Aquatic Plant Survey of Glasgo, Pachaug, Hopeville, and Ashland Ponds During 2009

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December 20, 2010

Executive Summary

This report presents aquatic plant survey results of the Town of Griswold ponds, Glasgo Pond, Pachaug Pond, Hopeville Pond, and Ashland Pond in 2009. The surveys were performed in part, to satisfy CT Department of Environmental Protection (DEP) permit requirements for winter water-level drawdown to control nuisance aquatic plants at the ponds. The Town of Griswold has sought to avoid the use of herbicides to control the aquatic plant infestations in the four ponds, relying instead on winter water-level drawdown.

Annual analysis of the affects of drawdown on the aquatic plants is needed for CT DEP to draw conclusions on the merit of the drawdown to control rooted aquatic plants. Pachaug Pond was surveyed in 2004 and 2008 to provide necessary data on aquatic plant distribution and abundance to continue a program of monitored drawdowns.

The 2004 study concluded that Pachaug Pond was infested with two invasive aquatic plant species; fanwort (Cabomba caroliniana) and variable-leaf milfoil (Myriophyllum heterophyllum).

The 2008 study concluded that Pachaug Pond was infested with four invasive rooted aquatic plant species; fanwort, variable-leaved milfoil, Eurasian milfoil (Myriophyllum spicatum), and minor naiad (Najas minor).

Fanwort was the most abundant plant in each of Glasgo, Hopeville, and Ashland Ponds, and the second most common plant in Pachaug Pond. Extremely dense stands of fanwort were mapped in each of the four ponds. Glasgo Pond had 10 acres of fanwort, Pachaug Pond had 127 acres, Hopeville Pond had 72 acres of dense fanwort and Ashland Pond had 31 acres of fanwort.

Fanwort was found growing to maximum colonization depths in each pond. In Glasgo Pond, fanwort was found to 7 feet, in Pachaug Pond to 8 feet, 10 feet in Hopeville Pond, and 13 feet in Ashland Pond.

Variable-leaf milfoil, the next most common invasive plant was found to cover approximately 7.5 acres in Glasgo Pond, and 38 acres in Pachaug Pond. In Hopeville, and Ashland Ponds, this species was found individually or in small isolated pockets consisting of only a few plants.

Eurasian milfoil was found to cover 12 acres in Pachaug Pond, and about 8 acres in Glasgo Pond. In Hopeville Pond, Eurasian milfoil was rare, with only 4 occurrences. There were no sightings of Eurasian milfoil in Ashland Pond.

Minor naiad probably the newest invader, was found only in Pachaug Pond at 47 points, and Hopeville Pond at 2 points.

Three obstacles prevent winter water level drawdown from having complete success,

1. each of the lakes have very rapid flushing rates, especially during the winter months when control of the water level at a target depth is necessary,

2. target plants grow to deeper depths than feasible drawdown levels.
3. sheltered coves in Pachaug Pond are apparently immune to affects of water level drawdown.

Mapping data collected during the surveys of Pachaug Pond suggest that a 3 foot drawdown provides some control of fanwort and variable milfoil along the shoreline of open water areas of the lake, but not in the secluded coves. It is likely similar results would be realized at Hopeville Pond or Ashland Pond if those were drawn down only 3 feet. Attempting deeper drawdowns increases the likelihood of causing drawdown related negative impacts.

Drawdown has negative side affects regardless of whether the target plants are impacted. Performing a drawdown at any of the four lakes may cause other deleterious affects each time it is used. Some of the impacts include,

1. Erosion of exposed lake bed during rain events,
2. Impacts to shoreline wetland vegetation due to desiccation,
3. Impacts to fish spawning areas,
4. Impacts to a wide range of aquatic animals,
5. Increased re-cycling of nutrients,
6. Increased loss of oxygen in deep water during the summer.

The suggested approach to managing the proliferation of invasive aquatic plant species in the four Grisworld ponds is:

1. Form an ad hoc committee to manage the aquatic plant control measures at the four ponds. The committee should include members from the Town of Griswold the Town of Voluntown and residents from each of the four ponds in Griswold and the upstream ponds in both towns. The committee through regular meetings would assist in the management of each of the ponds in the Pachaug River drainage basin, specifically according to the following tasks.
2. Institute regular annual aquatic plant surveys at each of the four ponds.
3. Conduct aquatic plant surveys of each of the upstream ponds not investigated during this study.
4. Submit requests to the DEP for winter water level drawdowns as needed.
5. Regularly review survey results to assess success of drawdown.
6. Begin investigations to determine if drawdown is having negative impacts to the ponds where it is used.
7. Identify specific areas of each pond where invasive aquatic plants present the greatest nuisance. Prioritize these areas for application of alternate methods to control invasive aquatic plants.
8. Alternate methods that appear to offer the best chance of success include,
    a. Herbicides – Fluridone pellets and 2-4D
    b. Suction Harvesting
    c. Bottom barrier
    d. Milfoil weevil (Eurasian milfoil only)
9. Develop a long-range management plan prioritizing treatment management areas within each pond.
10. Set up a schedule for using alternate methods at each of the prioritized areas.
11. Track success of drawdown and any alternate methods used to control invasive aquatic plants.
12. Annually review the management plan for upcoming year.

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Overview - Introduction

Project Scope

Northeast Aquatic Research (NEAR) was contracted by the Town of Griswold to conduct a survey of the aquatic plants in Ashland, Hopeville, Glasgo, and Pachaug Ponds during the summer of 2009. This report presents the results of the 2009 surveys of each of the four ponds. The surveys were performed in part, to satisfy CT Department of Environmental Protection permit requirements for winter water-level drawdown at the ponds. Historically, the town of Griswold has made requests to the CT DEP for winter drawdowns at each of the ponds to control aquatic vegetation, specifically invasive species. Current aquatic plant distribution data are needed for CT DEP to complete its evaluation of the permit requests for performing winter water level drawdown that exceed 3 feet at Pachaug and Glasgo Ponds, and for any drawdown at Hopeville and Ashland Ponds.

Additionally, the Town of Griswold wishes to begin considering each of the four ponds together when deciding on management alternatives to be used at any one lake. Also, the Town is concerned that water level drawdown may not be suitable for controlling plants in all locations in the ponds, and wants to pursue preliminary feasibility information that may lead to other methods of controlling nuisance plants.

The results from this study will be used as the starting place for a comprehensive management plan that includes all four ponds. The development of an inclusive plan will aid the town in conducting unified invasive species control practices in the future.

Project History

The first known weed management study of Pachaug Pond was conducted between 1999 and 2000 by Aquatic Control Technologies Inc.[1] who evaluated the magnitude of plant infestation and provided recommendations for treatments. Their report documented two invasive species in Pachaug Pond, fanwort (Cabomba caroliniana), variable-leaved milfoil (Myriophyllum heterophyllum), and suggested a chemical approach using herbicides to treat the fanwort because most of the problem areas appeared to be isolated in small coves, while the open-water shoreline lacked dense

[1] "Aquatic Vegetation Management Plan for Pachaug Pond, Griswold, Connecticut", June 2003.

beds of either invasive plant. That report also documented large beds of floating smartweed spreading over the water surface in selected coves. Their recommendation was to use a mechanical approach to control dense beds of smartweed.

The Town of Griswold has sought to avoid the use of herbicides to control the aquatic plant infestations in the four ponds, relying instead on winter water-level drawdown. A record winter water level drawdown for the four ponds is given in **Table 1.** The table shows the winters when drawdown occurred and target depth requested. Requests that were denied by CT DEP because no supporting vegetation data was included with the submission are also listed. Annual analysis of the affects of drawdown on the aquatic plants is needed for DEP to draw conclusions on the merit of the drawdown to control rooted aquatic plants. The data in **Table 1** may not be complete, as a full records search was not conducted. Based on information in **Table 1** winter water level drawdown has occurred frequently, if not regularly, at Glasgo and Pachaug Ponds, Hopeville Pond however has not been lowered since the early 1990's, and Ashland Pond has not been lowered at all.

Table 1 - Winter Water Level Drawdown Target Depth in Feet Below Spillway

Pond	Glasgo	Pachaug	Hopeville	Ashland
Winter				
1991 - 1992		2.5	7.5	
1992 -1993		1.5	0.5	
1993 – 1994		2.5	1.3	
1994 – 1995		2	13 (dam repair)	
1995 – 1996	1	1.5		
1996 – 1997	0.5 (for 1 week)	1		
1997 - 1998	1.7	1.5		
1998 - 1999	1.5 (for 1 week)	2		
1999 - 2000	?	~		
2000 - 2001	2.5	2.5		
2001 - 2002	2.5	2.5		
2002 – 2003	1.5 (for 1 week)	1.5		
2003 - 2004	3	3	Denied	
2004 – 2005	3 (briefly)	2.5, 5-Denied		
2005 - 2006	3	5	Denied	Denied
2006 - 2007	2.5	3	Denied	Denied
2007 – 2008		5-Denied		
2008 - 2009		5		
2009 - 2010				

To fulfill the requirements of the DEP permit Northeast Aquatic Research (NEAR) was contracted by the town of Griswold to conduct a survey of the aquatic plants of Pachaug Pond during the summers of 2004[2] and 2008[3]. During the 2003 – 2004 winter of the first study, while Pachaug Pond was drawn down, the dissolved oxygen was measured under the ice at several locations around the pond. This was done to determine if low oxygen conditions existed in the smaller volume of water contained in the pond under the ice during a drawdown. The 2004 NEAR report provided evidence that the under-ice oxygen levels remained at acceptable levels during the winter draw down of 2003-2004.

The 2004 study concluded two invasive aquatic plant species infested Pachaug Pond, fanwort and variable-leaf milfoil, as pointed out by ACT in 2003. The NEAR 2004 survey found fanwort growing in 17 sites, with surface area coverage of 23 acres, densest beds occurred principally in the shallow coves. Only sporadic and isolated fanwort was found along the shoreline of the main body of the lake. Variable-leaved milfoil was found at 10 sites, not as plentiful as fanwort, but generally always occurring in the same locations. In a couple of the coves, variable-leaved milfoil was as dense as fanwort. In 2004, Eurasian milfoil (Myrioplhyllum spicatum) was found in Pachaug, the first record of that species in that pond. One individual plant was found and removed at the south end of the lake.

In 2008, fanwort was found in 14 different established beds covering a total of 93 acres. Between 2004 and 2008, fanwort increased in area of distribution by over 300%. However, fanwort was scarce along the shoreline of the open-water areas of the lake. Fanwort along the shoreline of the open water areas decreased from about 3 acres in 2004 to none in 2008. The report suggested drawdown controls the growth of fanwort along the open shoreline of the lake, but not in the coves.

In 2008, variable-leaved milfoil was found in 10 established beds totaling 36 acres. Also in 2008, five locations of Eurasian Milfoil were found covering approximately 11 acres consisting of one large bed along the south and southeast shoreline, and 4 smaller beds near the southern islands. Also in 2008 a new invasive species, minor

[2] "Aquatic Plant Mapping and Dissolved Oxygen Monitoring in Pachaug Pond, 2003 – 2004", Nov. 2004.
[3] "Aquatic Plant Mapping in Pachaug Pond, 2008", February 2009.

naiad (Najas minor), was found in the lake. This species formed one large bed, covering about 13 acres at the south end of the lake.

With the conclusion of the 2008 survey by NEAR, Pachaug Pond, was known to be infested with four invasive rooted aquatic plant species; fanwort (Cabomba caroliniana), variable-leaved milfoil (Myriophyllum heterophyllum), Eurasian milfoil (Myrioplhyllum spicatum), and minor naiad (Najas minor).

Each of the other ponds, Glasgo, Hopeville, and Ashland, are connected to Pachaug Pond by the Pachaug River, Glasgo Pond is upstream of Pachaug Pond, while the other two are downstream. Because each is connected by the same river, it is possible that similar infestations of the four invasive aquatic plant species exist at the other ponds as well. Because only Pachaug Pond has been surveyed recently, baseline survey information was needed at Glasgo, Hopeville, and Ashland Ponds.

Methods

This study consisted of seven field visits to survey the aquatic plants in Ashland, Hopeville, Glasgo, and Pachaug Ponds in 2009, **Table 1**. The entire shoreline of each lake was observed by boat to map the distribution of aquatic plants. The process involved making 1,184 waypoints using a Garmin GPS model Map 76C to record aquatic plant presence. At each waypoint, all aquatic plant species within visual sight of the center of the boat were identified. Often the visual range of each waypoint overlapped with the next one. Generally, new waypoints would be made when the boat had travelled out of visual range of the last point. In this way, a continuous record of the condition of the shoreline was made. Notes on the abundance of the plants were made at each point, and the water depth was recorded. Each waypoint represents a sampling unit of the littoral zone. The number of waypoints made at each pond is given in **Table 2**.

Table 2 - Dates of Aquatic Plant Surveys in Griswold Ponds during 2009

Location	Survey Dates	# of Sampling Waypoints
Glasgo Pond	August 12, 2009	127
Hopeville Pond	August 14, 2009	220
Pachaug Pond	August 24, 2009	87
Pachaug Pond	September 1, 2009	220

Pachaug Pond	September 2, 2009	132
Pachaug Pond	September 3, 2009	208
Ashland Pond	September 15, 2009	165

Waypoints were generally spaced less than 100 feet apart along the shoreline, although shorter and longer distances occurred when the plant community changed rapidly, showed no change, or no plants were observed. Waypoints were generally made in water depths between the shore and about 9 feet deep (**Figure 1**). Some points were made in deeper water to determine the outer edge of the littoral zone, the area of the lake that support rooted plant growth.

