. At each of the sites water

discharge should be measured and at least 2 (maximum of 6) stage recorders installed to estimate daily flows. Groundwater levels and porewater quality should be monitored in the wetland sites.

d) Creation of a yearly phosphorus, nitrogen and hydrologic water budget. In the budget, detail how much of the phosphorus is coming from natural wetlands vs. septic systems vs. sediments, vs. other sources and detail how much is contributed by each subwatershed.
e) Analysis and discussion of all historic and current data to determine how does year to year changes in hydrology, groundwater levels or weather influence the concentration and export of nutrients to the lake and how does the nutrient budget change in wet vs. dry months. Modeling with SWMM or other appropriate software can be used for this task.
f) Delineate and describe wetland in the watershed and analyze the relationship between wetland area and export of phosphorus, iron and color from different subwatersheds.
g) Provide a recent macrophyte map of the lake, discuss changes in macrophyte communities since 1985 and management options including the use of recreational zoning (boat channels, swimming beach maintenance etc) and the use of benthic barriers and sediment curtains to enclose swimming areas. Include a discussion of rare or unusual species of algae or plants in the lake or bordering wetlands (e.g. moss, alder (N-fixing), duckweed, which may be adapted to the unusual nutrient and water quality conditions.
h) Determine how much of the light attenuation is due to true color vs algae vs suspended solids.
i) Determine the levels of E. coli bacteria in the pond and identify sources of bacteria in the watershed.
j) Review past studies of flow restrictions in Martins Brook and collect and analyze additional data on sediment depth and composition (organic matter content, grain size, and chemicals per 401 WQC for dredge spoils) in Martins Brook.

2) A draft D/F study will be delivered to DEP within 3 months of the final month of sampling and after addressing DEP comments will deliver 3 copies of the final D/F report to DEP within 2 months of receiving DEP comments.

3) The Town will implement a series of water flow improvements including culvert cleaning, removing flow restrictions, stormwater retention, adjustment of weir elevations, and beaver dam modifications on the Skug River and Martins Brook. The Town will document these improvements in photographs and narrative description in a project summary report to DEP.

4) The Town will purchase equipment such as harvester, trailer and conveyor, for use in the continued maintenance of nuisance aquatic plants. A roll-in docking system will be purchased to facilitate the access of this equipment to Martins Pond.

5) The Town shall conduct pilot applications of an aquatic herbicide in enclosures to control nuisance and exotic aquatic plants and a pilot alum treatment in enclosures to study the effects of reduced release of sediment phosphorus.

6) The Town shall conduct a pilot study in the Martins Pond area to identify the sources of sedimentation migration to the Pond.

7) The Town will conduct public education activities including implementation of a Community Septic-system Management Program and Detergent Reduction Program. The programs will be conducted for households within 300 feet of Martins Pond or its tributaries.

8) The Town will conduct public outreach activities including the promotion of education for children and teenagers through other existing programs such as scouts and school activities. The Town will purchase and place signs in the watershed area as reminders of environmental issues. The Town will purchase materials to foster these programs including storm drain stencils. The public outreach program will also include discussion of a Beaver Management Plan in a public forum.

9) The Town will conduct long term planning and pilot a program to address beaver issues in the Skug River and Martins Brook.

10) The Town agrees to observe pertinent statutes, rules and regulations of the Commonwealth as pertains to procurement of subcontracts, records retention and construction.

11) The award of this Contract by DEP does not constitute a permit or any other approval that may be required for the implementation of the project funded by this contract. The Town shall timely obtain, and comply with, all federal, state and local permits and approvals required for the sediment control and mitigation work project.

## Appendix B. Draft TMDL for Total Phosphorus for Martins Pond

**Martins Pond MA92038**
**North Reading, MA - Ipswich River Watershed**

**Total Estimated Nonpoint Source Pollution loads based on GIS-based Land Use**

Based on NPSLAKE Model of Mattson & Isaac (1999) - Lake Res. Manage. 15: 202-219.

Martins Pond Watershed Characteristics

| | | |
|---|---|---|
| | Watershed Area | 1994 ha |
| * | Average Annual Water Load | 12,163,400 $m^3$ |
| | Average Runoff | 61.0 cm $yr^{-1}$ |
| | Pond Area | 37.2 ha |
| § | Areal Water Loading to Pond - $q_s$ | 32.73 m $yr^{-1}$ |
| | Homes with Septic Systems Within 100 m of Pond | 125 in 2006 (63 in 1979) |
| | Other P Inputs | 0.0 kg $yr^{-1}$ |

* calculation: 0.61 m rainfall x 19,940,000 $m^2$
§ calculation: 12,163,400 $m^3$ / 372,000 $m^2$

**Estimate of Annual Nonpoint Source Pollution Loads by Land Use**
(based on 1979 and 2005 land use)

*P Loading Model:* $L_{ex} = 0.5$ *house septics* $+ 0.13$ *forest ha* $+ 0.3$ *rural ha* $+ 14$ *(urban ha)*$^{0.5}$

| Land Use[+] | Area '79 ha | Area '05 ha | P load '79 kg $yr^{-1}$ | P load '05 kg $yr^{-1}$ |
|---|---|---|---|---|
| ***Forest*** | 1365.7 | 888. | 177.5 | 115.5 |
| ***Rural*** | 181.7 | 563.5 | 54.5 | 169.1 |
| ***Urban*** | 417.6 | 208.8 | 286.1 | 202.3 |
| Other Land Uses | | | | |
| Water | 45.1 | 89.8 | 0.0 | 0.0 |
| Wetlands | 37.4 | 299.9 | 0.0 | 0.0 |
| Subtotal | 2047 | 1996 | 518.1 | 486.9 |
| Other P Inputs | NA | NA | 0.0 | 0.0 |
| Septic Systems | NA | NA | 31.5 | 62.5 |
| **Total** | **2047** | **1994** | **549.6** | **549.4** |

[+] MassGIS land use codes used for land use categories:

Forest: (3) Forest
Rural: (13) Low-density residential, lots > ½ acre; (1) Cropland; (2) Pasture; (6) Open Land; (7-9) Recreation; (17) Urban open; (21) Woody perennial
Urban: (10-12 Residential, lots < ½ acre; (15) Commercial; (16) Industrial; (18) Transportation; (19) Waste Disposal; (5) Mining

## Summary of Martins Pond Total Phosphorus Modeling Results

| | 1979 | 2005 |
|---|---|---|
| [a] Areal P Loading (L g $m^{-2}$ $yr^{-1}$) | 1.5 | **1.48** |
| [b] Reckhow (1979) Model TP (ppb) | 28.5 | **29.1** |

If all land were forested (excluding water/wetlands), total P export would be 255.5 kg $yr^{-1}$
Forested Condition Pond Total P would predicted to be 13.2 ppb

[a] calculation: L = total loading g / pond area $m^2$

2005 - 549400 / 372000 = 1.48 g $m^{-2}$ $yr^{-1}$

[b] Reckhow (1979) model: In-lake TP = L / (11.6 + 1.2 $q_s$) * 1000

2005 - 1.48 / (11.6 + 1.2*32.73)*1000

Note: 1979 land use data was gleaned from a 1984 D/F Study of Martins Pond; 1999 land use data was based on MassGIS® land use layers and was modified based on corrections made in the current study.

## Appendix C. Water Quality Results

**C.1. Temperature** ($^{o}$C) data collected in 2005-06. All sample results were generated using a calibrated YSI 6920-S Probe in the field. Dates marked with a * mean there were no data for that sampling date at that specific site. The probe was calibrated each day prior to use in the field.

| | Sampling Sites and Corresponding Sub-Watershed | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **MP1** | **MP3** | **WW6** | **WW5** | **WW4** | **WW3** | **WW2** | **WW1** | **WW-NA** | **WW-NB** | **WW-NC** | **WW-ND** | **WW-NE** |
| **Units are $^{o}$C** | | | | | | | | | | | | | |
| 3/7/05 | 1.5 | 1.0 | 1.5 | 1.5 | 1.5 | 1.5 | 1.0 | 4.0 | 2.0 | 3.5 | 2.8 | 1.5 | 2.0 |
| 4/14/05 | 13.1 | 14.0 | 12.5 | 8.6 | 13.0 | 12.4 | 13.0 | 9.0 | 8.5 | 12.3 | 11.6 | 10.9 | 9.8 |
| 5/10/05 | 13.3 | 12.5 | 11.0 | 9.5 | 13.0 | 11.5 | 12.2 | 11.5 | 10.5 | 12.9 | 14.0 | 13.1 | 12.6 |
| 6/2/05 | 18.0 | 18.5 | 15.8 | 15 | 18..4 | 15.0 | 14.0 | 16.0 | 14.0 | 13.9 | 15.8 | 16.5 | 17.2 |
| 6/24/05 | 26.9 | 24.5 | 21.2 | 19.3 | 23.5 | 20.6 | 18.9 | 19.5 | 19.0 | 18.9 | * | 18.4 | 18.8 |
| 6/28/05 | 28.7 | 28.6 | 23.5 | 23.0 | 26.5 | 24.9 | 22.9 | 23.6 | 21.2 | 27.7 | 24.1 | 19.5 | 19.5 |
| 7/13/05 | 28.6 | 26.2 | 23.6 | 22.1 | 26.1 | 23.1 | 22.5 | 23.3 | 19.7 | 26.8 | * | 19.1 | 21.0 |
| 7/26/05 | 30.1 | 27.0 | 22.0 | 23.0 | 27.6 | 24.0 | * | 22.4 | 19.8 | 27.8 | 26.3 | * | 19.3 |
| 8/9/05 | 26.8 | 27.4 | 24.9 | 22.4 | 27.3 | 22.9 | * | 21.0 | 19.7 | 24.2 | 24.1 | * | * |
| 8/19/05 | 24.6 | 24.3 | 21.4 | 18.5 | 24.8 | 18.3 | * | * | * | * | 22.1 | 17.9 | * |
| 9/14/05 | 26.4 | 25.2 | 20.8 | 19.6 | 23.3 | * | 17.8 | * | * | * | 21.1 | * | * |
| 9/28/05 | 21.9 | 18.9 | 18.1 | 16.8 | 21.4 | 15.5 | * | * | * | * | * | * | * |
| 10/18/05 | 18.2 | 19.3 | 17.3 | 17.7 | 18.5 | 16.8 | 15.4 | 18.6 | 17.9 | 20.5 | 18.8 | 18.2 | 18.9 |
| 11/4/05 | 10.1 | 10.0 | 9.1 | 9.4 | 9.6 | 9.8 | 8.9 | 11.9 | 9.0 | 8.5 | 8.3 | 9.5 | 10.2 |
| 12/22/05 | 1.3 | 1.8 | 1.6 | 1.5 | 1.1 | 2.3 | 1.5 | 1.0 | 1.8 | 2.0 | 2.2 | 1.8 | 3.1 |
| 1/12/06 | 0.9 | 0.7 | 0.8 | 1.3 | 2.6 | 0.7 | 1.2 | 0.8 | 1.9 | 0.6 | 4.2 | 2.7 | 4.3 |
| 2/8/06 | 2.5 | 3.8 | 1.3 | 1.9 | 3.7 | 2.9 | 1.8 | 3.0 | 1.7 | 2.0 | 3.1 | 2.1 | 3.9 |
| 3/21/06 | 6.9 | 7.3 | 5.9 | 6.2 | 7.9 | 6.0 | 5.9 | 6.7 | 8.1 | 6.7 | 8.3 | 6.7 | 9.9 |