Figure 1 - Percentage of Observation Points Made At Each 1 Foot Water Depth (N = 1106, 5% = 55 points)

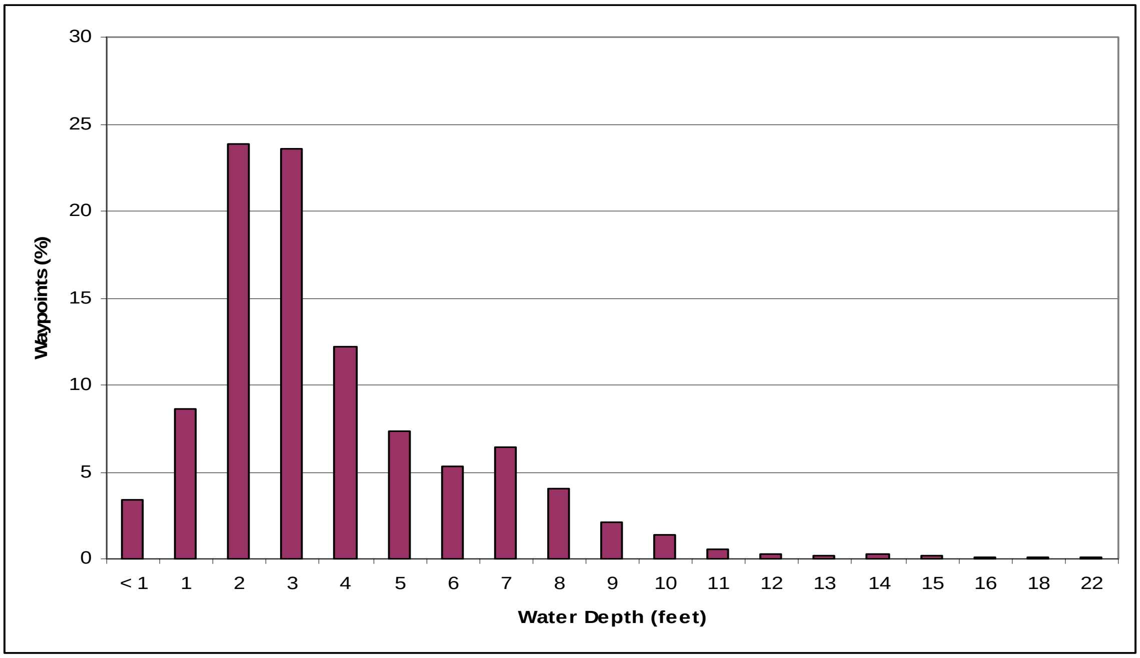


Table 3 - Littoral Zone Surface Areas and Waypoints per Littoral Acre in Griswold Ponds during 2009

Location	Maximum Depth of Plants (feet)	Littoral Zone (acres)	Waypoints / Littoral Acre
Glasgo Pond	9	32	4
Hopeville Pond	9	127	2
Pachaug Pond	9	767	1
Ashland Pond	13	74	2

Summary Hydraulics

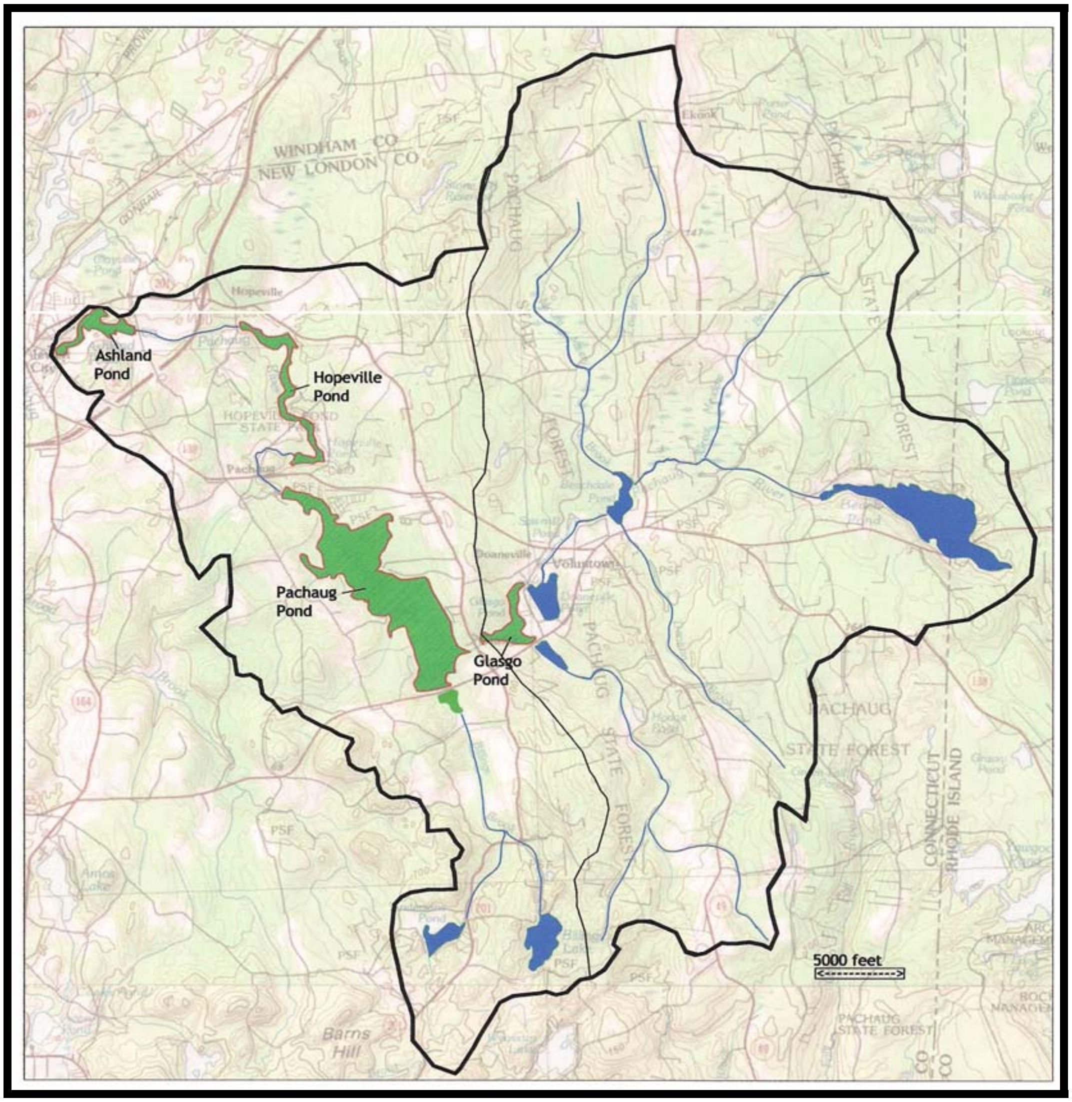
Each pond: Glasgo, Pachaug, Hopeville, and Ashland, in the order listed, is an impoundment of the Pachaug River. Glasgo Pond is upstream of the four, and Ashland Pond farthest downstream (**Map 1**). The Pachaug River has a large watershed that includes other water bodies, not surveyed during this survey. Beach Pond 389 acres, and Beachdale Pond, 41 acres, respectively, drain to Doaneville basin of Glasgo Pond, the small 8 acre Hodge Pond drains to the Southeast Marsh basin of Glasgo Pond, and Billings, 93 acres, and Anderson Pond, 46 acres, respectively, drain to the south end of Pachaug Pond.

The depth contours of each pond clearly show a narrow band of deep water running through their center suggesting the location of the prior river channel. The surface area, watershed area, mean and maximum depths, pond volume, and estimated flushing rates for each are given in **Table 4**. Pachaug Pond is the largest at 841 acres, and Ashland Pond the smallest at 102 acres. The maximum depths ranged from 22 feet at Glasgo Pond, to 17 feet at Pachaug Pond. The mean depths (volume divided by surface area) ranged from a low of 5.3 feet for Hopeville Pond, to a high of 7.6 feet for Glasgo Pond. The drainage area increases from 23,604 acres for Glasgo Pond to 39,065 acres for Ashland Pond. Flushing rates vary between 25 days for Pachaug due to its large volume of 4,600 acre-feet, to 3 to 5 days for the other three ponds.

Table 4 Summary Statistics for each Pond

	Surface Area (acres)	Maximum Depth (feet)	Mean Depth (feet)	Drainage Area (acres)	Pond Volume (acre-feet)	Flushing Rate (days)
Glasgo Pond	168			23,604		
Main Pond	77	22	7.6	“	587	5
Doaneville	68	?	?	“	?	?
S.East Marsh	23	?	?	“	?	?
Pachaug Pond	841	17	5.5	33,920	4,616	25
Hopeville Pond	143	19	5.3	37,824	759	3.7
Ashland Pond	102	18	6.4	39,065	664	3.2

Map 1 – Pachaug River Watershed Showing Location Of Ponds Surveyed During This Study in Green, And Those Not Studied in Blue.



Aquatic Plant Ecology

Aquatic plants are an important part of lake systems. They support a diverse community of organisms, mostly invertebrates that support the food chain in lakes. Aquatic plants also intercept runoff, store nutrients, and stabilize sediments. Aquatic plants create habitat for fisheries, providing for spawning, nursery areas for young fish, cover from predation, and ambush sites for predators. Aquatic plants in lakes occur in three basic vegetation habitats; emergent, floating-leaved, and submersed.

1. Emergent plants are those rooted in shallow water, between 0.5 and 4 feet of water, but have a majority of stems and leaves out of the water. Generally, these

species grow along natural wetland shorelines where the soils are saturated. Rarely do emergent plants grow in water deeper than about 1 foot. Species in this group include cattails, bulrush, pickerelweed, and the non-native invasive plant phragmites.

2. Floating-leaved plants are the water lilies, water shield, floating-heart, and a few of the pondweeds. These plants produce primarily floating leaves with little or no underwater leaf development. Water lilies are generally restricted to shallow waters of less than about 6 feet. A subclass of the floating-leaved plants group is the tiny free-floating plants, duckweed and watermeal. These tiny plants, less than a quarter of inch in size, grow near the shore in quite waters.

3. Submersed plants are those that grow entirely underwater. These plants grow out to deeper waters of the lake. Submersed plants include Eurasian milfoil and tape grass. These plants are rooted in the sediments reaching various heights into the water column. Sometimes submersed plants can reach the water surface to form floating leaves or short aerial flowers. When some submersed plants reach the water surface, the shoots spread out and continue to grow forming dense "topped-out" growths. Eurasian milfoil commonly does this. Two of the pondweeds can do this to a lesser extent, large-leaf pondweed, and floating-leaved pondweed. However, most native plants develop shoots that remain underwater, unless they grow in shallow water.

Aquatic plants require sufficient light to grow. The area of the lake where submersed plants can grow is called the photic zone, or the area of the lake where sunlight reaches the bottom allowing rooted aquatic plants to grow. The maximum depth of colonization (MDC) by rooted aquatic plants can be estimated using the Secchi disk depth (SD) by the equation: $\log MDC = 0.61 \log SD + 0.26$ (Canfield et al., 1985). For Griswold Ponds, the average Secchi disk depth from all basins during this study was about 6 feet, suggesting the maximum depth plants can grow will be about 9 feet. Glasgo Pond had the poorest water clarity of 3 feet suggesting maximum depth of plant growth in this pond would be 5.6 feet. Each aquatic plant species requires different amounts of light, some species requiring high light levels so these appear only in very shallow water, others require much less, than others so occur in deeper water. This tends to spread the growth of plants across a depth gradient as different species favor different depths.

General Aquatic Plant Summary

Pachaug Pond was reported in 2008 to contain four invasive aquatic plant species, fanwort (Cabomba caroliniana), variable-leaved milfoil (Myriophyllum heterophyllum), Eurasian milfoil (Myriophyllum spicatum), and minor naiad (Najas minor). During the 2009 survey, fanwort, variable-leaved milfoil, and Eurasian milfoil were found in each pond. Minor naiad was not found in Glasgo or Ashland Ponds and rarely in Hopeville Pond (**Table 5**).

The complete list of aquatic plant species observed during this study is given in **Table 6**. Glasgo Pond the fewest species with 25, Pachaug Pond had the most species at 49. Hopeville Pond and Ashland Pond had similar numbers at 31 and 30 species, respectively.

Table 5 - Percent Occurrence of Invasive Aquatic Plant Species in the Four Ponds

	Glasgo	Pachaug	Hopeville	Ashland
Fanwort	48	40	74	64
E. Milfoil	29	7	2	0.6
V. Milfoil	20	10	12	26
M. Naiad	0.0	5	0.9	0.0

Table 6 - Aquatic Plant Species Observed in Griswold Ponds during 2009

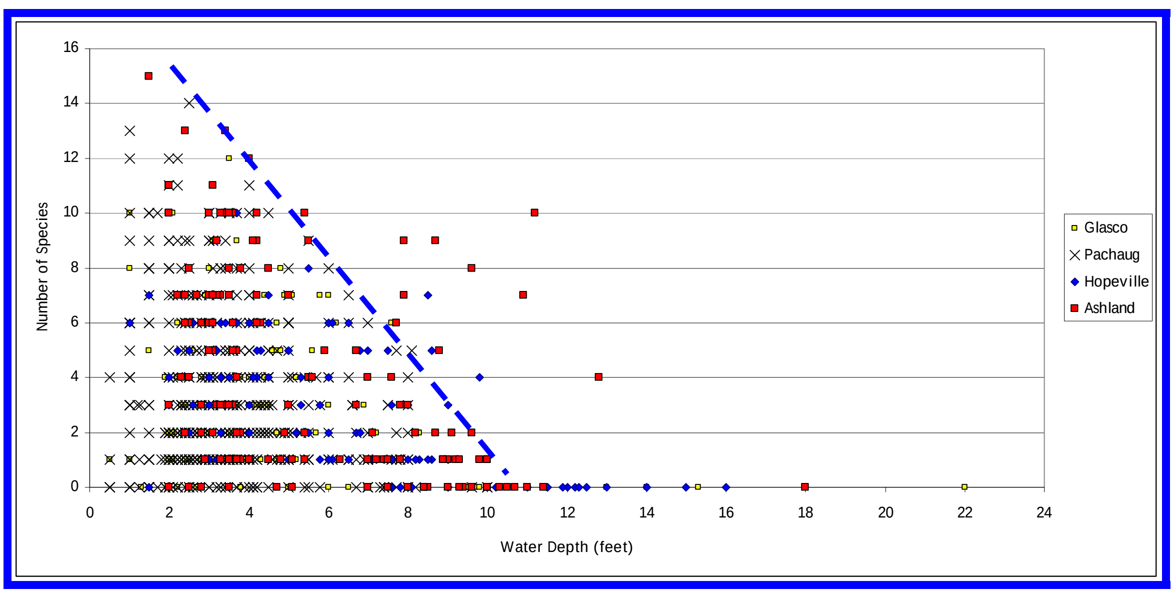
Species Name	Common Name	Glasgo	Pachaug	Hopeville	Ashland
Emergent Species					
Dulichium arundinaceum	Three-way Sedge		X		
Eleocharis robbinsii	Spike-rush		X	X	
Eleocharis sp	Spike-rush		X		X
Eriocaulon aquaticum	Pipewort	X	X		
Juncus sp.	Rush				
Ludwigia sp.	Water-purslane	X	X	X	
Peltandra virginica	Arrow-arum				X
Phragmites communis	Common Reed		X	X	
Pontederia cordata	Pickerel Weed	X	X	X	X
Sagittaria sp.	Arrowhead		X	X	X

Scirpus spp.	Bulrush	X	X	X	X
Sparganium americanum	Burreed		X		X
Floating-leaved Species					
Brasenia schreberi	Water Shield	X	X	X	X
Filamentous Algae			X	X	X
Lemna sp.	Duckweed	X	X	X	X
Nuphar variegata	Yellow Water lily	X	X	X	X
Nymphaea odorata	White Water lily	X	X	X	X
Nymphoides cordata	Floating Heart	X	X	X	X
Polygonum amphibium	Smartweed		X		X
Sparganium fluctuans	Burreed		X	X	X
Spirodela polyrhiza	Great Duckweed		X		X
Wolffia sp.	Water Meal	X		X	X
Submersed Species					
Cabomba caroliniana	Fanwort	X	X	X	X
Callitriche sp.	Water Starwort		X		
Ceratophyllum dermersum	Coontail	X	X	X	X
Ceratophyllum echinatum	Coontail	X			
Elatine sp.	Waterwort		X		
Elodea nuttallii	Water weed		X		
Fontinalis sp.	Aquatic Moss	X	X		X
Isoetes sp.	Quillwort		X		
Myriophyllum heterophyllum	Variable-leaf Milfoil	X	X	X	X
Myriophyllum humile	Low Milfoil		X		
Myriophyllum spicatum	Eurasian Milfoil	X	X	X	X
Najas flexilis	Naiad		X	X	
Najas guadalupensis	Naiad		X		
Najas minor	Minor Naiad		X	X	
Nitella sp.	Musk Grass		X		
Potamogeton (unknown #1)	Pondweed			X	
Potamogeton (unknown #2)	Pondweed	X		X	
Potamogeton amplifolius	Pondweed	X	X		
Potamogeton bicupulatus	Pondweed		X	X	X
Potamogeton gramineus	Pondweed		X		
Potamogeton natans	Pondweed	X	X	X	X
Potamogeton perfoliatus	Pondweed		X		
Potamogeton pusillus	Pondweed	X		X	
Potamogeton robbinsii	Pondweed	X	X	X	X
Potamotegon epihydrus	Pondweed	X	X	X	X

Sagittaria graminea	Arrowhead		X		
Utricularia (unknown #1)	Bladderwort		X		X
Utricularia gibba	Bladderwort		X		X
Utricularia purpurea	Bladderwort		X		
Utricularia radiata	Bladderwort	X	X	X	
Utricularia striata	Bladderwort		X	X	X
Utricularia vulgaris	Bladderwort	X	X	X	X
Vallisneria americana	Tape Grass	X	X	X	
	Total =	**25**	**49**	**31**	**30**

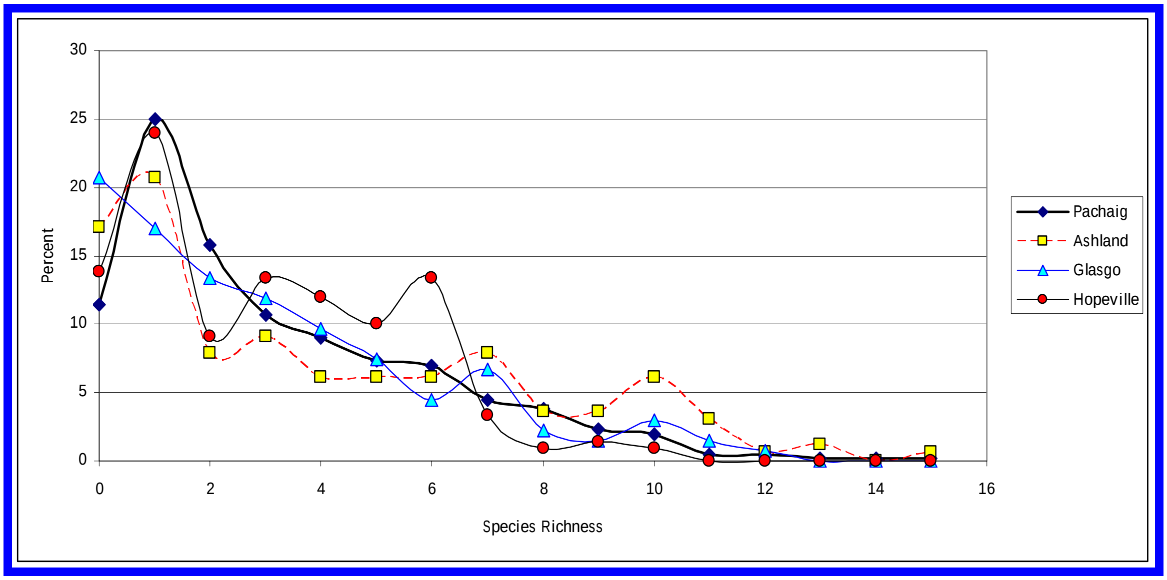
The number of different species occurring at each waypoint is shown in **Figure 2,** all data from each of the four ponds was combined together. The maximum number of species occurred in water of 2-3 feet deep. Numbers of species present decreased with increasing water depth until about 11 feet when generally no plants occurred (**Figure 2**). There was a linear decrease in the number of species present at each depth increment of about 1 species per foot as shown by the dashed line in **Figure 2**. Ashland Pond proved to have more species in deeper water than the other ponds, as shown in **Figure 2** by the red squares representing 4 to 10 species between 8 and 13 feet of water depth.

Figure 2 Species Richness Sorted by Water Depth



The number of species present (species richness) at any single waypoint, for each pond is shown in **Figure 3**. The graph shows that the most common condition is for only a single species to be present, roughly 25% of the points had only one species. Species richness values (number of species) between 2 and 6 were common at each pond; Hopeville Pond had a larger percentage of sites with 2 - 6 species than the other ponds, however Hopeville Pond also had the fewest number of sites with more than 6 species. The highest number of species occurring at a single waypoint were; 10 for Hopeville Pond, 12 Glasgo Pond, and 15 for both Ashland Pond and Pachaug Ponds.

Figure 3 - Species Richness Curves for each Pond



The most common or frequently observed species of aquatic plants in each pond is given in **Table 7**. Common species are defined here as those that occur with a frequency of at least 10%. Each survey consisted of traversing the entire shoreline of each pond so that the littoral zone of each lake was observed. The frequency of occurrence values is a good representation of the tendency of each species to dominate the plant community in each pond. The invasive species are shown in red. Fanwort was the most common aquatic plant, by a large margin, in Hopeville, Glasgo, and Ashland Ponds, but the second most common plant in Pachaug Pond. The two invasive milfoil species were less common in Pachaug, and Hopeville Ponds, but both were common in Glasgo Pond. In Ashland Pond, variable-leaf milfoil was common, and Eurasian milfoil was rare.

Table 7 - Most Common Aquatic Plant Species in Each Pond. Invasive species are in red, floating leaved species are highlighted with yellow.

Pachaug		Hopeville		Glasgo		Ashland	
Species	**%**	**Species**	**%**	**Species**	**%**	**Species**	**%**
White Water lily	55	Fanwort	74	Fanwort	51	Fanwort	70
Fanwort	44	Bladderwort	27	Floating-heart	39	Yellow Water lily	35
Floating-heart	23	Floating-heart	26	Water Shield	31	Floating-heart	33
Arrowhead (sterile)	19	Water Shield	26	Eurasian Milfoil	30	Variable-leaf Milfoil	32
Robbins Pondweed	18	White Water lily	25	Variable-leaf Milfoil	23	Water Shield	31
Yellow Water lily	16	Yellow Water lily	22	Robbins Pondweed	19	Arrow-arum	25
Floating-leaf Pondweed	12	Tape Grass	21	Yellow Water lily	19	Pickerel Weed	22
Water Shield	12	Coontail	15	White Water lily	17	White Water lily	21
Bladderwort	12	Variable-leaf Milfoil	13	Tape Grass	17	Robbins Pondweed	15
Arrow-arum	11	Bladderwort	11	Floating-leaf Pondweed	14	Burreed (emergent)	14
Water Meal	11	Red-leaf Pondweed	10	Bladderwort	12	Floating-leaf Pondweed	12
Variable-leaf Milfoil	8	Eurasian Milfoil	2	Bladderwort	12	Duckweed	11
Eurasian Milfoil	6					Coontail	10
						Water Meal	10
						Smart Weed	10
						Bladderwort	10
						Eurasian Milfoil	0.6

The data in **Table 7** shows that few species are plentiful, or dominant, in the ponds, and they tended to be the same species in each pond, for instance, water lilies were common in each of the four ponds. Ashland Pond had 16 species that occurred with frequencies of 10% or more, the other ponds had about 10 species Given the total number of species found in each pond (see **Table 6)**, most species were actually hard to find, either uncommon, occurrences between 2 and 10%, or rare, occurrences of 1% or less (**Figure 4**). This is typical for lakes to have a handful of dominant species and many uncommon and rare species. However, with a high abundance of invasive and floating-leaved species the less common plants are at a competitive disadvantage for light, nutrients and substrate space. Data collected during this study suggest that many species of aquatic plants occur at low to very low frequencies. Often the uncommon and rare species were found in only one site where conditions were ideal for their growth.

Species accumulation curves for the three smaller ponds (**Figure 5**) indicate that most species were found during the survey. The curves shown in **Figure 5** are steep below 50 waypoints indicating that new species were found quickly, after more than 100 waypoints new species were added slowly. New species probably could be found in each pond but the level of effort required to add each new species will continue to increase. Each of the curves shows no new species were added during the last 50 points.

Figure 4 - Frequencies of Occurrence of Observed Species at Each Pond

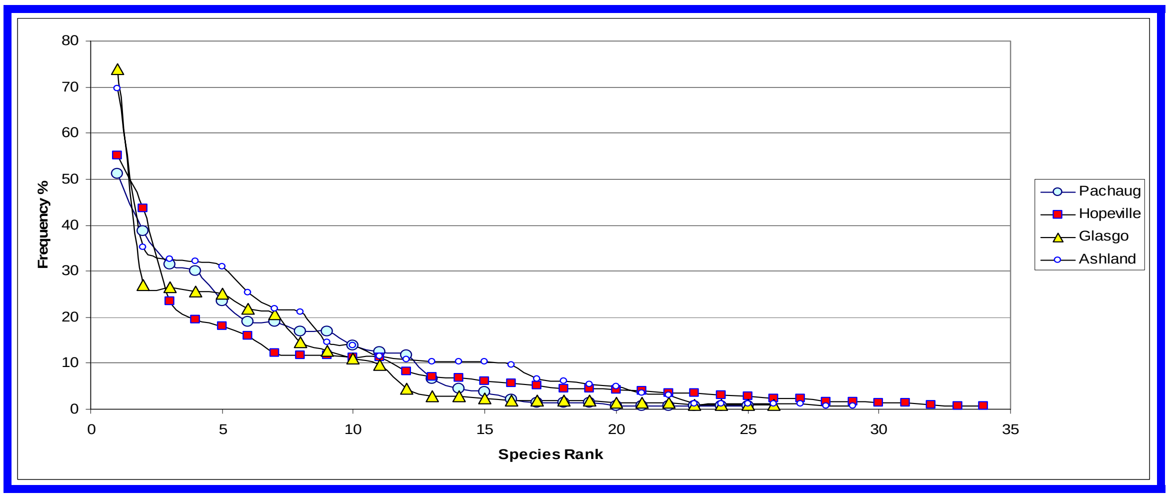
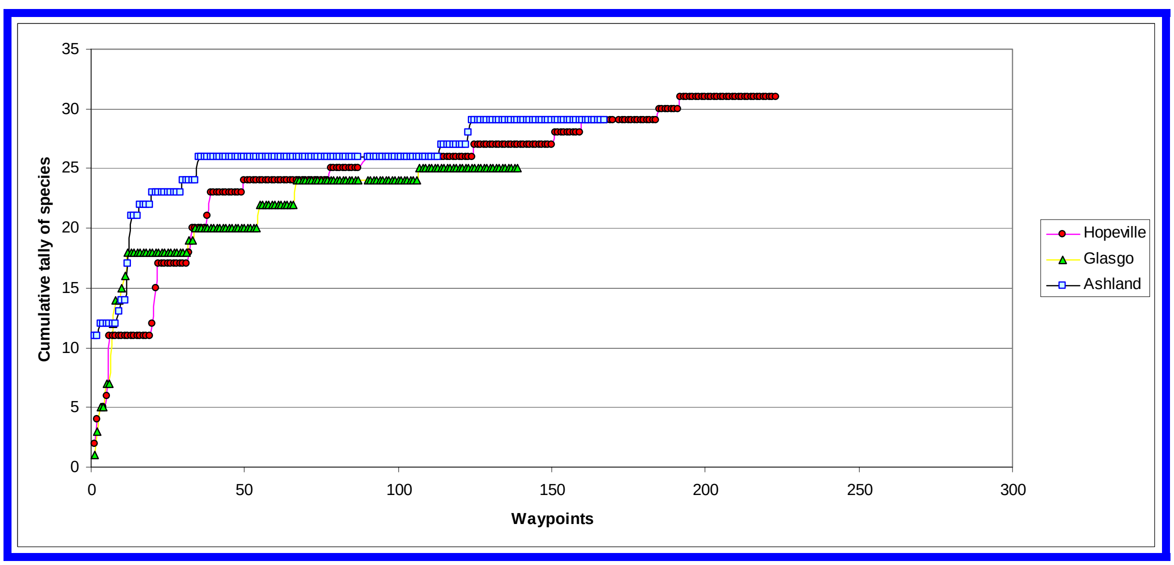