**C.2.** C**onductivity** (microsiemens/cm at 25°C) data collected in 2005-06. Dates marked with a * mean there was no flow and no surface water available for sampling or there was simply no valid data collected on that date at that specific site. All sample results were generated using a calibrated conductivity meter. Dates marked with a * mean there were no data for that sampling date at that specific site. The probe was calibrated each day prior to use in the field.

| Sampling Sites and Corresponding Sub-Watershed | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Date* | MP1 | MP3 | WW6 | WW5 | WW4 | WW3 | WW2 | WW1 | WW-NA | WW-NB | WW-NC | WW-ND | WW-NE |
| **Units are µs/cm** | | | | | | | | | | | | | |
| 3/7/2005 | 275 | 279 | 273 | 277 | 251 | 302 | 322 | 107 | 433 | 72 | 212 | 325 | 380 |
| 4/14/2005 | 339 | 341 | 308 | 260 | 274 | 291 | 313 | 95 | 425 | 61 | 201 | 339 | 341 |
| 5/10/2005 | 305 | 309 | 265 | 256 | 246 | 256 | 205 | 86 | 430 | 268 | 189 | 356 | 344 |
| 6/2/2005 | 308 | 291 | 258 | 252 | 240 | 245 | 155 | 88 | 405 | 299 | 165 | 316 | 320 |
| 6/24/2005 | 309 | 282 | 265 | 250 | 247 | 241 | 108 | 99 | 389 | 320 | 186 | 314 | 317 |
| 7/13/2005 | 312 | 319 | 268 | 257 | 251 | 235 | 208 | 87 | 420 | 328 | 156 | 327 | 325 |
| 7/26/2005 | 305 | 307 | 232 | 230 | 245 | 205 | 142 | 79 | 418 | 271 | 198 | 402 | 337 |
| 8/9/2005 | 335 | 339 | 178 | 191 | 265 | 162 | 156 | 114 | 395 | 334 | 201 | 356 | 135 |
| 8/23/2005 | 299 | 308 | 268 | 267 | 330 | 267 | 145 | 101 | 308 | 310 | 146 | 224 | 106 |
| 9/14/2005 | 298 | 297 | 272 | 252 | 260 | 97 | * | * | 325 | * | 111 | 113 | 129 |
| 9/28/2005 | 311 | 312 | 272 | 259 | 250 | 156 | 129 | * | 289 | * | 152 | 126 | 158 |
| 10/14/2005 | 299 | 273 | 341 | 242 | 250 | 178 | * | * | 225 | 206 | 138 | 141 | 167 |
| 11/4/2005 | 225 | 250 | 265 | 195 | 219 | 166 | 153 | 151 | 277 | 169 | 157 | 125 | 138 |
| 12/22/2005 | 178 | 169 | 180 | 178 | 205 | 150 | 260 | 121 | 287 | 60 | 169 | 154 | 120 |
| 1/12/2006 | 285 | 294 | 266 | 250 | * | 245 | 165 | 100 | 404 | 333 | 82 | 150 | 349 |
| 2/8/2006 | 192 | 188 | 104 | 97 | 219 | 100 | 123 | 35 | 174 | 154 | 74 | 138 | 166 |
| 3/21/2006 | 99 | 102 | 92 | 92 | 95 | 107 | 116 | 36 | 170 | 140 | 105 | 140 | 189 |

**QA/QC**: Split samples were analyzed for each sample date. All split samples were analyzed and all values were within 2%. Known conductivity standards were also analyzed in the laboratory for each sample set and all measured values were within 3% of the known standard.

**C.3. pH** - All sample results were generated using a calibrated YSI 6920-S Probe in the field. Dates marked with a * mean there are no data for that sampling date. The probe was calibrated each day prior to use in the field and field checks were also utilized using known standards (4.01, 6.00 and 7.00).

| Sampling Sites and Corresponding Sub-Watershed | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Date* | MP1 | MP3 | WW6 | WW5 | WW4 | WW3 | WW2 | WW1 | WW-NA | WW-NB | WW-NC | WW-ND | WW-NE |
| **All Values are pH Units** | | | | | | | | | | | | | |
| 1/17/2005 | 6.65 | 6.58 | 6.43 | 6.59 | 6.42 | 6.31 | 6.22 | 5.68 | 6.89 | 6.14 | 6.42 | 6.62 | 6.49 |
| 2/3/2005 | 6.68 | 6.52 | 6.42 | 6.63 | 6.51 | 6.53 | 6.35 | 5.79 | 6.98 | 6.15 | 6.39 | 6.75 | 6.52 |
| 3/7/2005 | 6.50 | 6.43 | 6.55 | 6.69 | 6.42 | 6.63 | 6.76 | 5.76 | 7.20 | 6.21 | 6.52 | 6.84 | 6.68 |
| 4/14/2005 | 6.59 | 6.66 | 6.64 | 6.58 | 6.47 | 6.89 | 6.77 | 5.84 | 7.09 | 6.26 | 6.31 | 6.77 | 6.75 |
| 5/10/2005 | 6.75 | 6.89 | 6.60 | 6.69 | 6.66 | 6.83 | 6.67 | 5.91 | 6.90 | 6.37 | 6.30 | 6.55 | 6.80 |
| 6/2/2005 | 6.43 | 6.46 | 6.43 | 6.47 | 6.33 | 6.47 | 6.32 | 6.09 | 6.75 | 6.55 | 6.41 | 6.58 | 6.50 |
| 6/24/2005 | 7.35 | 7.09 | 6.66 | 6.69 | 6.89 | 6.81 | 6.57 | 5.75 | 6.94 | 6.73 | * | 6.57 | 6.68 |
| 7/13/2005 | 7.11 | 6.97 | 6.65 | 6.63 | 6.65 | 6.76 | 6.64 | 5.57 | 6.54 | 6.08 | 6.56 | 6.34 | * |
| 7/26/2005 | 7.20 | 7.12 | 6.79 | 6.80 | 6.72 | 7.07 | 6.79 | 5.74 | 6.66 | 6.18 | 6.54 | 6.58 | 6.73 |
| 8/9/2005 | 8.71 | 7.00 | 6.88 | 6.85 | 6.81 | 6.89 | 6.69 | 6.20 | 6.64 | 6.04 | 6.78 | 6.34 | 6.94 |
| 8/23/2005 | 7.99 | 7.39 | 6.57 | 6.62 | 6.79 | 6.90 | 6.62 | 6.03 | 6.44 | 6.22 | 6.59 | 6.64 | 6.75 |
| 9/14/2005 | 7.90 | 7.86 | 6.57 | 6.62 | 6.63 | 6.90 | 6.55 | * | * | * | 6.51 | 6.65 | 6.82 |
| 9/28/2005 | 7.11 | 6.98 | 6.55 | 6.67 | 6.70 | | 6.57 | * | * | * | * | * | 6.51 |
| 10/14/2005 | 7.59 | 7.30 | 6.80 | 6.96 | 7.37 | 7.14 | * | * | * | * | 6.50 | 6.62 | * |
| 11/4/2005 | 7.01 | 6.79 | 6.65 | 6.72 | 7.02 | 6.89 | 6.85 | 6.10 | 6.70 | 6.00 | 6.43 | 6.67 | 6.85 |
| 12/22/2005 | 6.61 | 6.68 | 6.58 | 6.62 | 6.71 | 6.77 | 7.06 | 6.12 | 6.99 | 5.93 | 6.48 | 6.52 | 6.73 |
| 1/12/2006 | 6.15 | 5.94 | 6.39 | 6.49 | 6.49 | 6.41 | 6.31 | 5.41 | 6.68 | 5.86 | 6.39 | 6.52 | 6.41 |
| 2/8/2006 | 6.59 | 6.52 | 6.43 | 6.61 | 6.52 | 6.49 | 6.55 | 5.55 | 6.70 | 5.98 | 6.51 | 6.60 | 6.52 |
| 3/21/2006 | 6.65 | 6.63 | 6.84 | 6.57 | 6.62 | 6.71 | 6.92 | 5.57 | 6.75 | 6.24 | 6.47 | 6.64 | 6.61 |

**QA/QC**: Split samples were analyzed for each sample date. All split samples were analyzed and all values were within 1%. Fisher pH standards were also analyzed in the laboratory for each sample set and all measured values were within 2% of the known standard.

**C.4. Color** (Platinum-Cobalt Units – PCU) - All sample results were generated using a Hach Color Test Kit Model CO-1 in the laboratory after samples were transported from the field (Method 2120B). Dates marked with an * mean there are no data for that sampling date at that specific location. Before color measurements were conducted in the laboratory, laboratory assistants first had to report color values to the QC officer using a set of blind standard solutions (ranging from 10 to 160 PCUs) before and after field samples were analyzed. Measured values of standards had to be within 10% of the standard value for the field samples results to be accepted.

| Sampling Sites and Corresponding Sub-Watershed | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Date* | MP1 | MP3 | WW6 | WW5 | WW4 | WW3 | WW2 | WW1 | WW-NA | WW-NB | WW-NC | WW-ND | WW-NE |
| **Units are Platinum Cobalt Units (PCUs)** | | | | | | | | | | | | | |
| 3/7/2005 | 40 | 35 | 30 | 40 | 20 | 40 | 50 | 60 | 25 | 35 | 30 | 20 | 30 |
| 4/14/2005 | 35 | 30 | 35 | 20 | 20 | 30 | 55 | 100 | 25 | 30 | 45 | 35 | 45 |
| 5/10/2005 | 60 | 85 | 45 | 70 | 25 | 95 | 125 | 140 | 65 | 45 | 50 | 50 | 40 |
| 6/2/2005 | 70 | 65 | 60 | 65 | 20 | 60 | 75 | 100 | 40 | 45 | 60 | 25 | 30 |
| 6/24/2005 | 80 | 95 | 40 | 70 | 15 | 65 | 90 | 120 | 45 | 50 | 30 | 35 | 45 |
| 7/13/2005 | 75 | 80 | 55 | 80 | 20 | 80 | 95 | 125 | 50 | 65 | 40 | 35 | 45 |
| 7/26/2005 | 70 | 75 | 90 | 95 | 20 | 110 | 130 | 140 | 60 | 70 | 45 | 45 | 55 |
| 8/9/2005 | 45 | 80 | 70 | 70 | 25 | 100 | 125 | 160 | 40 | 55 | 50 | 30 | 35 |
| 8/23/2005 | 50 | 40 | 30 | 35 | 20 | 40 | 140 | 150 | 40 | 75 | 55 | 65 | 25 |
| 9/14/2005 | 70 | 85 | 35 | 35 | 20 | 50 | 110 | 150 | 45 | 70 | 60 | 70 | 20 |
| 9/28/2005 | 35 | 55 | 20 | 35 | 20 | 40 | 95 | 160 | 50 | 65 | 40 | 65 | 25 |
| 10/14/2005 | 35 | 50 | 45 | 15 | 20 | 30 | 60 | 140 | 80 | 65 | 45 | 65 | 20 |
| 11/4/2005 | 45 | 55 | 40 | 30 | 35 | 40 | 65 | 145 | 40 | 55 | 40 | 50 | 25 |
| 12/22/2005 | 65 | 65 | 40 | 40 | 25 | 20 | 25 | 160 | 25 | 60 | 35 | 40 | 30 |
| 1/12/2006 | 45 | 50 | 35 | 45 | 25 | 60 | 25 | 100 | 20 | 70 | 30 | 25 | 25 |
| 2/8/2006 | 40 | 40 | 35 | 35 | 30 | 50 | 30 | 85 | 20 | 50 | 25 | 20 | 25 |
| 3/21/2006 | 45 | 45 | 30 | 35 | 20 | 40 | 30 | 60 | 25 | 40 | 20 | 20 | 35 |

**QA/QC**: Split samples were analyzed for each sample date. All split samples were analyzed and all values were within 5%. Known color standards were also analyzed in the laboratory for each sample set and all measured values were within 8% of the known standard.

**C.5. Dissolved Oxygen** (mg/L) - All sample results were generated using a calibrated YSI 6920-S Probe in the field. Dates marked with an * mean there were no data for that sampling date at that specific site. The probe was calibrated each day prior to use in the field and membrane integrity was checked after each measurement.

| Sampling Sites and Corresponding Sub-Watershed | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **MP1** | **MP3** | **WW6** | **WW5** | **WW4** | **WW3** | **WW2** | **WW1** | **WW-NA** | **WW-NB** | **WW-NC** | **WW-ND** | **WW-NE** |
| **Units are mg/L** | | | | | | | | | | | | | |
| 3/7/2005 | 11.0 | 10.8 | 11.0 | 10.6 | 11.3 | 10.2 | 10.2 | 8.7 | 12.3 | 6.8 | 6.4 | 7.4 | 10.2 |
| 4/14/2005 | 11.2 | 10.0 | 10.5 | 12.0 | 11.0 | 10.2 | 12.0 | 10.5 | 9.3 | 10.0 | 9.5 | 12.0 | 8.3 |
| 5/10/2005 | 9.4 | 10.5 | 10.0 | 12.0 | 9.3 | 12.0 | 10.0 | 6.0 | 9.2 | 6.3 | 7.1 | 8.9 | 5.1 |
| 6/2/2005 | 7.0 | 7.5 | 8.5 | 9.5 | 4.6 | 11.0 | 10.3 | 5.3 | 12.0 | 4.0 | 5.2 | 3.3 | 3.3 |
| 6/24/2005 | 6.6 | 6.8 | 0.7 | 0.9 | 4.7 | 11.8 | 1.7 | 1.1 | 0.6 | 0.8 | 3.2 | 0.8 | 0.9 |
| 6/28/2005 | 5.2 | 5.3 | 1.6 | 2.3 | 5.3 | 1.8 | 2.1 | 2.1 | 2.8 | 0.7 | 2.9 | 2.5 | 2.1 |
| 7/13/2005 | 9.4 | 8.6 | 3.6 | 6.0 | 6.3 | 1.8 | 7.8 | 2.7 | 8.6 | 2.6 | 2.1 | 4.8 | 7.1 |
| 7/26/2005 | 14.0 | 9.1 | 2.4 | 5.8 | 6.3 | 8.4 | * | 2.5 | 7.3 | 1.5 | 2.0 | 2.7 | 3.0 |
| 8/9/2005 | 7.3 | 8.3 | 2.2 | 5.1 | 7.3 | 9.6 | * | 1.9 | 6.0 | 2.7 | 3.3 | 2.0 | * |
| 8/19/2005 | 9.5 | 8.6 | 3.1 | 5.0 | 7.7 | 7.0 | * | * | * | * | 5.8 | 7.1 | 4.8 |
| 9/14/2005 | 8.8 | 7.3 | 1.7 | 4.5 | 8.4 | * | 4.5 | * | * | * | * | * | * |
| 9/28/2005 | 9.5 | 8.5 | 5.2 | 7.5 | 8.9 | * | * | * | * | * | 4.9 | * | * |
| 10/18/2005 | 8.7 | 9.2 | 6.1 | 6.2 | 9.3 | 7.7 | 9.8 | 3.6 | 8.5 | 5.2 | * | 6.3 | 4.3 |
| 11/4/2005 | 13.0 | 12.5 | 6.1 | 14.1 | 12.6 | 15.6 | 12.7 | 4.0 | 7.2 | 6.1 | 6.9 | 5.5 | 5.1 |
| 12/22/2005 | 8.5 | 9.5 | 9.6 | * | 9.5 | 12.1 | 9.8 | 5.2 | 6.3 | 5.8 | 6.2 | 6.5 | 6.5 |
| 1/8/2006 | 5.8 | 6.8 | 7.1 | 6.9 | 8.2 | 11.5 | 7.8 | 6.2 | 4.2 | 4.3 | 7.8 | 7.3 | * |
| 2/8/2006 | 9.2 | 7.6 | 6.8 | 7.2 | 10.2 | 15.2 | 9.2 | 5.2 | 8.6 | 4.8 | * | 6.9 | 7.3 |
| 3/21/2006 | 11.9 | 10.2 | 9.9 | 9.0 | 9.6 | 11.3 | 9.3 | 7.5 | 9.7 | 6.3 | 9.3 | 9.2 | 8.1 |

**C.6. Percent Saturation of Oxygen** - All sample results were generated based on results from the calibrated YSI 6920-S Probe in the field. Percent saturation was determined based on barometric pressure, water temperature and dissolved oxygen concentrations. Dates marked with a * mean there are no data for that sampling date at that specific location

| Sampling Sites and Corresponding Sub-Watershed | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **MP1** | **MP3** | **WW6** | **WW5** | **WW4** | **WW3** | **WW2** | **WW1** | **WW-NA** | **WW-NB** | **WW-NC** | **WW-ND** | **WW-NE** |
| **Units are % Saturation** | | | | | | | | | | | | | |
| 3/7/2005 | 79 | 76 | 78 | 75 | 80 | 72 | 71 | 66 | 89 | 51 | 62 | 53 | 73 |
| 4/14/2005 | 86 | 97 | 98 | 103 | 105 | 111 | 114 | 91 | 79 | 93 | 79 | 109 | 73 |
| 5/10/2005 | 96 | 99 | 91 | 105 | 88 | 101 | 93 | 55 | 82 | 60 | 96 | 85 | 48 |
| 6/2/2005 | 74 | 80 | 86 | 94 | 49 | 117 | 102 | 53 | 117 | 39 | 103 | 34 | 34 |
| 6/28/2005 | 85 | 87 | 89 | 97 | 67 | 102 | 92 | 36 | 78 | 49 | 75 | 27 | 23 |
| 7/13/2005 | 108 | 107 | 43 | 69 | 79 | 99 | 91 | 31 | 95 | 32 | 65 | 52 | 80 |
| 7/26/2005 | 188 | 116 | 28 | 68 | 81 | 114 | * | 29 | 80 | 19 | 89 | 29 | 33 |
| 8/9/2005 | 112 | 105 | 27 | 59 | 93 | 82 | * | 22 | 66 | 33 | 34 | 22 | 30 |
| 8/19/2005 | 111 | 103 | 35 | 54 | 93 | 105 | * | * | * | * | 68 | 75 | 41 |
| 9/14/2005 | 110 | 89 | 19 | 49 | 100 | * | 48 | * | * | * | * | * | * |
| 9/28/2005 | 109 | 92 | 55 | 77 | 99 | * | * | * | * | * | 77 | * | * |
| 10/18/2005 | 93 | 100 | 64 | 65 | 100 | 70 | 98 | 39 | 90 | 58 | * | 67 | 46 |
| 11/4/2005 | 115 | 111 | 53 | 113 | 110 | 80 | 109 | 37 | 62 | 52 | 49 | 48 | 45 |
| 12/22/2005 | 95 | 92 | 63 | * | 91 | 75 | 95 | 55 | 89 | 86 | 89 | 62 | 43 |
| 1/8/2006 | 88 | 86 | 70 | 68 | 75 | 82 | 86 | 65 | 75 | 56 | 91 | 75 | * |
| 2/8/2006 | 75 | 79 | 68 | 75 | 78 | 82 | 69 | 78 | 71 | 42 | * | 74 | 48 |
| 3/21/2006 | 82 | 80 | 85 | 92 | 119 | 112 | 87 | 96 | 63 | 49 | 79 | 60 | 62 |

**C.7. Chlorophyll-a concentration** (µg/L) - All sample results were generated using a calibrated YSI 6920-S Probe in the field. Dates marked with an * mean there were no data for that sampling date at that specific location.