Figure 5 - Species Accumulation Curves for Hopeville, Glasgo, and Ashland Ponds

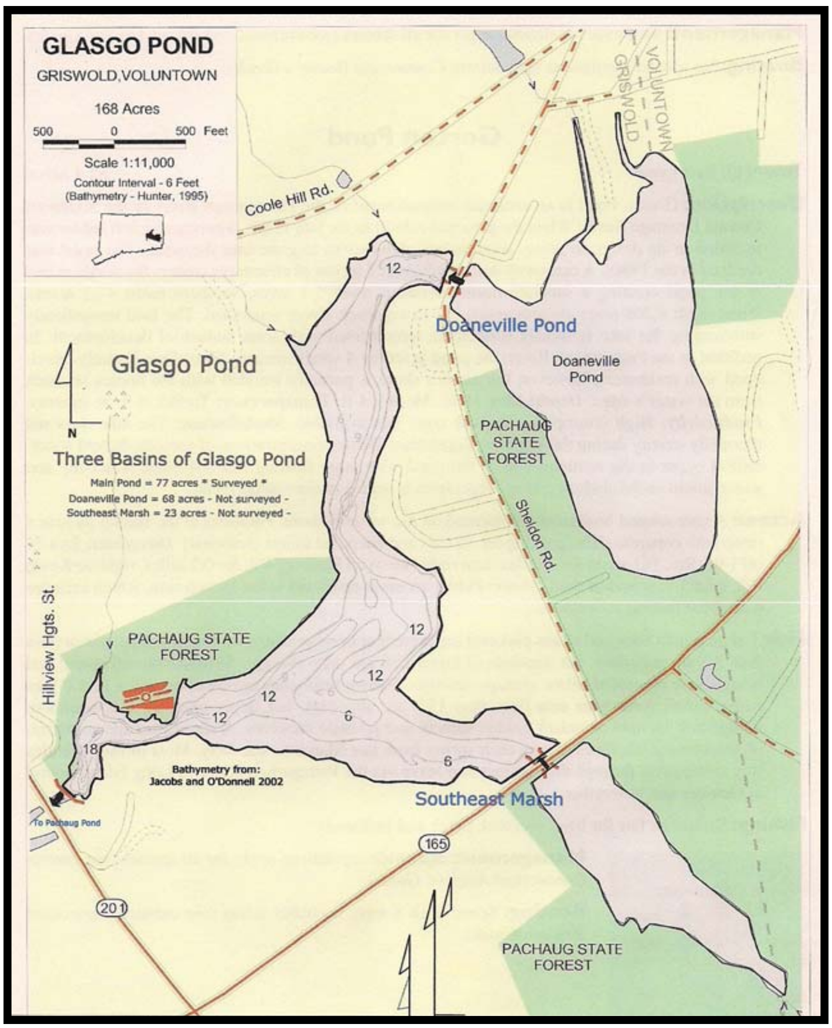


Specific Pond Results

Glasgo Pond

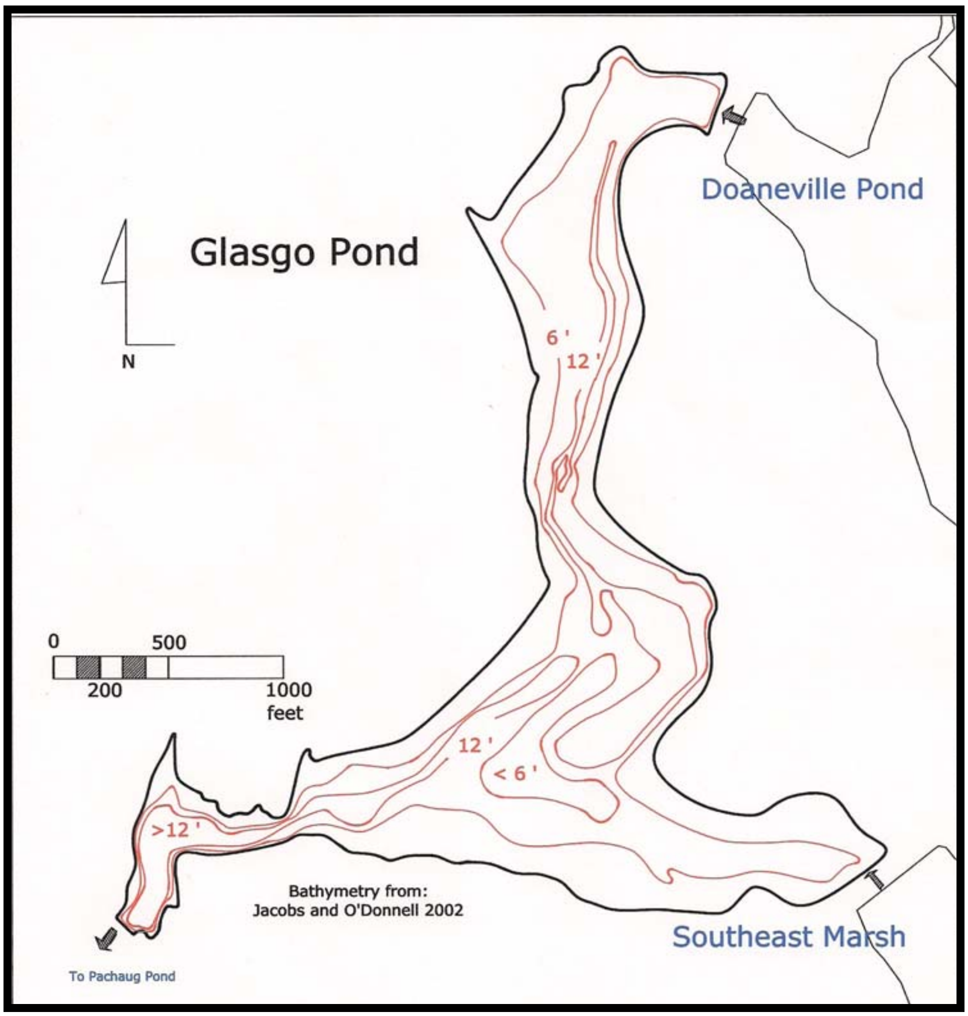
Glasgo Pond consists of three connected water bodies (**Map 2**). A large open water pond called here Glasgo Pond, a large open water pond called Doaneville Pond connected by box culvert under Sheldon Road, and a large wetland area called here Southeast Marsh, connected by culvert under CT Route 165. Glasgo Pond, the main pond, was surveyed during this study. Doaneville Pond and Southeast Marsh were not surveyed. The eastern shore of Doaneville Pond is in the Town of Voluntown, CT. The surface area of each of the basins is given in **Table 3**, page 8.

Map 2 – Glasgo Pond Showing its Three Separate Basins



The water depths of Glasgo Pond are shown in **Map 3**. Contours come from Jacobs and O'Donnell 2002. The area between the shore and the 6 foot contour is 26 acres or about 33% of the total surface area of the Glasgo Pond. The area between 6 feet and 9 feet deep, is approximately 6 acres. A narrow band of 12 feet of water depth runs most of the length of the pond. Near the dam, at the southwest end of the pond, water depths of 18 to 22 feet were found during this survey. The water clarity on the day of the survey was less than 3 feet due to a dark reddish tannin color. With clarity of only 3 feet the estimated maximum depth of plant growth is about 6 feet deep.

Map 3 – Glasgo Pond Water Depth Contours



The frequency of occurrence for the 25 species of aquatic plants found at Glasgo Pond is listed in **Table 8**. The invasive species each had high occurrence values indicating that they were common, 51% for fanwort, 23% for variable-leaf milfoil, and 30% for Eurasian milfoil.

Table 8 - Frequency of Occurrence for Species Found in Glasgo Pond

Species	Common Name	Habitat	Percent Occurrence
Cabomba caroliniana	**Fanwort**	**S**	**51**
Nymphoides cordata	Floating Heart	F	39
Brasenia schreberi	Water Shield	F	31
Myriophyllum spicatum	**Eurasian Milfoil**	**S**	**30**
Myriophyllum heterophyllum	**V-leaf Milfoil**	**S**	**23**
Potamogeton robbinsii	Pondweed	S	19
Nuphar variegate	Yellow Water lily	F	19
Nymphaea odorata	White Water lily	F	17
Vallisneria americana	Tape Grass	S	17
Potamogeton natans	Pondweed	F	14
Utricularia radiata	Bladderwort	F	12
Utricularia vulgaris	Bladderwort	S	12
Lemna sp.	Duckweed	F	7
Potamotegeon epihydrus	Pondweed	S	4
Fontinalis sp.	Aquatic Moss	S	4
Ceratophyllum echinatum	Coontail	S	2
Potamogeton amplifolius	Coontail	S	1
Potamogeton pusillus	Pondweed	S	1
Pontederia cordata	Pickerel Weed	E	1
Ludwigia sp.	Water-purslane	E	1
Ceratophyllum dermersum	Pondweed	S	1
Eriocaulon aquaticum	Pipewort	E	1
Wolffia sp.	Water Meal	F	1
Potamogeton (unknown #1)	Pondweed	S	1
Scirpus sp.	Bulrush	E	1

Bold = invasive species

The specific species / depth curve for Glasgo Pond is shown in **Figure 6**. The chart shows that plants were encountered out to a maximum depth of about 9 feet. Species richness was near maximum (12 species maximum) out to about 5 feet of water depth, and still better than half (6 species) out to about 7 feet of water depth. This indicates that the littoral zone of Glasgo Pond is well populated with different species to near the maximum depth of growth.

The water depths at which the three invasive species were found is shown in **Figure 7**. Each of the three species were found out to 7 feet of water. The frequency of occurrence of each species increased with increasing water depth to a maximum percent occurrence at 4 feet of water depth. Each of three invasive species was found, but with less frequency, in deeper water between 5 feet and 7 feet deep.

Figure 6 - Glasgo Pond Species Richness by Water Depth

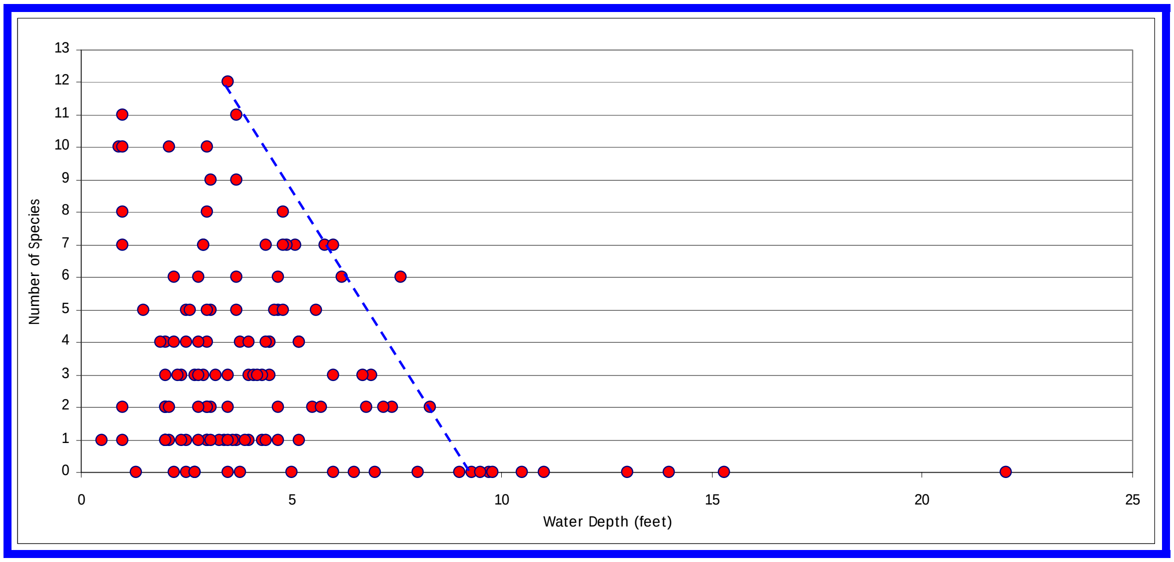
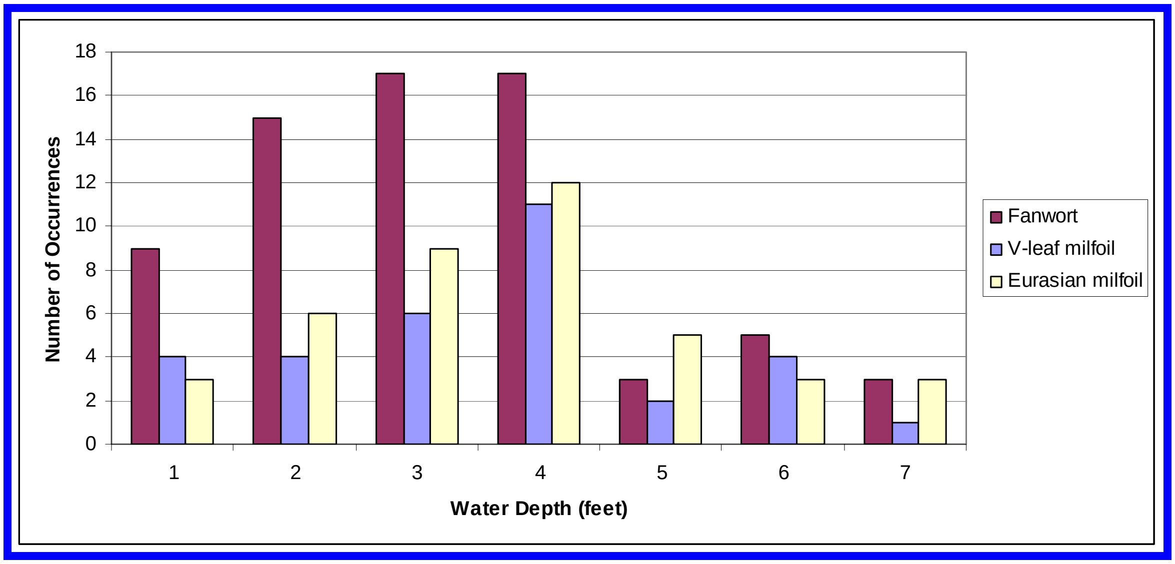
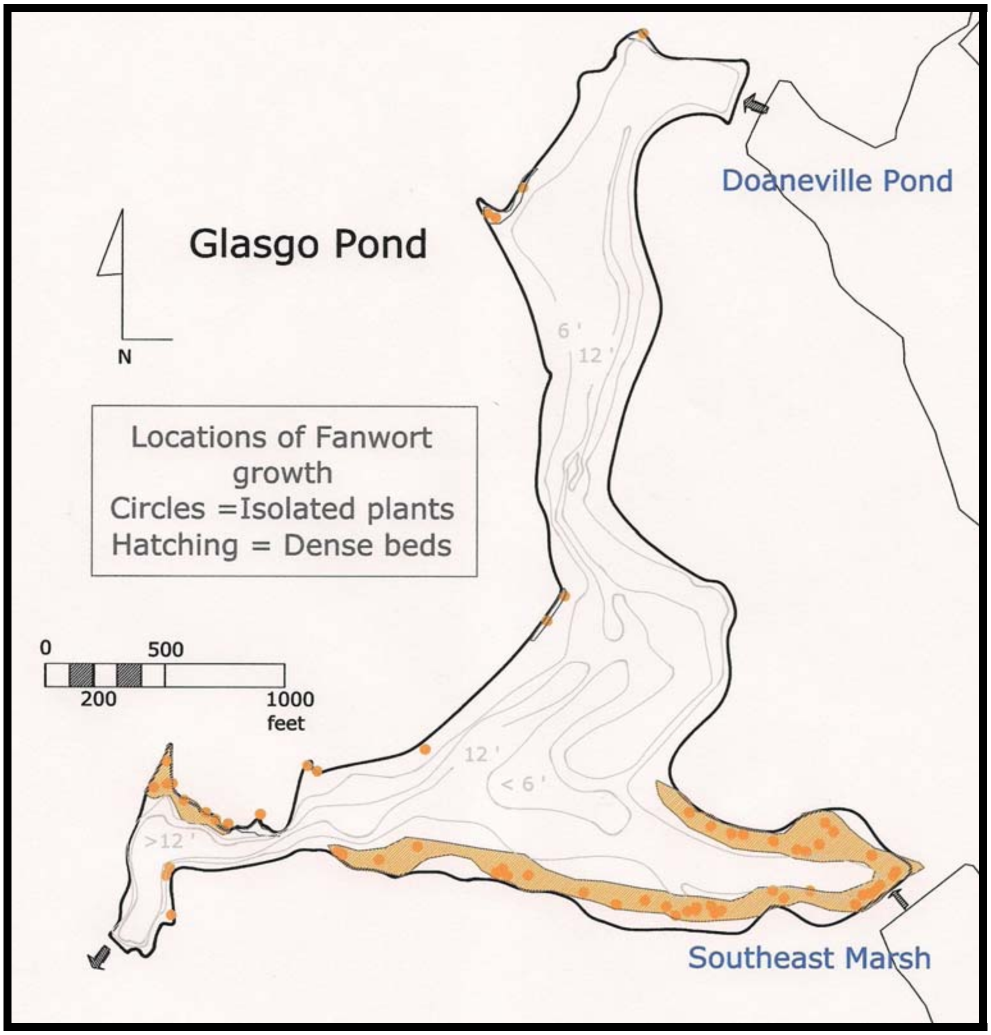


Figure 7 - Frequency of Invasive Aquatic Plant Species in Glasgo Pond at Each 1 Foot Depth Increment



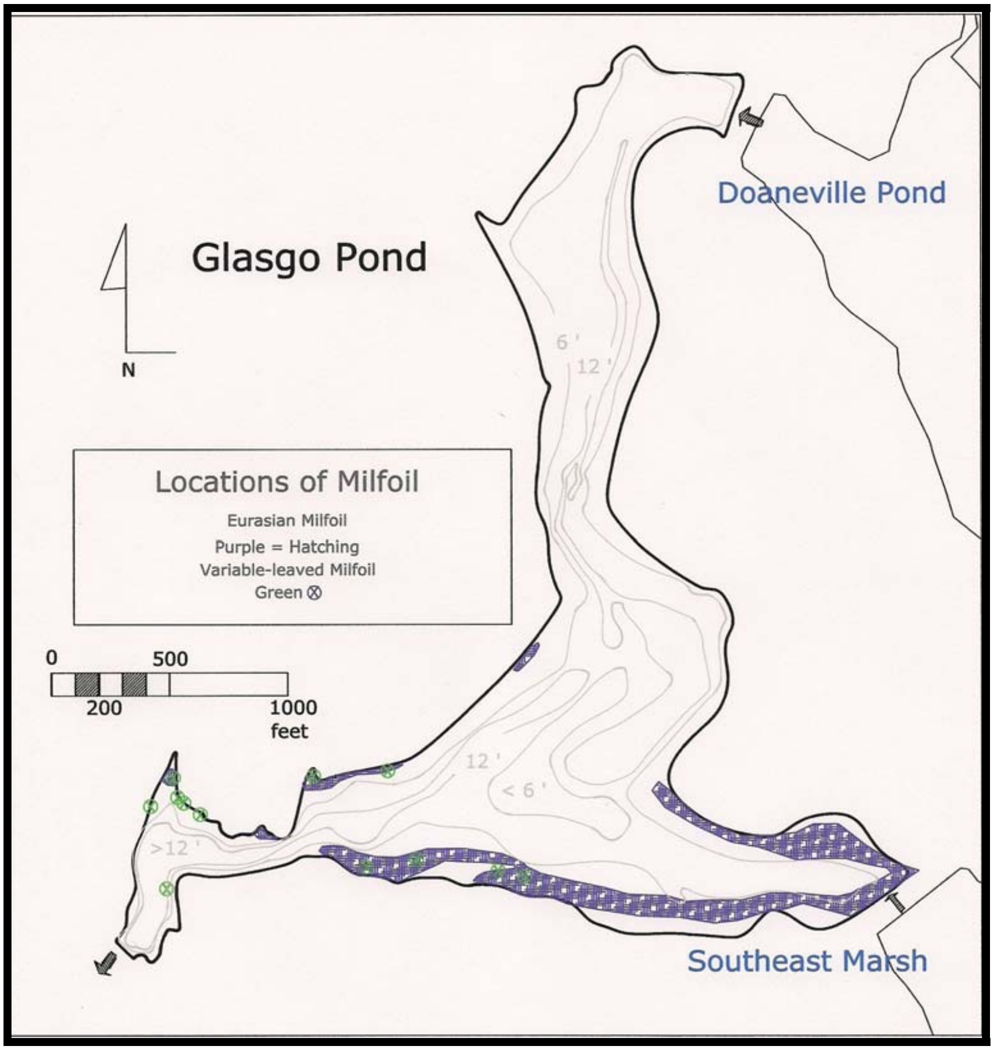
The distribution of fanwort in Glasgo Pond is shown in **Map 4**. There was approximately 10 acres of dense fanwort in Glasgo Pond found along the southern shore and in the cove connecting to Southeast Marsh, suggesting a source of fanwort may be in the Southeast Marsh drainage basin, which includes Billings and Anderson Ponds. There were few sporadic, isolated fanwort plants in the sheltered coves on the western shore of the pond, but no fanwort was found along the northeastern shore.

Map 4 – Glasgo Pond Fanwort Distribution



The distribution of the two invasive milfoils (Eurasian milfoil and variable-leaf milfoil) in Glasgo Pond followed the distribution of fanwort with both species found only along the southern shores of the pond **Map 5**. Eurasian milfoil was very common and abundant, growing at high density, along the southeastern shore and in the cove where Southeast Marsh discharges into Glasgo Pond, suggesting that the drainage basin of Southeast Marsh may be a source of Eurasian milfoil to Glasgo Pond. Variable-leaf milfoil was not distributed in the same way as Eurasian milfoil but instead was found sporadically along the northern shore between the boat launch and the dam suggesting introduction by boats launching at the ramp.

Map 5 – Glasgo Pond Invasive Milfoil Distribution

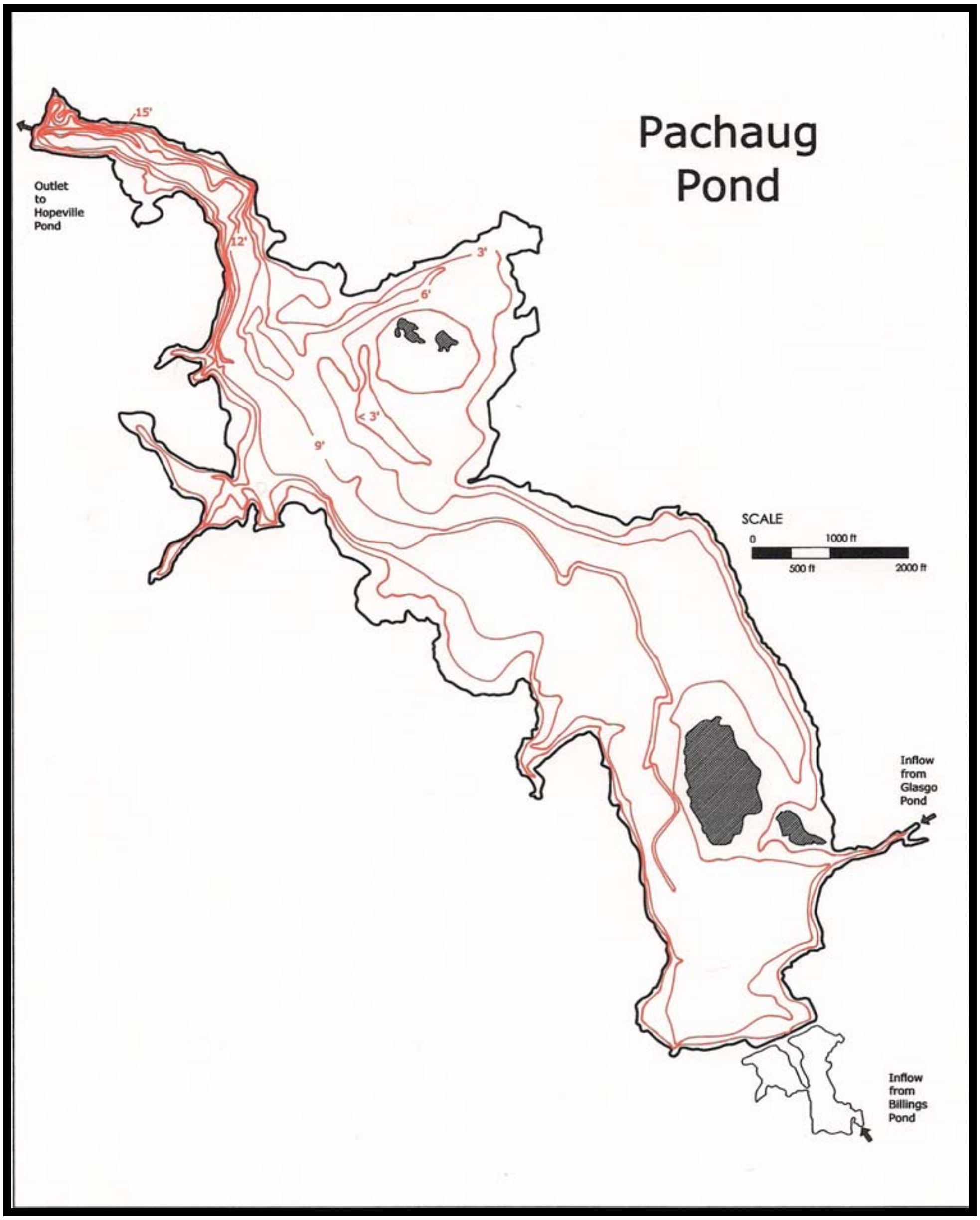


Pachaug Pond

Pachaug Pond is an 841 acre lake located directly downstream of Glasgo Pond. The lake has a uniformly shallow basin with water depths between 3 and 9 feet throughout most of the south and central areas, and depths to 15 feet in the north area near the dam. The water depth contours are shown in **Map 6,** redrawn from Jacobs and O'Donnell 2002[4].