| Sampling Sites and Corresponding Sub-Watershed | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | **MP1** | **MP3** | **WW6** | **WW5** | **WW4** | **WW3** | **WW2** | **WW1** | **WW-NA** | **WW-NB** | **WW-NC** | **WW-ND** | **WW-NE** |
| **Units are µg/L** | | | | | | | | | | | | | |
| 3/7/2005 | 1.6 | 1.6 | 1.6 | 1.6 | 1.5 | 2.4 | 1.3 | 2.4 | 2.1 | 1.9 | 2.6 | 0.6 | 1.8 |
| 4/14/2005 | 2.3 | 2.2 | 2.0 | 1.1 | 0.9 | 1.9 | 0.8 | 2.7 | 1.3 | 2.1 | 4.1 | 1.2 | 2.4 |
| 5/10/2005 | 2.1 | 2.1 | 2.4 | 0.8 | 2.5 | 3.6 | 0.8 | 4.0 | 0.8 | * | 1.9 | 2.1 | 2.9 |
| 6/2/2005 | 8.9 | 7.4 | 3.5 | 6.1 | 1.8 | 4.1 | 2.3 | 3.9 | 2.9 | 4.7 | 3.8 | 1.3 | 3.6 |
| 6/28/2005 | 13.1 | 12.0 | 4.9 | 4.8 | 3.0 | 6.8 | 6.7 | 14.0 | 5.8 | 3.8 | 5.9 | 3.3 | 3.3 |
| 7/13/2005 | 12.0 | 11.2 | 5.5 | 5.5 | 2.3 | 9.0 | 7.8 | 13.0 | 6.9 | 11.3 | 8.0 | 6.0 | 4.4 |
| 7/26/2005 | 20.1 | 14.1 | 7.3 | 7.5 | 4.8 | 9.0 | 11.0 | 13.2 | 5.6 | 14.4 | 6.7 | 4.4 | 3.6 |
| 8/9/2005 | 16.5 | 12.0 | 9.5 | 9.7 | 6.1 | 15.4 | * | 17.2 | 9.1 | 11.4 | 10.2 | 3.6 | 5.3 |
| 8/19/2005 | 7.2 | 9.9 | 6.4 | 5.3 | 15.0 | 7.3 | * | 37.1 | 7.3 | 14.0 | 8.6 | 5.3 | 3.6 |
| 9/14/2005 | 8.5 | 12.1 | 3.8 | 3.0 | 2.3 | 3.0 | * | * | * | * | 6.1 | 3.6 | 2.0 |
| 9/28/2005 | 11.1 | 6.9 | 2.9 | 1.7 | 2.3 | * | 11.0 | * | * | * | * | * | * |
| 10/18/2005 | 7.6 | 8.8 | 4.2 | 2.3 | 1.9 | * | * | * | * | * | * | * | * |
| 11/4/2005 | 7.9 | 2.6 | 5.1 | 3.0 | 2.2 | 3.1 | 7.5 | 8.9 | 4.1 | 5.0 | 3.9 | 3.1 | 4.2 |
| 12/22/2005 | 3.0 | 3.7 | 6.0 | 4.8 | 2.5 | 3.4 | 5.0 | 10.5 | 3.6 | 7.1 | 6.1 | 2.1 | 3.4 |
| 1/12/2006 | 4.0 | 4.5 | 4.5 | 5.6 | 6.5 | 5.1 | 16.0 | 8.3 | 10.6 | 3.9 | 4.3 | 5.0 | 13.5 |
| 2/8/2006 | 5.6 | 1.9 | 5.0 | 4.2 | 3.7 | 4.9 | 9.0 | 8.0 | 8.6 | 11.5 | * | 3.4 | 3.7 |
| 3/21/2006 | 2.5 | 1.6 | 2.5 | 1.9 | 1.9 | 2.5 | 2.6 | 1.6 | 2.9 | 2.5 | 3.1 | 2.1 | 2.0 |

**C.8. Turbidity** (NTU) – All sample results were generated using a Hach 2100 N Tubidimeter at Merrimack College after samples were transported to the laboratory (EPA Method 180.1). Dates marked with an * mean there were no data for that sampling date at that specific location.

| Sampling Sites and Corresponding Sub-Watershed | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Date* | MP1 | MP3 | WW6 | WW5 | WW4 | WW3 | WW2 | WW1 | WW-NA | WW-NB | WW-NC | WW-ND | WW-NE |
| **All Values are NTUs** | | | | | | | | | | | | | |
| 3/7/2005 | 0.99 | 1.08 | 1.58 | 2.98 | 0.34 | 1.91 | 1.30 | 1.60 | 1.32 | 0.99 | 1.23 | 3.25 | 3.25 |
| 4/14/2005 | 0.46 | 0.30 | 0.99 | 2.55 | 0.29 | 0.43 | 0.62 | 0.63 | 1.68 | 0.56 | 0.97 | 2.64 | 4.09 |
| 5/10/2005 | 1.02 | 0.96 | 1.65 | 1.47 | 0.43 | 1.25 | 0.95 | 0.59 | 2.30 | 1.02 | 0.65 | 1.09 | 3.77 |
| 6/2/2005 | 1.50 | 1.24 | 1.55 | 2.47 | 0.96 | 1.17 | 0.90 | 1.50 | 3.9 | 1.46 | 1.23 | 2.8 | 4.05 |
| 6/24/2005 | 6.30 | 2.69 | 8.70 | 5.69 | 0.59 | 2.28 | 1.73 | 1.21 | 2.54 | 1.85 | 1.24 | 5.75 | 4.57 |
| 7/13/2005 | 4.36 | 3.99 | 6.58 | 5.57 | 0.58 | 2.01 | 1.59 | 0.94 | 3.20 | 1.95 | 1.33 | 2.91 | 5.02 |
| 7/26/2005 | 14.35 | 13.02 | 3.65 | 8.61 | 1.28 | 4.18 | 6.05 | 5.21 | 13.25 | 4.08 | * | 19.50 | 4.89 |
| 8/9/2005 | 16.23 | 15.92 | 2.80 | 7.68 | 2.15 | 3.36 | 4.12 | 4.30 | 8.40 | 6.05 | 1.56 | 22.10 | 4.91 |
| 8/23/2005 | 6.98 | 7.12 | 2.01 | 7.00 | 1.09 | 3.25 | 3.56 | 2.56 | 6.58 | 3.58 | 1.72 | 12.56 | 7.24 |
| 9/14/2005 | 5.84 | 8.02 | 1.40 | 7.43 | 0.70 | 5.31 | 7.86 | 6.25 | * | * | 1.42 | * | * |
| 9/28/2005 | 2.46 | 3.45 | 1.78 | 1.60 | 1.06 | 4.84 | 3.56 | 15.10 | 12.20 | 2.01 | * | 3.10 | 6.29 |
| 10/14/2005 | 4.85 | 5.69 | 5.23 | 9.23 | 2.22 | 6.34 | 2.58 | 14.56 | * | 1.18 | 3.56 | 5.02 | 11.25 |
| 11/4/2005 | 3.29 | 2.31 | 1.61 | 2.04 | 1.07 | 2.08 | 1.48 | 17.10 | 1.08 | 1.84 | 2.69 | * | * |
| 12/22/2005 | 0.92 | 1.15 | 1.23 | 1.41 | 1.11 | 1.40 | 2.05 | 1.33 | 1.62 | 1.71 | 1.02 | 3.96 | 4.00 |
| 1/12/2006 | 0.84 | 0.73 | 1.22 | 1.55 | 0.95 | 2.00 | 1.56 | 1.28 | * | 1.59 | 2.00 | * | * |
| 2/8/2006 | 1.08 | 1.18 | 1.52 | 1.92 | 1.03 | 2.89 | 0.92 | 1.83 | 1.23 | 1.63 | 1.28 | 4.95 | 3.69 |
| 3/21/2006 | 0.65 | 1.06 | 6.14 | 11.30 | 0.43 | 0.84 | 1.02 | 0.72 | 1.18 | 1.32 | 0.26 | 4.20 | 3.21 |

**QA/QC**: Split samples were analyzed for each sample date. All split samples were analyzed and all values were within 6%. Known color standards were also analyzed in the laboratory for each sample set and all measured values were within 4% of the known standard.

**C.9. Sulfate – ($SO_4^{2-}$ - mg/L) -** All sample results were generated using a Dionex ICS-90 Ion Chromatograph at Merrimack College after samples were transported to the laboratory. Dates marked with a * mean there are no data for that sampling date at that specific location.

| Sampling Sites and Corresponding Sub-Watershed | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Date* | MP1 | MP3 | WW6 | WW5 | WW4 | WW3 | WW2 | WW1 | WW-NA | WW-NB | WW-NC | WW-ND | WW-NE |
| **Units are mg/L** | | | | | | | | | | | | | |
| 3/7/2005 | 9.2 | 9.0 | 9.6 | 9.6 | 9.1 | 10.7 | 11.3 | 4.5 | 13.5 | 10.8 | 3.5 | 13.8 | 15.2 |
| 4/14/2005 | 8.9 | 9.0 | 9.2 | 9.1 | 6.4 | 10.2 | 10.5 | 5.2 | 5.4 | 10.9 | 4.1 | 12.6 | 14.8 |
| 5/10/2005 | 8.1 | 8.2 | 7.4 | 8.5 | 6.8 | 8.5 | 7.8 | 5.2 | 13.7 | 11.9 | 5.3 | 12.5 | 14.2 |
| 6/2/2005 | 6.5 | 6.4 | 7.4 | 7.7 | 6.9 | 7.2 | 7.7 | 4.9 | 13.5 | 13.4 | 4.8 | 11.8 | 11.9 |
| 6/24/2005 | 5.6 | 5.3 | 6.5 | 7.1 | 6.0 | 6.2 | 6.7 | 4.2 | 9.8 | 8.9 | 5.1 | 10.4 | 12.8 |
| 7/13/2005 | 5.6 | 5.1 | 4.8 | 5.8 | 5.6 | 4.9 | 4.3 | 2.8 | 11.4 | 4.4 | 4.3 | 6.2 | 13.8 |
| 7/26/2005 | 8.4 | 4.8 | 3.9 | 4.9 | 5.4 | 3.6 | 7.4 | 2.0 | 4.1 | 3.1 | 4.2 | 11.0 | 15.4 |
| 8/9/2005 | 4.9 | 5.0 | 0.3 | 7.1 | 5.1 | 4.8 | 3.5 | 1.6 | 11.0 | 2.9 | 5.0 | 9.9 | 15.7 |
| 8/23/2005 | 5.2 | 5.2 | 7.7 | 0.2 | 5.7 | 8.3 | 3.4 | 1.2 | 9.5 | 3.6 | 4.7 | 5.1 | 19.1 |
| 9/14/2005 | 5.2 | 5.0 | 8.2 | 7.9 | 5.3 | 8.8 | 5.6 | 0.9 | 9.0 | 2.1 | 4.8 | 9.1 | 0.0 |
| 9/28/2005 | 5.1 | 5.2 | 10.0 | 7.6 | 5.5 | 14.2 | 6.2 | 3.4 | 7.9 | 10.1 | 5.6 | 11.1 | 17.4 |
| 10/14/2005 | 8.1 | 8.6 | 13.6 | 11.7 | 5.9 | 6.9 | 9.8 | 4.9 | 19.2 | 13.7 | 7.5 | 11.9 | 17.5 |
| 11/4/2005 | 17.6 | 17.5 | 19.7 | 19.6 | 5.8 | 5.5 | 27.8 | 8.9 | 25.9 | 14.3 | 8.2 | 13.2 | 21.7 |
| 12/22/2005 | 10.9 | 11.8 | 12.3 | 12.0 | 6.3 | 13.8 | 19.3 | 9.7 | 20.0 | 10.7 | 8.6 | 12.0 | 17.7 |
| 1/12/2006 | 15.6 | 14.5 | 11.9 | 11.1 | 7.5 | 12.3 | 17.8 | 7.5 | 18.3 | 10.8 | 9.6 | 10.6 | 16.1 |
| 2/8/2006 | 11.0 | 10.1 | 9.6 | 10.8 | 7.6 | 11.0 | 14.0 | 6.2 | 17.2 | 14.3 | 6.5 | 13.1 | 15.0 |
| 3/21/2006 | 12.3 | 11.6 | 12.9 | 12.7 | 8.7 | 11.2 | 12.3 | 4.5 | 17.9 | 11.7 | 4.0 | 12.9 | 16.8 |