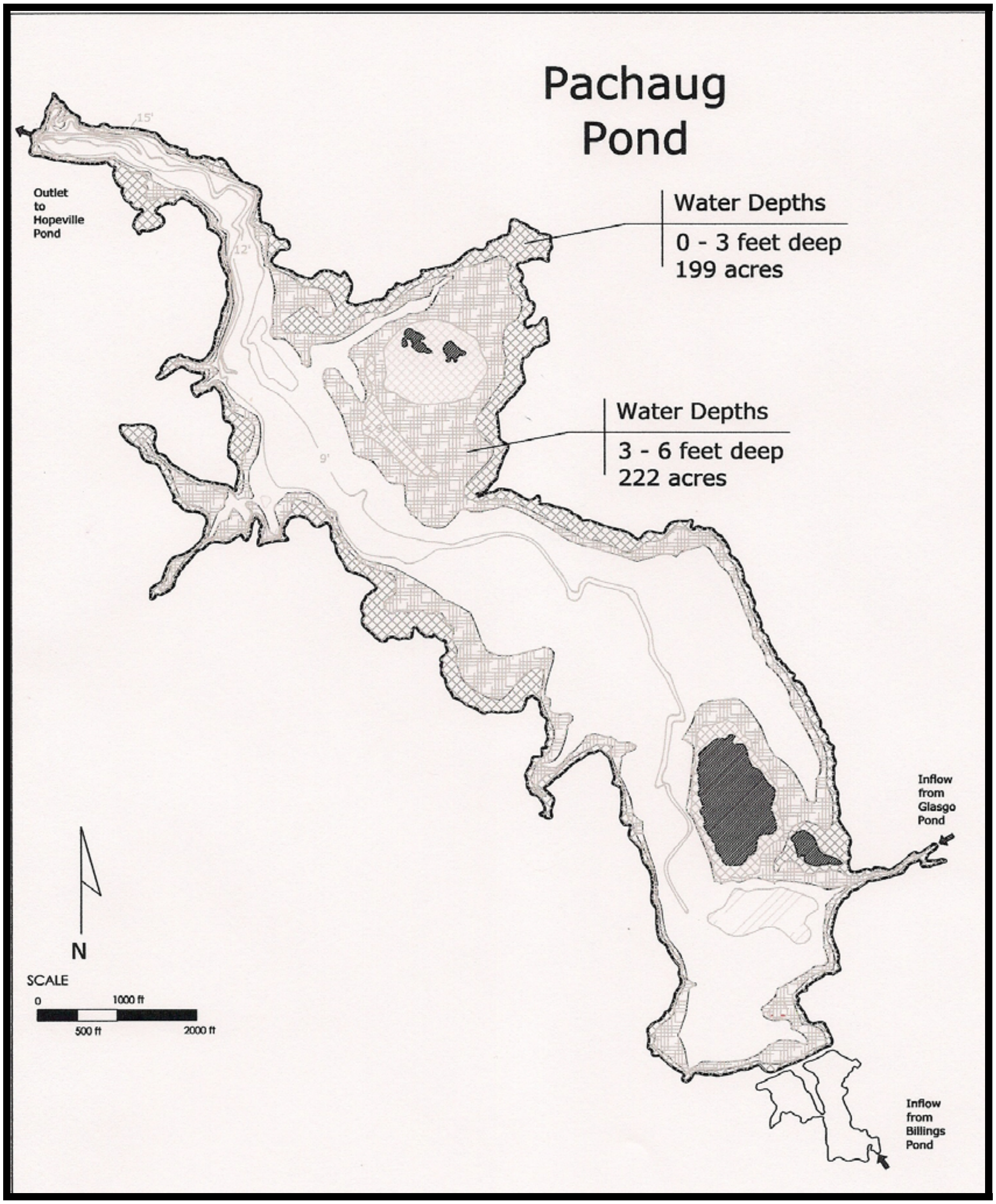
[4] "A Fisheries Guide to Lakes and Ponds of Connecticut" Robert P. Jacobs & Eileen B. O'Donnell. 2002. CT DEP Bulletin #35

Map 6 – Pachuag Pond Water Depth Contours



In Pachaug Pond the surface area between 0 – 3 feet is 199 acres, with 220 acres between 3 and 6 feet. There is a very large flat central basin where the water depth is between 6 and 9 feet covering about 350 acres. Water deeper than 9 feet is confined to a narrow central trough, and a small area near the dam. The lake areas between 0 – 3 feet and 3 – 6 feet are shown in **Map 7**.

Map 7 - Pachaug Pond Aquatic Plant Habitat Zones

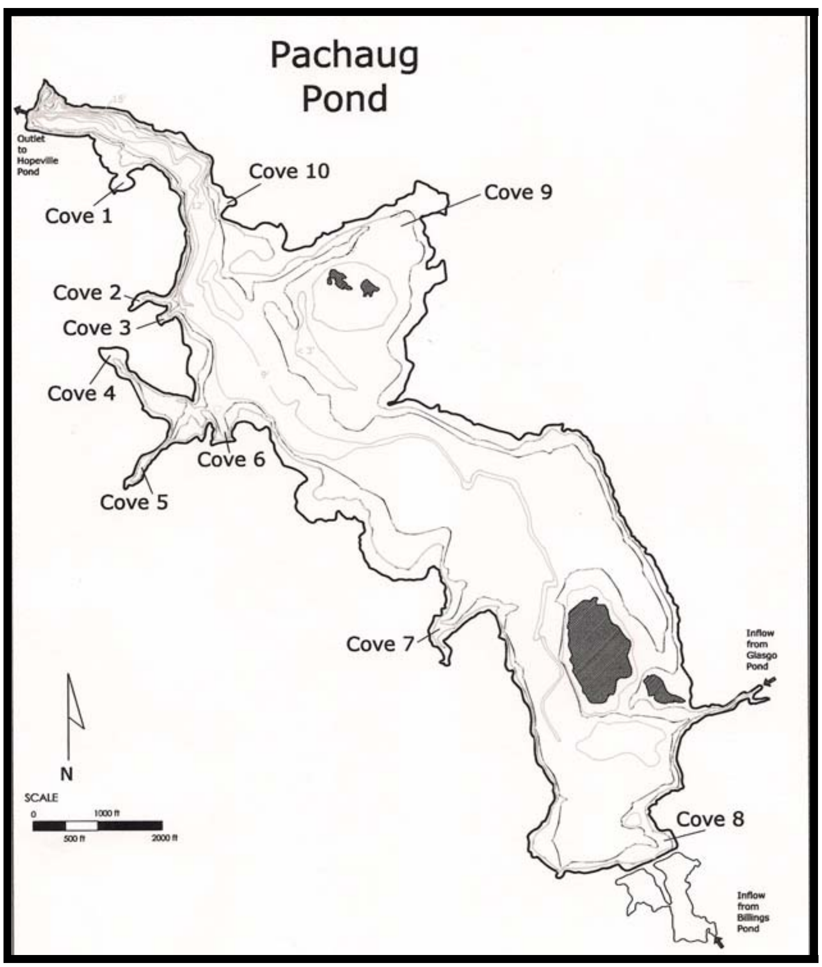


One of the characteristics of Pachaug Pond is the several sheltered coves located along the western shore, coves identified on the eastern shore are less well defined. There are ten coves identified in **Map 8** that were found to have very dense plant growth. The surface areas and maximum water depth of each cove is given in **Table 9**. One important condition of the coves is that water is often deeper within the coves than directly outside in the main body of the lake. In coves 1 and 3, a shallow bar separated the cove from the lake.

Table 9 - Weed Infested Coves of Pachaug Pond

Cove #	Acres	Max Depth (ft)
1	1.7	6
2	3.0	9
3	0.75	8
4	11.5	6
5	5.4	6
6	1.0	9
7	4.4	5
8	5.5	5
9	17.7	6
10	0.7	4
Total	51.7	

Map 8 - Pachaug Pond Coves



The 2009 survey of Pachaug Pond was the third conducted by NEAR at this pond, with prior surveys in 2004 and 2008. The frequency of occurrence for the 49 species of aquatic plants found at Pachaug Pond in 2009 is listed in **Table 12** together with frequency values for plants found during the prior two surveys, 2008 and 2004. Fanwort has been the second most common plant in Pachaug Pond in all three surveys. The frequency of the fanwort has increased from 30% to 44% between 2004 and 2009. Both Eurasian and variable-leaf milfoil showed an increase in frequency between 2004 and 2008. However, each appears to have remained constant between 2008 and 2009. Minor naiad has shown a stead increase in frequency of occurrence since 2004.

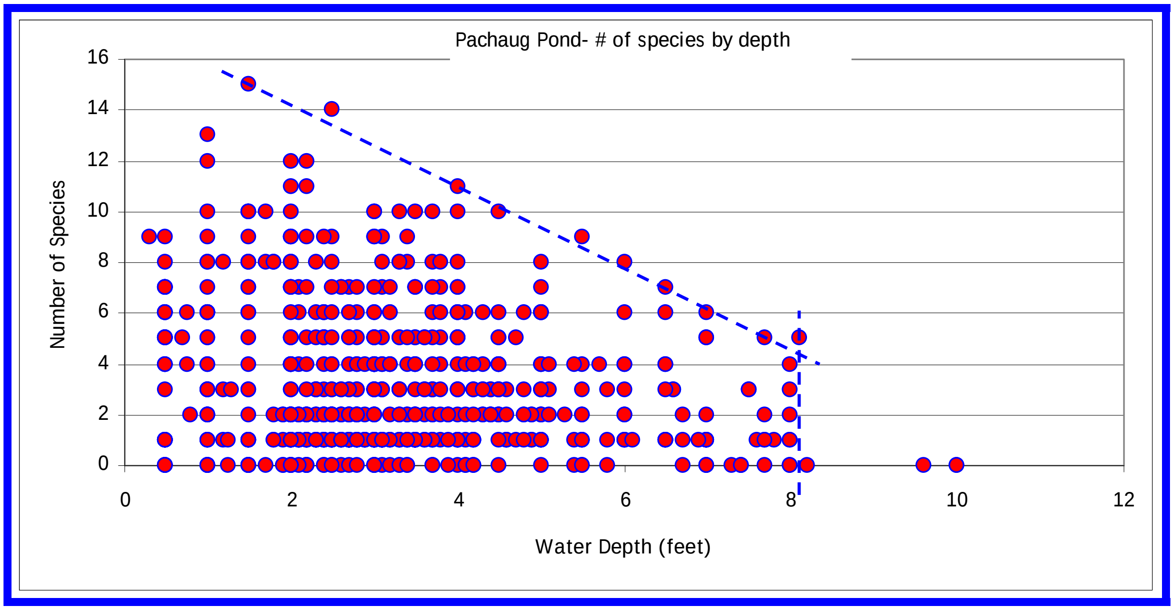
Table 10 - Frequency of Occurrence for Species Found in Pachaug Pond

Scientific Name	Common Name	2009	2008	2004
Vallisneria americana	Tape Grass	55	40	67
Cabomba caroliniana	**Fanwort**	**44**	**32**	**30**
Brasenia schreberi	Water Shield	23	15	24
Sparganium fluctuans	Burreed -aquatic	19	13	11
Nymphaea odorata	White Water Lily	18	9	19
Nymphoides cordata	Floating Heart	16	17	20
Utricularia radiata	Bladderwort	12	9	18
Myriophyllum heterophyllum	**V.leaf Milfoil**	**12**	**12**	**6**
Pontederia cordata	Pickerel Weed	12	1	9
Nuphar variegata	Yellow Water lily	11	9	18
Potamotegeon epihydrus	Pondweed	11	27	41
Myriophyllum spicatum	**Eurasian Milfoil**	**8**	**8**	**0.6**
Najas minor	**Minor Naiad**	**7**	**4**	**0**
Ceratophyllum dermersum	Coontail	7	0	4
Nitella sp.	Musk Grass	6	1	27
Eleocharis sp.	Spike Rush	6	0	4
Polygonum amphibium	Smartweed	5	4	7
Sagittaria graminea	Arrow Head	5	0	0
Lemna sp.	Duckweed	4	0	0.6
Potamogeton natans	Pondweed	4	4	8
Utricularia vulgaris	Bladderwort	4	0	0
Phragmites sp.	Common Reed	3	0	1
Potamogeton bicupulatus	Pondweed	3	0.3	12
Filamentous algae		3	0	0
Utricularia striata	Bladderwort	3	0	0

Najas flexilis	Water Naiad	2	0	12
Dulichium arundinaceum	Rush	2	0	3
Scirpus spp.	Bulrush	2	0	4
Utricularia purpurea	Bladderwort	2	0	0
Potamogeton amplifolius	Pondweed	2	1	0.6
Potamogeton robbinsii	Pondweed	1	0	0
Utricularia gibba	Bladderwort	1	0	0
Utricularia (unknown)	Bladderwort	1	0	0
Callitriche heterophylla	Water Starwort	1	0	0.6
Ludwigia palustris	Water Purslane	0.5	0	0
Eleocharis robbinsii	Spike Rush	0.5	1	0
Potamogeton perfoliatus	Pondweed	0.5	1	0
Potamogeton gramineus	Pondweed	0.5	0	4
Elatine sp.		0.3	0	0
Sagittaria sp.	Arrow Head	0.3	0	0
Fontinalis sp.	Aquatic Moss	0.2	0	0.6
Eriocaulon aquaticum	Pipewort	0.2	0	0
Elodea nuttallii	Water Weed	0.2	0	0
Isoetes sp.	Quillwort	0.2	0	0
Najas guadalupensis	Water Naiad	0.2	0	17
Spirodela polyrhiza	Great Duckweed	0.2	0	0.6
Ceratophyllum echinatum	Coontail	0	0	0
Potamogeton pusillus	Pondweed	0	0	0
Wolffia sp.	Water Meal	0	0	1
Potamogeton	Pondweed	0	0	0
Potamogeton	Pondweed	0	0	0
Peltandra virginica	Arrow Arum	0	0	0
Sparganium americanum	Burreed	0	0	1
Juncus sp.	Rush	0	0	0.6
Typha spp.	Cattail	0	0.3	1

The specific species / depth curve for Pachaug Pond is shown in **Figure 8**. The chart shows that plants were encountered out to a maximum depth of about 9 feet. Species richness was near maximum (15 species maximum) out to about 3 feet of water depth, and still better than half (7 species) out to about 7 feet of water depth. This indicates that the littoral zone of Pachaug Pond is well populated with different species to near the maximum depth of growth.