**C.10. Chloride** (mg/L) - All sample results were generated using a Dionex ICS-90 Ion Chromatograph at Merrimack College after samples were transported to the laboratory (EPA Method 300.0). Dates marked with an * mean there were no data for that sampling date at that specific location.

| Sampling Sites and Corresponding Sub-Watershed | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Date* | MP1 | MP3 | WW6 | WW5 | WW4 | WW3 | WW2 | WW1 | WW-NA | WW-NB | WW-NC | WW-ND | WW-NE |
| **Units are mg/L** | | | | | | | | | | | | | |
| 3/7/2005 | 63.4 | 65.5 | 63.1 | 57.5 | 83.3 | 68.9 | 73.2 | 15.6 | 85.2 | 79.8 | 18.2 | 82.3 | 89.5 |
| 4/14/2005 | 87.5 | 86.3 | 70.8 | 78.2 | 70.5 | 73.2 | 79.5 | 16.6 | 8.5 | 102.3 | 19.6 | 85.6 | 69.9 |
| 5/10/2005 | 89.6 | 90.9 | 58.6 | 71.9 | 76.3 | 73.4 | 55.0 | 18.4 | 130.2 | 116.1 | 24.6 | 89.1 | 91.1 |
| 6/2/2005 | 23.9 | 19.2 | 19.1 | 17.8 | 22.8 | 13.9 | 12.5 | 4.5 | 36.8 | 26.6 | 5.5 | 25.2 | 32.1 |
| 6/24/2005 | 25.6 | 23.8 | 22.5 | 21.4 | 22.5 | 21.1 | 18.0 | 7.0 | 35.3 | 28.5 | 16.8 | 26.4 | 25.3 |
| 7/13/2005 | 24.8 | 25.3 | 18.6 | 18.9 | 23.0 | 15.9 | 10.1 | 4.2 | 39.5 | 22.3 | 18.9 | 27.1 | 26.7 |
| 7/26/2005 | 26.4 | 26.3 | 13.3 | 14.6 | 20.0 | 11.6 | 25.7 | 5.6 | 36.8 | 28.4 | 25.1 | 79.2 | 28.9 |
| 8/9/2005 | 26.7 | 26.6 | 11.1 | 24.3 | 29.6 | 23.9 | 7.0 | 5.5 | 24.1 | 34.7 | 19.0 | 33.8 | 29.2 |
| 8/23/2005 | 26.4 | 26.0 | 25.0 | 24.2 | 24.4 | 15.0 | 15.8 | 5.0 | 30.0 | 25.8 | 13.7 | 80.7 | 29.5 |
| 9/14/2005 | 53.4 | 53.9 | 29.6 | 51.1 | 49.9 | 14.2 | 20.4 | 6.8 | 28.4 | 23.1 | 27.1 | 72.2 | 33.7 |
| 9/28/2005 | 31.1 | 31.8 | 39.1 | 27.4 | 29.0 | 15.8 | 25.8 | 7.7 | 11.1 | 22.8 | 28.2 | 73.7 | 31.6 |
| 10/14/2005 | 28.5 | 28.6 | 48.0 | 23.5 | 24.7 | 20.3 | 30.5 | 12.5 | 29.8 | 20.2 | 17.8 | 67.2 | 45.6 |
| 11/4/2005 | 23.2 | 22.4 | 67.3 | 23.7 | 25.6 | 24.0 | 38.3 | 18.3 | 41.7 | 16.9 | 15.3 | 72.5 | 79.6 |
| 12/22/2005 | 61.3 | 64.4 | 54.2 | 51.3 | 42.5 | 65.3 | 44.6 | 19.2 | 96.1 | 82.4 | 28.9 | 80.9 | 78.6 |
| 1/12/2006 | 54.7 | 52.9 | 53.7 | 55.0 | 56.1 | 68.7 | 56.9 | 14.8 | 102.8 | 85.6 | 31.5 | 71.9 | 88.0 |
| 2/8/2006 | 50.8 | 54.3 | 60.9 | 58.2 | 61.7 | 68.2 | 75.7 | 10.7 | 126.5 | 87.3 | 43.2 | 69.8 | 96.9 |
| 2/23/2006 | 66.7 | 69.8 | 72.0 | 63.9 | 61.9 | 65.3 | 67.3 | 11.5 | 79.8 | 86.4 | 39.5 | 91.6 | 92.4 |
| 3/21/2006 | 95.3 | 106.0 | 78.4 | 75.4 | 70.3 | 71.5 | 65.8 | 12.8 | 115.4 | 99.7 | 24.3 | 81.2 | 90.5 |

**C.11. Nitrate** (mg/L) - All sample results were generated using a Dionex ICS-90 Ion Chromatograph at Merrimack College after samples were transported to the laboratory (EPA Method 300.0). Dates marked with an * mean there were no data for that sampling date at that specific location.

| | Sampling Sites and Corresponding Sub-Watershed | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Date* | MP1 | MP3 | WW6 | WW5 | WW4 | WW3 | WW2 | WW1 | WW-NA | WW-NB | WW-NC | WW-ND | WW-NE |
| **Units are mg/L** | | | | | | | | | | | | | |
| 3/7/2005 | 3.01 | 2.99 | 2.36 | 2.86 | 1.76 | 2.21 | 3.22 | 0.25 | 5.46 | 2.28 | 2.69 | 12.16 | 14.56 |
| 4/14/2005 | 1.46 | 1.49 | 1.88 | 1.56 | 0.56 | 1.27 | 1.82 | 0.30 | 0.74 | 0.69 | 0.89 | 3.25 | 9.85 |
| 5/10/2005 | 0.65 | 0.58 | 0.94 | 1.84 | 0.14 | 0.91 | 1.27 | 0.34 | 3.10 | 2.12 | 0.02 | 7.26 | 13.45 |
| 6/2/2005 | 0.85 | 0.57 | 1.02 | 1.16 | 0.02 | 0.70 | 0.95 | 0.02 | 2.57 | 8.36 | 0.02 | 6.83 | 6.16 |
| 6/24/2005 | 0.13 | 0.19 | 1.71 | 1.85 | 0.09 | 0.72 | 0.85 | 0.25 | 1.20 | 7.25 | 0.02 | 5.38 | 7.02 |
| 7/13/2005 | 0.11 | 0.17 | 1.77 | 2.03 | 0.02 | 0.86 | 1.72 | 0.12 | 1.45 | 1.49 | 0.36 | 6.52 | 7.82 |
| 7/26/2005 | 0.08 | 0.09 | 0.79 | 1.65 | 0.02 | 0.69 | 0.77 | 0.02 | 2.07 | 0.02 | 0.92 | 1.36 | 7.76 |
| 8/9/2005 | 0.02 | 0.02 | 0.26 | 1.76 | 0.06 | 0.87 | 2.97 | 0.02 | 1.31 | 0.02 | 0.06 | 0.86 | 8.73 |
| 8/23/2005 | 0.02 | 0.02 | 0.02 | 1.81 | 0.02 | 1.98 | 0.75 | 0.02 | 1.80 | 0.02 | 0.02 | 0.37 | 4.60 |
| 9/14/2005 | 0.05 | 0.02 | 0.21 | 2.56 | 0.02 | 5.32 | 1.58 | 2.13 | 2.36 | 0.16 | 0.02 | 1.11 | 10.00 |
| 9/28/2005 | 0.10 | 0.09 | 0.51 | 2.98 | 0.17 | 1.34 | 3.53 | 1.99 | 6.80 | 0.29 | 0.02 | 6.23 | 8.37 |
| 10/14/2005 | 0.22 | 0.07 | 0.54 | 2.92 | 0.13 | 1.72 | 2.67 | 0.34 | 7.57 | 0.94 | 0.67 | 13.79 | 9.58 |
| 11/4/2005 | 1.23 | 1.16 | 1.23 | 2.06 | 1.19 | 0.98 | 3.08 | 0.98 | 6.03 | 1.02 | 1.21 | 2.13 | 7.24 |
| 12/22/2005 | 1.99 | 0.91 | 1.61 | 1.98 | 0.15 | 0.42 | 2.79 | 3.07 | 4.29 | 1.25 | 0.96 | 1.58 | 5.13 |
| 1/12/2006 | 2.01 | 2.04 | 2.67 | 3.00 | 0.26 | 2.89 | 2.15 | 1.41 | 7.37 | 1.92 | 0.68 | 4.12 | 8.74 |
| 2/8/2006 | 2.68 | 3.12 | 2.53 | 2.61 | 0.78 | 1.96 | 2.54 | 1.20 | 6.57 | 3.58 | 1.19 | 3.29 | 6.58 |
| 2/23/2006 | 4.75 | 5.40 | 2.12 | 2.43 | 0.65 | 2.38 | 3.96 | 0.02 | 5.78 | 9.04 | 1.65 | 6.23 | 18.15 |
| 3/21/2006 | 2.36 | 1.80 | 2.81 | 2.84 | 0.53 | 1.02 | 3.21 | 0.02 | 4.32 | 0.13 | 2.28 | 9.65 | 9.47 |

**C.12. Total N** (mg/L) - All sample results were generated using a Cd-Reduction Method at Merrimack College after samples were transported to the laboratory (Standard Method 4500-N C). Dates marked with an * mean there were no data for that sampling date at that specific location.

| Sampling Sites and Corresponding Sub-Watershed | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Date* | MP1 | MP3 | WW6 | WW5 | WW4 | WW3 | WW2 | WW1 | WW-NA | WW-NB | WW-NC | WW-ND | WW-NE |
| **Units are mg/L** | | | | | | | | | | | | | |
| 3/7/2005 | * | 3.360 | 3.240 | 2.140 | 2.250 | 3.170 | 2.510 | 1.290 | 14.800 | * | * | 16.400 | * |
| 4/14/2005 | * | 5.120 | * | * | * | 3.780 | * | * | * | * | * | 2.250 | * |
| 5/10/2005 | * | 3.740 | * | 3.430 | 4.230 | 0.570 | * | 1.340 | 6.910 | 3.980 | 1.580 | 11.720 | 23.420 |
| 6/2/2005 | 1.930 | * | 1.650 | 2.270 | * | 2.330 | 1.950 | 1.380 | 12.700 | 14.590 | 1.510 | 9.810 | * |
| 6/24/2005 | 0.580 | 0.390 | 3.510 | 14.610 | 1.890 | * | * | 0.390 | * | * | * | * | * |
| 7/13/2005 | * | 0.730 | 2.670 | 21.680 | 0.710 | 3.080 | 2.780 | 0.750 | 4.660 | 7.600 | * | 3.680 | 2.290 |
| 7/26/2005 | * | 0.950 | 0.470 | 3.670 | * | 0.680 | 6.390 | 0.770 | 4.100 | 1.630 | * | 2.450 | 10.690 |
| 8/9/2005 | * | 10.600 | * | * | * | * | * | * | 7.340 | 1.140 | * | 2.360 | * |
| 8/23/2005 | 0.380 | 3.030 | 2.640 | 9.860 | 0.820 | 16.220 | * | * | * | * | * | 13.170 | * |
| 9/14/2005 | 0.680 | 0.410 | 1.760 | 25.470 | 0.610 | * | 8.710 | 1.620 | * | * | * | * | * |
| 9/28/2005 | 0.680 | 1.120 | 0.670 | 9.110 | 5.540 | 1.850 | * | 0.560 | 1.690 | * | * | 15.300 | 14.690 |
| 10/14/2005 | * | 2.130 | * | * | * | * | * | 1.123 | * | * | * | * | * |
| 11/4/2005 | * | 1.265 | 4.473 | * | * | 0.993 | * | * | 8.49 | 0.720 | * | * | 1.265 |
| 12/22/2005 | * | 3.576 | 2.755 | 2.093 | * | 5.474 | * | * | 5.281 | 2.611 | * | * | 3.576 |
| 1/12/2006 | * | * | * | * | * | * | * | * | * | * | * | * | * |
| 2/8/2006 | * | 6.912 | 0.728 | 6.215 | 1.646 | 4.924 | 2.652 | 0.492 | 6.309 | 13.375 | * | 14.140 | 6.304 |
| 2/23/2006 | * | * | * | * | * | * | * | * | * | * | * | * | * |
| 3/21/2006 | 2.839 | 1.812 | 4.191 | 2.383 | 1.143 | 1.972 | * | 0.252 | 9.386 | 0.768 | * | * | 1.812 |

**C.13. Total P** (mg/L) – Surface water samples were analyzed for total P using digestion (Method 4500-PB.5) and colorimetric determination of P (Method 4500-PE) as outlined in APHA (1998). A total of 271 samples were analyzed at quantitative chemistry facilities at Merrimack College. Fifty (50) duplicate samples were analyzed at the UMass Environmental Analysis Laboratory in Amherst, MA. This represents 18.5% of all samples (the Scope of Services noted that 10% of samples collected should be duplicated and run at another certified laboratory). The duplicated sample results are highlighted in yellow below their split sample and beneath that the % difference between Merrimack College results and UMass EAL results are shown. Dates marked with an * means there were no samples or there are no valid data for that sampling date at that specific location.

| Sampling Sites and Corresponding Sub-Watershed | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Date* | MP1 | MP3 | WW6 | WW5 | WW4 | WW3 | WW2 | WW1 | WW-NA | WW-NB | WW-NC | WW-ND | WW-NE |
| **Units are mg/L** | | | | | | | | | | | | | |
| 3/7/2005 | 0.015 | 0.018 | 0.021 | 0.015 | 0.007 | 0.012 | 0.020 | 0.025 | 0.003 | 0.011 | 0.009 | * | 0.007 |
| 4/14/2005 | 0.019 | 0.023 | 0.025 | 0.019 | 0.014 | 0.022 | 0.035 | 0.029 | 0.026 | 0.018 | 0.011 | 0.039 | 0.014 |
| 5/10/2005 | 0.011 | 0.011 | 0.030 | 0.023 | 0.005 | 0.020 | 0.032 | 0.035 | 0.080 | 0.026 | 0.036 | 0.020 | 0.005 |
| *UMass EAL* | *0.012* | | *0.032* | | | *0.023* | | *0.038* | | *0.022* | | | *0.005* |
| % difference | 9.1 | | 6.7 | | | 15.0 | | 8.6 | | 15.2 | | | 0.0 |
| 6/2/2005 | 0.093 | 0.035 | 0.048 | 0.044 | 0.031 | 0.055 | 0.100 | 0.103 | 0.094 | 0.065 | 0.056 | 0.052 | 0.031 |
| | | | | | | | | | | | | | |
| 6/8/2005 | * | 0.034 | .058 | .056 | .019 | .0054 | * | 0.133 | 0.112 | * | * | 0.050 | 0.050 |
| *UMass EAL* | * | *0.032* | *0.060* | *0.052* | *0.022* | *0.054* | * | *0.135* | *0.107* | * | * | *0.046* | *0.050* |
| % difference | | 5.9 | 3.4 | 7.1 | 15.8 | 0.0 | | 0.1 | 4.5 | | | 8.0 | 0.0 |
| | | | | | | | | | | | | | |
| 6/24/2005 | 0.072 | 0.051 | 0.081 | 0.093 | 0.026 | 0.084 | 0.095 | 0.165 | 0.111 | 0.125 | 0.071 | 0.082 | * |
| 7/13/2005 | 0.059 | 0.062 | 0.082 | 0.057 | 0.032 | 0.028 | 0.099 | 0.177 | 0.097 | 0.258 | 0.058 | 0.098 | 0.045 |
| 7/26/2005 | 0.079 | 0.085 | 0.109 | 0.115 | 0.045 | 0.012 | 0.166 | 0.192 | * | 0.123 | * | * | 0.029 |
| | | | | | | | | | | | | | |
| 8/9/2005 | 0.088 | 0.090 | 0.050 | 0.061 | 0.041 | 0.093 | 0.158 | 0.350 | 0.081 | 0.103 | 0.042 | 0.032 | 0.047 |
| *UMass EAL* | | | | | | *0.091* | *0.160* | *0.350* | | | | | *0.050* |
| % difference | | | | | | 2.2 | 1.3 | 0.0 | | | | | 6.4 |
| | | | | | | | | | | | | | |
| 8/23/2005 | 0.080 | 0.140 | 0.033 | 0.042 | 0.012 | 0.070 | 0.144 | 0.263 | 0.101 | 0.124 | 0.021 | 0.042 | 0.014 |
| *UMass EAL* | *0.082* | *0.137* | *0.033* | *0.045* | *0.014* | *0.071* | * | * | * | * | * | *0.050* | * |
| % difference | 2.5 | 2.1 | 0.0 | 7.1 | 16.7 | 1.4 | | | | | | 19.0 | |
| | | | | | | | | | | | | | |
| 9/14/2005 | 0.091 | 0.091 | 0.026 | 0.043 | 0.003 | 0.114 | 0.151 | 0.192 | 0.097 | 0.057 | 0.128 | 0.046 | 0.003 |
| 9/28/2005 | 0.093 | 0.090 | 0.034 | 0.048 | 0.002 | 0.398 | 0.145 | 0.266 | 0.083 | 0.101 | 0.234 | 0.045 | 0.002 |
| *UMass EAL* | *0.095* | *0.090* | *0.033* | *0.045* | *0.002* | *0.389* | *0.146* | *0.261* | *0.080* | *0.099* | *0.238* | *0.042* | *0.003* |
| % difference | 2.2 | 0.0 | 2.9 | 6.3 | 0.0 | 2.3 | 0.7 | 1.9 | 3.6 | 2.0 | 1.7 | 6.7 | 50.0 |
| | | | | | | | | | | | | | |
| 10/14/2005 | 0.062 | 0.023 | 0.029 | 0.033 | 0.019 | 0.169 | 0.157 | 0.209 | 0.045 | * | 0.113 | 0.033 | 0.012 |
| 11/4/2005 | 0.048 | 0.048 | 0.034 | 0.027 | 0.008 | 0.022 | 0.026 | 0.212 | 0.039 | 0.045 | 0.020 | 0.027 | 0.005 |
| *UMass EAL* | | *0.045* | | *0.025* | | *0.022* | | *0.215* | *0.035* | | | *0.025* | |
| % difference | | 6.3 | | 7.4 | | 0.0 | | 1.4 | 10.3 | | | 7.4 | |
| | | | | | | | | | | | | | |
| 12/22/2005 | 0.031 | 0.029 | 0.028 | 0.291 | 0.012 | 0.052 | 0.031 | 0.095 | 0.026 | 0.057 | 0.013 | 0.027 | 0.009 |
| *UMass EAL* | | | | *0.289* | | *0.050* | | *0.089* | | *0.055* | | | *0.009* |
| % difference | | | | 0.7 | | 3.8 | | 6.3 | | 3.5 | | | 0.0 |
| | | | | | | | | | | | | | |
| 1/12/2006 | 0.020 | 0.021 | 0.021 | 0.102 | 0.023 | 0.231 | 0.098 | 0.059 | 0.020 | * | 0.021 | 0.022 | * |
| 2/8/2006 | 0.011 | 0.010 | 0.010 | 0.040 | 0.013 | 0.757 | 0.123 | 0.054 | 0.012 | 0.014 | * | 0.011 | 0.013 |
| 2/23/2006 | 0.014 | 0.013 | 0.022 | 0.019 | 0.009 | 0.321 | 0.029 | 0.031 | 0.003 | 0.011 | 0.009 | 0.019 | 0.007 |
| 3/21/2006 | 0.015 | 0.018 | 0.021 | 0.015 | 0.007 | 0.012 | 0.020 | 0.025 | 0.026 | 0.018 | 0.011 | 0.026 | 0.014 |