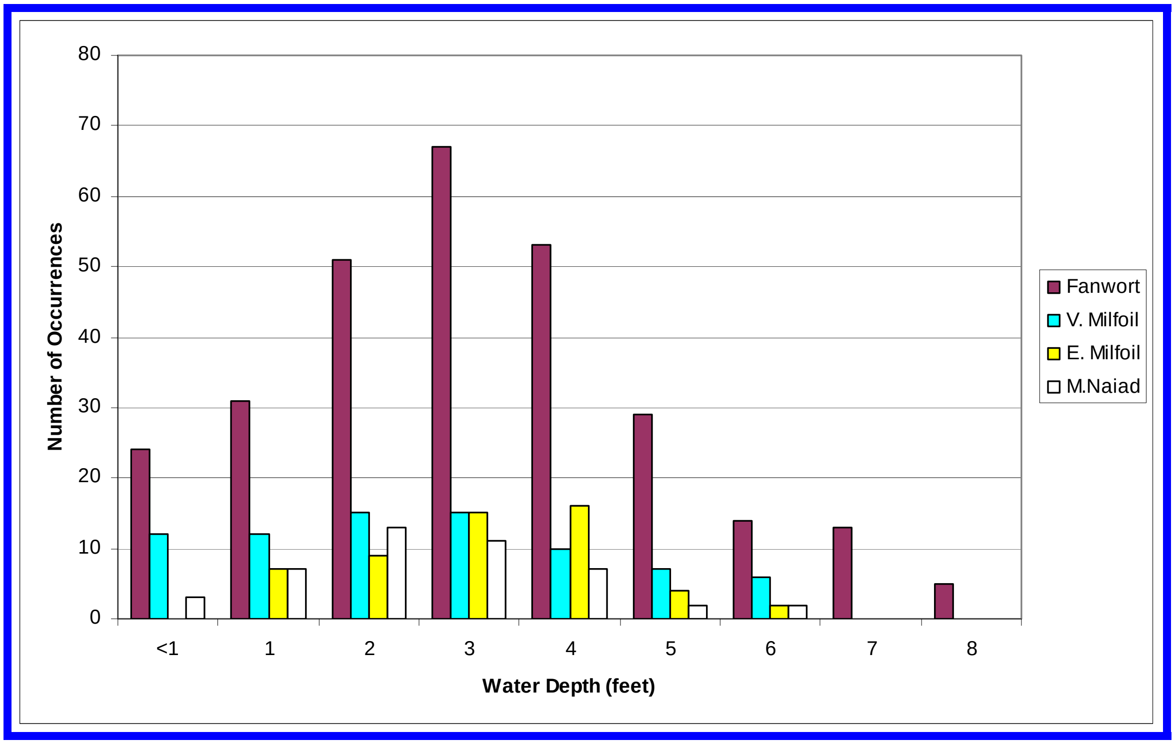
Figure 8 - Pachaug Pond Species Richness by Water Depth



The water depths at which the four invasive species were found is shown in **Figure 9**. Fanwort was common in water less than 1 foot deep, with over 20% of the sightings from 0 to 1 foot deep, suggesting that there are a significant number of fanwort plants unaffected by drawdown. Fanwort showed increased frequency of occurrence with increasing water depth until a maximum of almost 70% between 3 and 4 feet deep. However, fanwort was very common, 30%, between 5 and 6 feet deep and was still present in water out to 8 feet deep. Variable-leaf milfoil appears to favor shallower water because it occurred with similar frequency between 0 and 5 feet. Eurasian milfoil favored slightly deeper water, as it was not present in water less than 1 foot deep and had highest frequency in 4-5 feet of water depth. Minor naiad was present between 0 and 5 feet of water depth, and most common in water between 2 – 4 feet deep.

The higher frequency of occurrence for fanwort between 2 - 4 feet of water depth suggests a drawdown affect. Fanwort may be limited in water that is exposed during drawdown < 3 feet deep (see **Table 1** page 7), and clusters the plants in water immediately deeper than the drawdown range. The occurrence of plants in very shallow water indicates that lack of drawdown affect in the coves where fanwort was present at high density up to the shoreline. Variable-leaf milfoil shows no change in frequency of occurrence over the range of water depths because it occurred almost exclusively in the coves were drawdown showed no affect on the plant growth. Eurasian milfoil and naiad appeared to be limited in very shallow water by the drawdown. These plants are not abundant in the coves as fanwort and variable-leaf milfoil.

Figure 9 - Frequency of Invasive Aquatic Plant Species in Pachaug Pond at Each 1 Foot Depth Increment

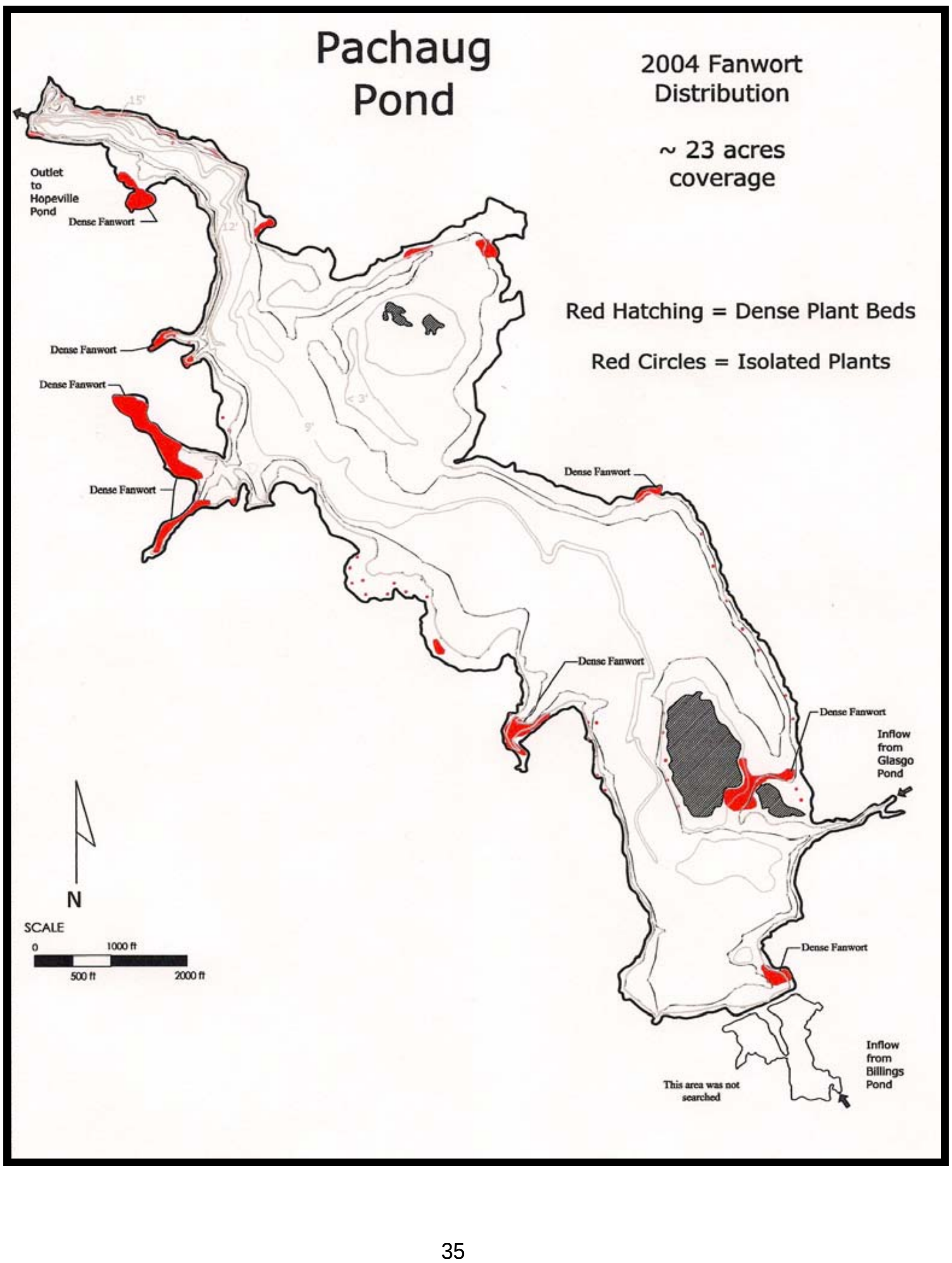


Fanwort Distribution

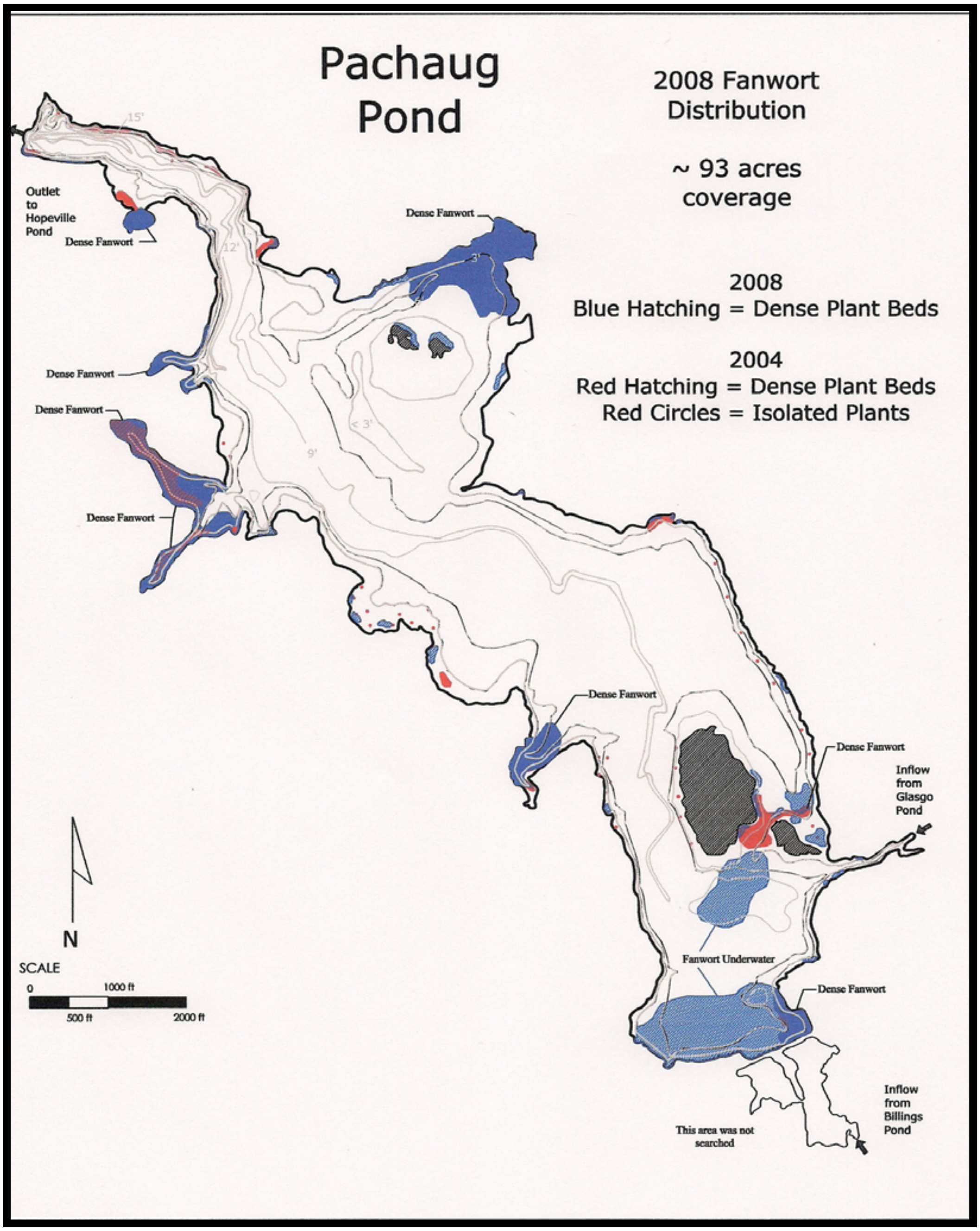
The distribution of fanwort in Pachaug Pond has been spreading in aerial coverage since the first mapping survey in 2004, with 127 acres found in 2009, up from 93 acres in 2008, and 23 acres in 2004. Survey results from each of the three surveys conducted by NEAR at Pachaug Pond are shown in the following set of three maps. **Map 9** shows the distribution of fanwort in 2004, **Map 10** shows fanwort in 2008, and **Map 11** shows the mapping results from the 2009 survey.