Previous Sampling Validation of Merrimack College Samples

| Sampler | Date | Location | Total P mg/L |
|---|---|---|---|
| DEP | 7/15/04 | Gray Road (WW-1) | 0.120 |
| Merrimack | 7/15/04 | Gray Road (WW-1) | 0.123 |
| DEP | 7/15/04 | Route 28 (WW-6) | 0.080 |
| Merrimack | 7/15/04 | Route 28 (WW-6) | 0.076 |
| DEP | 9/2/04 | Central Street (WW-5) | 0.055 |
| Merrimack | 9/2/04 | Central Street (WW-5) | 0.059 |
| DEP | 9/2/04 | Route 28 (WW-6) | 0.070 |
| Merrimack | 9/2/04 | Route 28 (WW-6) | 0.062 |
| DEP | 9/2/04 | Harold Parker Road (WW-3) | 0.065 |
| Merrimack | 9/2/04 | Harold Parker Road (WW-3) | 0.065 |

## Appendix D. Surface Water Quality Standards for Class B Waters in Massachusetts

*314 CMR 4.00: Massachusetts Surface Water Quality Standards*

(3) Inland Water Classes:

(b) Class B - These waters are designated as a habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation. Where designated they shall be suitable as a source of public water supply with appropriate treatment. They shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value.

1. Dissolved Oxygen
   a. Shall not be less than 6.0 mg/L in cold water fisheries nor less than 5.0 mg/L in warm water fisheries unless background conditions are lower;
   b. natural seasonal and daily variations above these levels shall be maintained; levels shall not be lowered below 75% of saturation in cold water fisheries nor 60% of saturation in warm water fisheries due to a discharge; and
   c. site-specific criteria may apply where background levels are lower than specified levels, to the hypolimnion of stratified lakes or where the Department determines that designated uses are not impaired.

2. Temperature -
   a. Shall not exceed 68°F (20°C) in cold water fisheries nor 83°F (28.3°C) in warm water fisheries, and the rise in temperature due to a discharge shall not exceed 3°F (1.7°C) in rivers and streams designated as cold water fisheries nor 5°F (2.8°C) in rivers and streams designated as warm water fisheries (based on the minimum expected flow for the month); in lakes and ponds the rise shall not exceed 3°F (1.7°C) in the epilimnion (based on the monthly average of maximum daily temperature); and
   b. natural seasonal and daily variations shall be maintained. There shall be no changes from background conditions that would impair any use assigned to this Class, including site-specific limits necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms.

3. pH - Shall be in the range of 6.5 through 8.3 standard units and not more than 0.5 units outside of the background range. There shall be no change from background conditions that would impair any use assigned to this Class.

4. Fecal Coliform Bacteria - Shall not exceed a geometric mean of 200 organisms per 100 ml in any representative set of samples nor shall more than 10% of the samples exceed 400 organisms per 100 ml. This criterion may be applied on a seasonal basis at the discretion of the Department.

5. Solids - These waters shall be free from floating, suspended and settleable solids in concentrations and combinations that would impair any use assigned to this Class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.

6. Color and Turbidity - These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this Class.

7. Oil and Grease - These waters shall be free from oil, grease and petrochemicals that produce a visible film on the surface of the water, impart an oily taste to the water or an oily or other

undesirable taste to the edible portions of aquatic life, coat the banks or bottom of the water course, or are deleterious or become toxic to aquatic life.

8. Taste and Odor - None in such concentrations or combinations that are aesthetically objectionable, that would impair any use assigned to this Class, or that would cause tainting or undesirable flavors in the edible portions of aquatic life.

**Appendix E. Harvesting Summary Report from ACT**

AQUATIC CONTROL TECHNOLOGY, INC.
POND AND LAKE MANAGEMENT SPECIALISTS

February 13, 2006

Mr. Michael Soraghan, Town Engineer
Town of North Reading
235 North Street
North Reading, MA 01864

**Re: 2005 Project Completion Report for Harvesting Project on Martin's Pond**

Dear Mr. Soraghan

Please accept this as our 2005 Project Completion Report for the mechanical harvesting project at Martin's Pond.

**Summary of 2005 Project**

The focus of the 2005 harvesting effort was to remove dense beds of fanwort (*Cabomba caroliniana)* a non-native and highly invasive aquatic plant infesting Martin's Pond. It was hoped that the harvesting project would provide season long control of fanwort. This would improve access for riparian owners and users. It was also hoped that carefully removing the plant biomass would eliminate a source of plant fragments that could potentially spread this infestation. Finally, the harvesting would help facilitate studies of long-term fanwort control strategies being conducted by Dr. Jon Lyon at Merrimack College.

The harvesting project was scheduled to occur during the week of July 11, 2005. The contract called for the work to be completed during the month of July. It was hoped that a July harvest would remove the plants before they reached their peak biomass, but be late enough in the growing season that it would provide summer long plant control. Immediately prior to arriving on site, we received a Proposed Harvesting Area Map and a Fanwort Distribution Map for June 2005 from Dr. Jon Lyon. Four priority areas were delineated on the map.

| | | |
|---|---|---|
| Area A | 2.2 acres | northwest shoreline |
| Area B | 2.7 acres | north-central shoreline |
| Area C | 1.8 acres | northeast shoreline |
| Area D | 2.1 acres | southern shoreline |
| TOTAL | 8.8 acres | |

We were directed to harvest the priority areas first and remaining time could be expended on harvesting more widely scattered fanwort growth found in other sections of the littoral zone. The harvesting was completed using our Aqua Marine H7-400 Harvester. The machine cuts a 7 foot wide by 7 foot deep

swath and stores the harvested vegetation in a 400 cubic foot storage area. Once the storage area was full, the harvester traveled back to the boat ramp located on the northeast shoreline and offloaded the harvested vegetation. A 100 foot long section of fragment barrier was installed in the water at the off-loading area to help contain any plant fragments that fell back into the water during the offloading procedure.

The harvester operated for a total of 32 hours between July 11th and July 15th. This allowed for each priority area to be harvested at least twice and a single pass was made trying to collect visible fanwort growth in the remainder of the littoral zone. The fanwort density was reportedly lower than what had been observed in previous years. This increased harvesting efficiency because offloading was not required as frequently as anticipated, which translated into more harvesting time and less travel time. After 32 hours it was mutually agreed to stop the harvesting. The Contract provided for an expenditure of $13,450 in 2005 to harvest for 60 hours plus equipment mobilization. For the 32 hour harvesting project we billed the Town a total of $6,620 in 2005.

**Recommendations for 2006 Project**

From an operational standpoint, the 2005 project appeared to run smoothly. We do not see any obvious reasons to alter the scope of work in 2006, but we would be interested to hear if the Town, the Martin's Pond Association or Dr. Jon Lyon at Merrimack College has any suggestions in this regards. Hopefully the reduced fanwort densities provided some real cost savings for the Town.

We trust you were satisfied with the 2005 project and we look forward to working with the Town again in 2006. Please do not hesitate to contact us if you have any questions or would like additional information.

Sincerely,

**AQUATIC CONTROL TECHNOLOGY, INC.**

Marc Bellaud
Senior Biologist

## Appendix F. Summary of Recommendations from the 2003 Lakes and Ponds Grant

The following is a list of recommendations from the Martins Pond Assessment Study Final Report (a Lakes and Pond Study Report) submitted by Merrimack College and Malcolm Pirnie Engineers in January 2003. These recommendations were incorporated into the design and implementation of the current study.

### Summary of Recommendations

### Loosestrife and Wetland Assessment Recommendations

- Develop a program to monitor purple loosestrife in the Martins Brook wetland for the next 2-3 years to assess changes in purple loosestrife density, cover, biomass and herbivory attributed to *Galerucella sp.* beetles.
- In addition, wetland vegetation assessments should continue to monitor changes in the abundance and frequency of native wetland species, to determine if their cover increased as purple loosestrife begins to diminish.
- Monitoring of *Galerucella sp.* beetle's herbivory patterns should be implemented to track the migration of the beetles to other areas of the wetland. Tracking the migration will also add valuable information for any subsequent releases that may occur.
- Immediate assessment of beetle populations in late spring 2003 at the onset of emergence from the dormant stage. This needs to be done to ensure that the previous population was able to produce a viable offspring which can continue the cycle in the fall of 2003.
- A second release may be necessary to supplement the existing population and to ensure the existence of a healthy population of beetles in the wetland.
- Patience is needed; the beetles need time to do their job. It should be noted that noticeable results may not be seen for several years. Project leaders must remain focused on controlling purple loosestrife and determined to guide the project to its end. Purple loosestrife first has to be stopped from spreading before it can be controlled.

### Martins Pond Assessment Recommendations

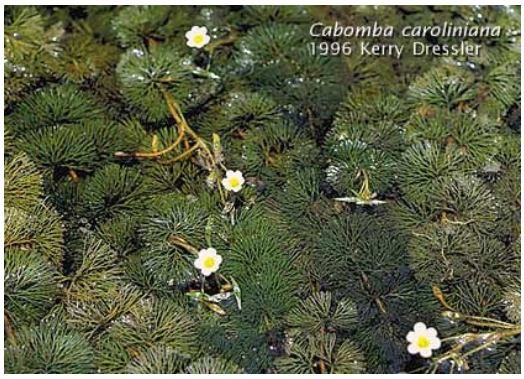
- Re-sample the macrophyte vegetation in 2003 to assess any temporal changes in macrophyte distribution and abundance.
- Any exotic plant control measures should be conducted on a pilot-study basis rather than pond-wide. Any plant control measures should be conducted on a small-scale to ensure the results of control measures, both intended and unintended, match management goals.
- High turbidity is currently limiting the extent of aquatic plant growth. Efforts to reduce any of the components of turbidity (tannins, algal biomass, total suspended solids) could increase light penetration and result in dramatic increases in the extent of aquatic plant (macrophyte) growth in the littoral zone. Smaller-scale, pilot-studies to reduce turbidity should be conducted and results used to guide pond-wide efforts. There are no quick fixes; all management actions have consequences that need to be monitored and assessed to ensure they match management goals.
- Additional detailed mapping of the ponds sediments, including sediment depths, are needed to address siltation and sedimentation rates in the pond.

## Water Quality Recommendations

- Support and continue monitoring water quality (including total P) in Martins Pond and upstream along the Skug River through June 2003. A full year of water quality data is needed to assess seasonal changes in water quality in Martins Pond. Additional sampling sites upstream are also needed to identify the source(s) of high P levels in waters entering Martins Pond.
- Continue monitoring total and fecal coliform levels in Martins Pond and upstream along the Skug River until June 2003. A full year of coliform data is needed to assess seasonal changes in coliform in Martins Pond and the Skug River. Additional sampling sites upstream are also needed to identify the source(s) of high coliform levels in waters entering Martins Pond.
- Support combining water quality data with flow data to develop nutrient budgets for Martins Pond. This approach is needed to facilitate development of TMDL's for the pond. Financial support for this effort is needed to begin the process of addressing water quality concerns in Martins Pond and the Martins Pond watershed.
- Conduct a sediment study along Martins Brook from Martins Pond outlet past Route 62 to assess sediment composition and chemistry prior to any potential stream channel modifications.
- Develop a water quality monitoring network from members of the Martins Pond Association to track the newly installed water level gauges in and around Martins Pond, Skug River and Martins Brook.
- Link water quality monitoring with water quality efforts in the Ipswich River watershed. Understanding and addressing the linkages between the Martins Pond watershed, Martins Pond, Martins Brook and the Ipswich River is required, especially in the formation of TMDL's for Martins Pond.
- Swimming in Martins Pond is not advised – especially after rainfall events. Total and fecal coliform spike after rain events and residents around the pond should be fully aware of the potential health risks of swimming under these poor water conditions.

# Fanwort: An Invasive Aquatic Plant

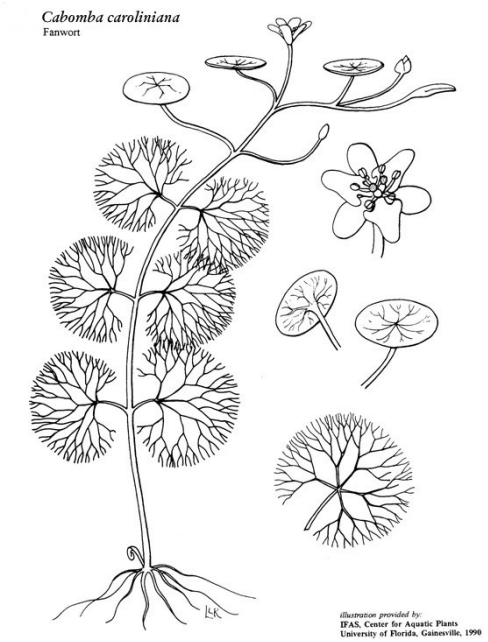
*Cabomba caroliniana*




**Description**

- Fanwort is a submerged invasive aquatic plant that can form dense mats at the water surface.
- The delicate green underwater leaves are fan-like and average 2 inches across. Leaves are arranged in opposite pairs on the stem. Small oval floating leaves are occasionally present.
- Small diamond-shaped floating leaves with the stem attached in the center may develop.
- Tubular stems can attain lengths of 6 feet.
- The white or cream flowers are ½" wide and form during May through September; however, some variations of Fanwort have pinkish or purplish flowers.

**Fanwort**



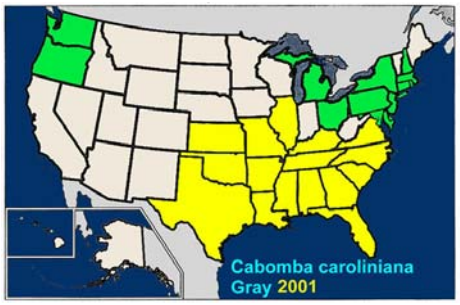

**Habitat**

Fanwort is a very hardy and persistent species that has established itself in a wide range of aquatic habitats. Fanwort is native to southern United States, but is non-native in northern regions.

- Over-winters in the frozen lakes of northern climates and can thrive in warm southern water bodies.
- Grows under a wide range of water chemistry conditions and can be found in both oligotrophic (low nutrient) and eutrophic (nutrient rich) lakes. Fanwort can tolerate a wide range of temperature and pH.
- Prefers slow moving waters, including lakes and ponds, but occasionally can be found in rivers.

**Distribution Map**

*Cabomba caroliniana*




states where Fanwort is native
states with non-native Fanwort infestations

**Reproduction**

Fanwort reproduces by both vegetative methods and seed formation.

- Vegetatively, *C. caroliniana* reproduces by stem (rhizome) fragmentation. Stems are very fragile, fragment easily and most pieces can re-sprout and grow into new plants
- Seeds are also formed, and Fanwort can re-grow from seeds remaining in lake or pond sediment.

**Impacts and Threats Posed by Fanwort**

Fanwort is a highly competitive plant that is capable of rapid growth and spread. Fanwort can displace native species, reduce biodiversity, hamper recreational uses, reduce real estate value, diminish aesthetic values, and decrease water quality.

- Once established, Fanwort can negatively impact and out-compete native vegetation. Fish and animals that were dependent on the native vegetation must relocate or perish, leading to a decline in biodiversity.
- Fanwort can greatly impede boaters, fisherman, water skiers and swimmers, and these limitations on water use can negatively impact real estate values.
- *C. caroliniana* produces dense large mats of vegetation on the water surface, thus intercepting sunlight to the exclusion of other submerged plants.
- Sediment levels increase with increasing Fanwort abundance.
- When dense mats of Fanwort decay, the available oxygen in the water may be depleted. The resulting low oxygen conditions (anoxic) can lead to fish kills and harm other aquatic organisms.

**Management Methods**

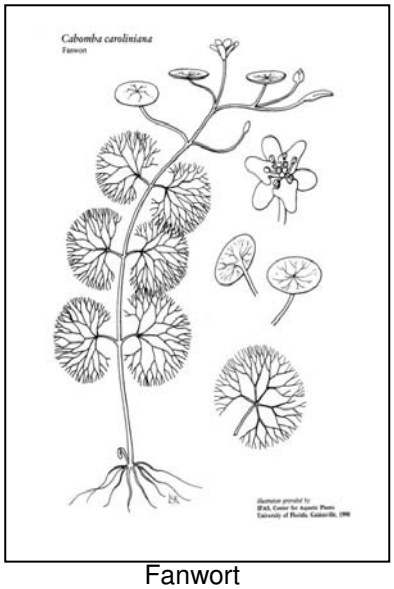
Management methods currently include mechanical removal, drawdowns and herbicides. No known biological controls exist.

- Although harvesting can greatly reduce the Fanwort biomass in a water body, harvesting causes fragmentation and fragments are capable of producing new plants. Some fragments may drift down stream or attach to boats and wildlife and create new infestations elsewhere.
- Drawdowns can be an effective mode of Fanwort control if the drawdown is of an adequate time and depth to prevent re-growth from seeds, however, drawdowns may affect fish, aquatic organisms, reptiles, amphibians and downstream conditions.
- Several herbicides have been use to control Fanwort, but the most effective is Fluridone (a systemic herbicide).
- Benthic barriers may be used in small areas including swimming beaches, boating lanes and around docks. The barriers restrict light and upward growth but can have a negative impact on benthic organisms, and need to be properly anchored and maintained.

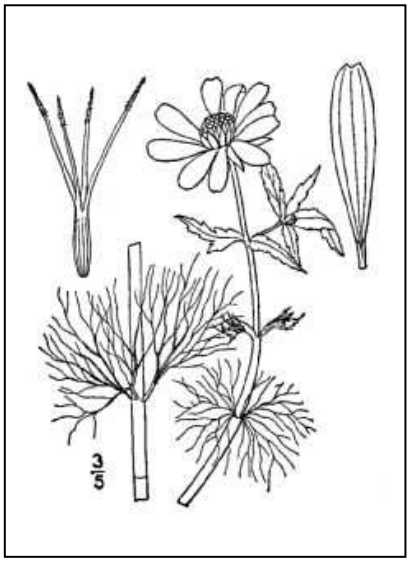
**Other Information**

- Fanwort is on the Massachusetts Prohibited Plant List (as of January 1, 2006).
- Fanwort was first discovered in 1930 in Hatfield, MA. Since then, despite management efforts, Fanwort has spread throughout most of New England. Due to its delicate appearance Fanwort is still in high demand at pet stores, aquarium dealers and over the Internet.
- Informational websites:
  http://aquat1.ifas.ufl.edu/welcome.html (Center for Aquatic Invasive Species, Florida)
  www.ccy.wa.gov/programs/wq/plants/weeds/cabomba.html (Washington State Ecology Dept.)
  www.ProtectYourWaters.net (Aquatic Nuisance Species national web site)
- Fanwort is often confused with the native Water Buttercup (*Ranunculus*) and Water Marigold (*Megalodonta beckii*). (see drawing below)
  -Water Buttercup has leaves that are arranged singly on the stem, not in opposite pairs.
  -Water Marigold has opposite leaves that attach directly to the stem with no petiole between the leaf and stem.

**Fanwort compared to native Water Marigold**



Fanwort


Water Marigold

**References**:

1) www.mass.gov/dcr/waterSupply/lakepond/geir.htm (Generic Environmental Impact Report)
http://plants.ifas.ufl.edu/cacapic.html (Center for Aquatic and Invasive Species)
http://www.bio.umass.edu/biology/conn.river/cabomba.html (UMass- Conn. River Page)
http://www.ecy.wa.gov/programs/wq/plants/weeds/cabomba.html (WA State Dept. of Ecology)
2) Photographs were obtained from:
Kerry Dressler 1996 (cover photograph)
http://aquat1.ifas.ufl.edu/ (line drawing of Fanwort)
http://plants.usda.gov/cgi_bin/plant_profile.cgi?symbol=MEBE2
(Line drawing of Water Buttercup from USDA Plant Profile website)
3) The distribution map was taken from:
http://plants.ifas.ufl.edu/cacapic.html (Center for Aquatic and Invasive Species)

**For more information please contact:**

D.C.R. Office of Water Resources, Lakes and Ponds Program
Michelle Robinson at: michelle.robinson@state.ma.us
or visit the Lakes and Ponds website at: www.mass.gov/lakesandponds
Prepared by Michelle Robinson: November 2002