Mapping in 2009 shows that fanwort continues to occur at very high densities within the coves around the lake. Each of the numbered coves showed either an increase in coverage or no change. Fanwort along the shore of the main body of the lake occurred as sporadic isolated plants that tended to vary in location from survey to survey. This new survey data supports earlier conclusions that water level drawdown has little if any affect on fanwort within the coves and sheltered bays around the lake. New fanwort plants attempting to colonize the littoral zone of the main body of the lake appear to be controlled by drawdown because of the temporal nature of occurrences in this zone. The range of water depths where the plant was found, 0 - 8 feet, indicates that the available habitat for fanwort in Pachaug Pond is about 770 acres. Other than the deeper water at the south end of the lake, fanwort has been found only rarely in this habitat zone in the main body of the lake.

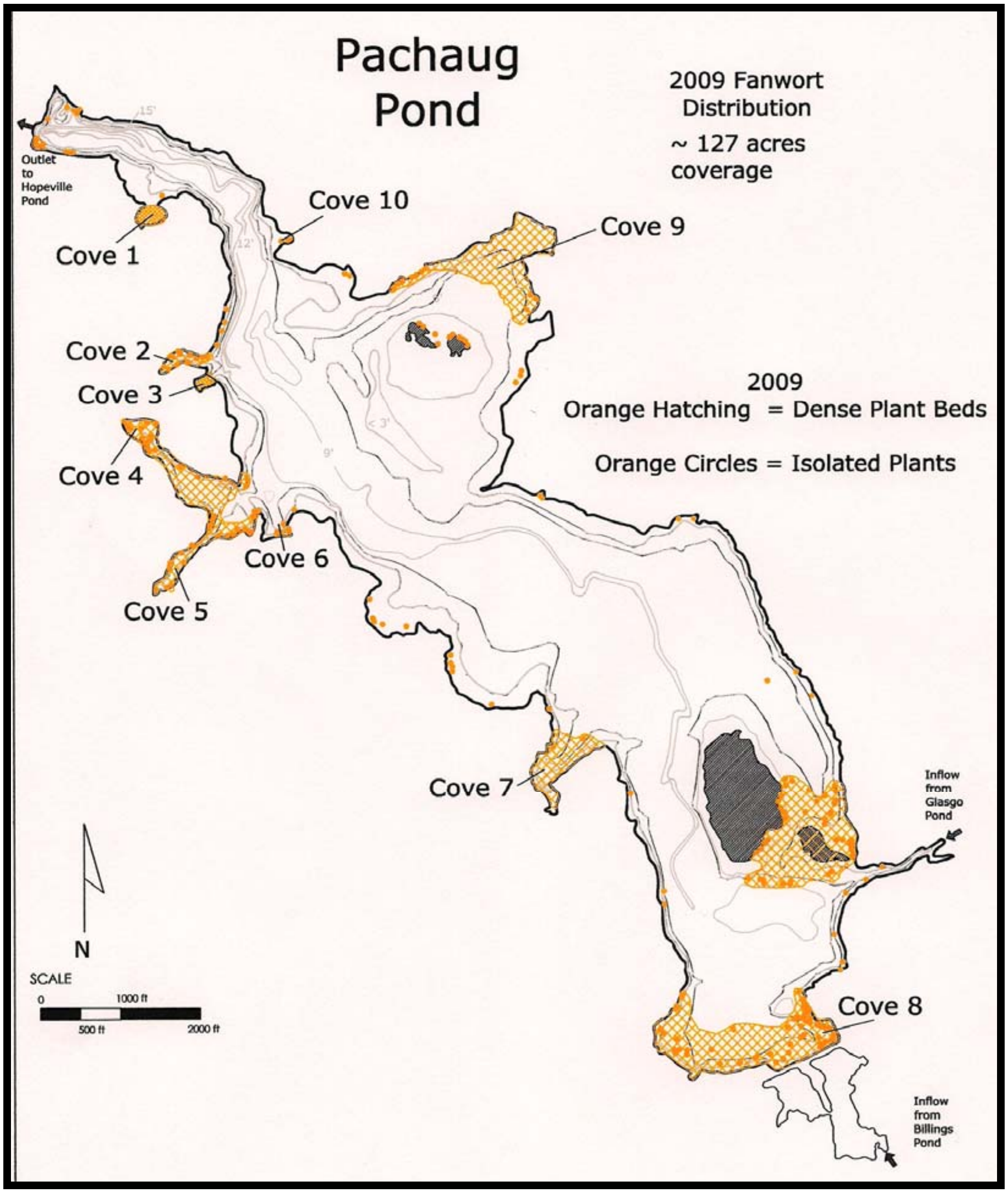
Map 9 – Distribution of Fanwort in Pachaug Pond in 2004



Map 10 - Distribution of Fanwort in Pachaug Pond in 2008



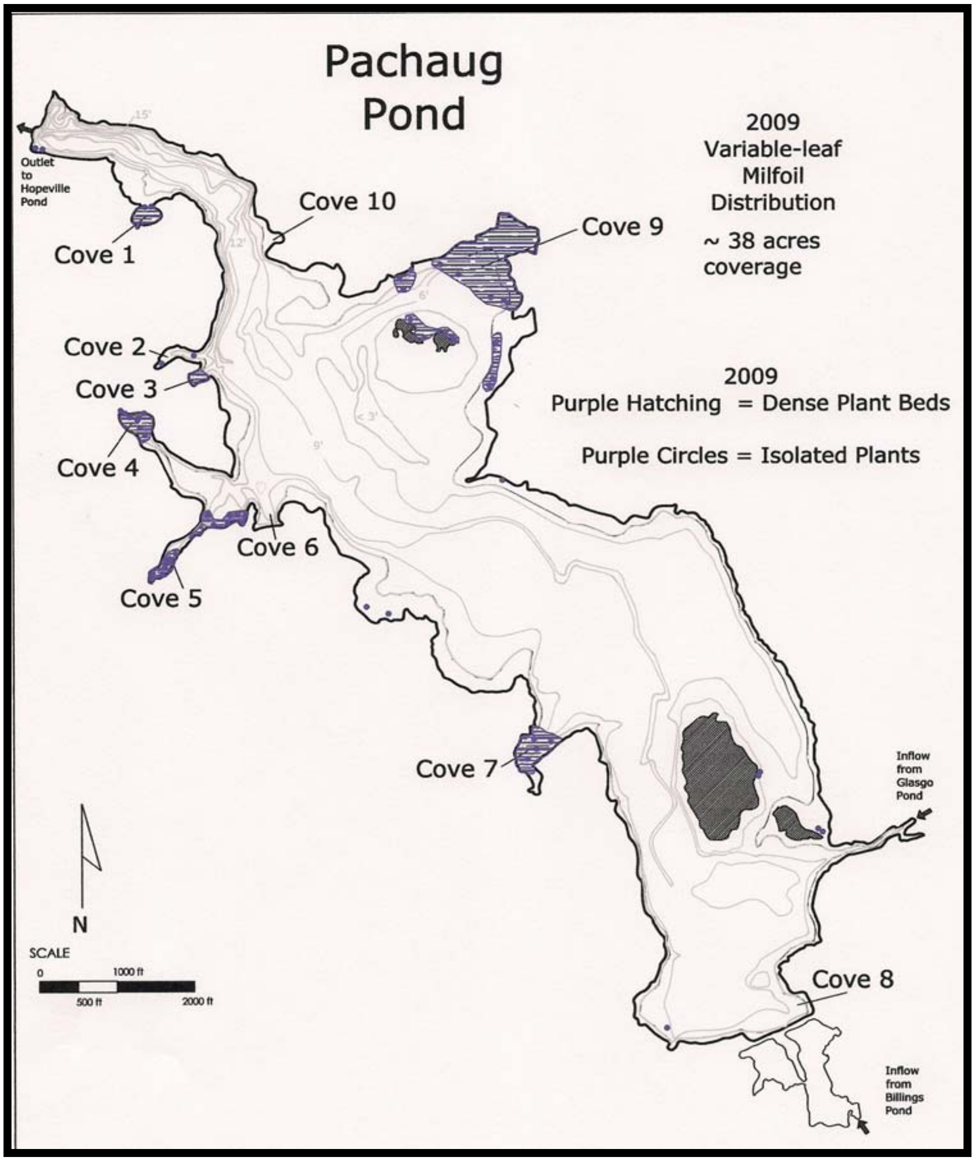
Map 11 - Pachaug Pond Fanwort Distribution in 2009



Variable-leaf Milfoil

The distribution of variable-leaf milfoil in Pachaug Pond followed the distribution of fanwort **Map 12**, in that generally variable-leaf milfoil was found where fanwort was already present, only 8 of 79 locations of variable-leaf milfoil did not contain fanwort. There were about 38 acres of variable-leaf milfoil in Pachaug Pond during the 2009 survey, very similar to the 36 acres reported in 2008, suggesting the this invasive plant species is not currently expanding in coverage. It is possible that variable-leaf milfoil has a more specific habitat requirement than fanwort preventing it from spreading out of the coves.

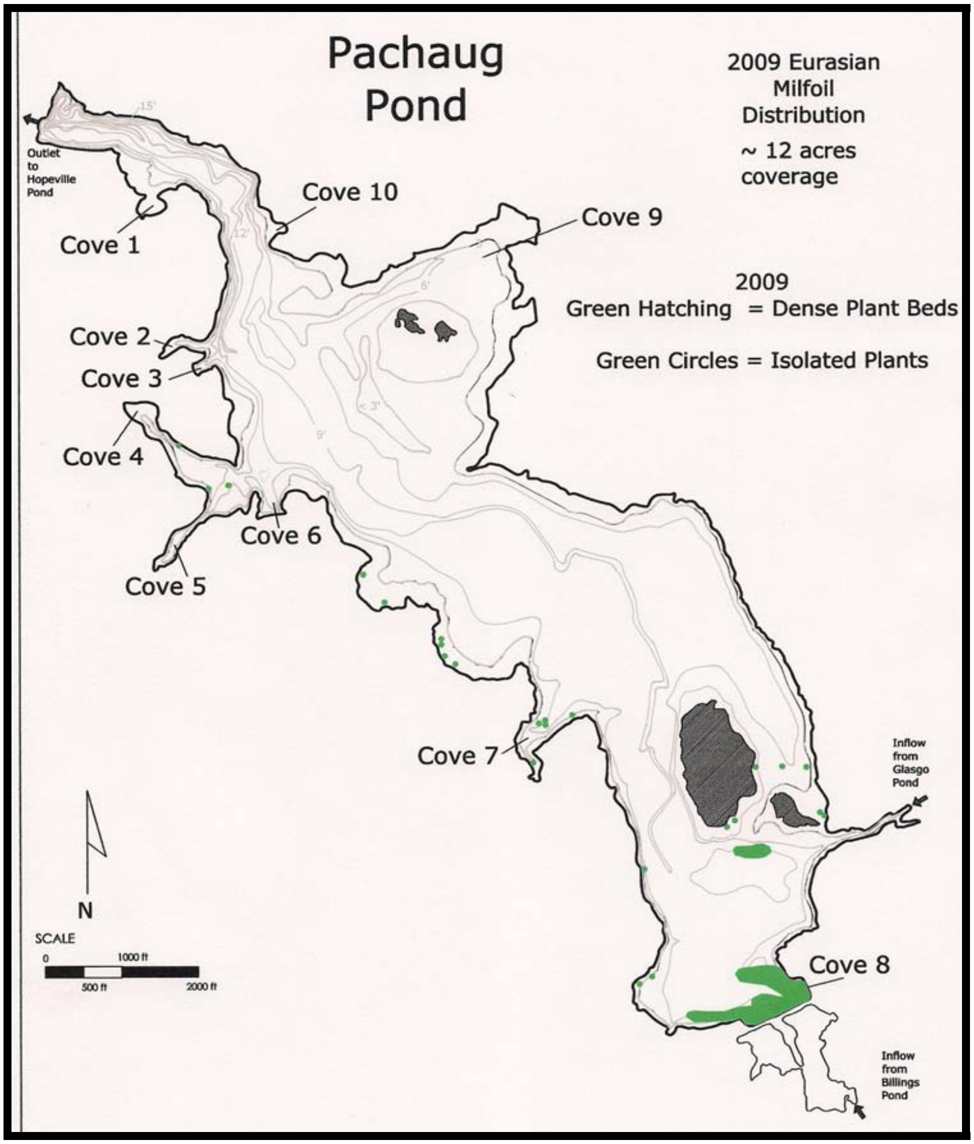
Map 12 - Pachaug Pond Variable-leaf Milfoil Distribution in 2009



Eurasian Milfoil

Eurasian milfoil has shown rapid spread in Pachaug Pond since its first sighting in 2004 and the recent mapping in 2009. Eurasian milfoil was found at 54 waypoints in 2009 almost twice the 28 points where it was found in 2008. Eurasian milfoil now exists in dense beds covering about 12 acres mostly at the southeast end of the lake.

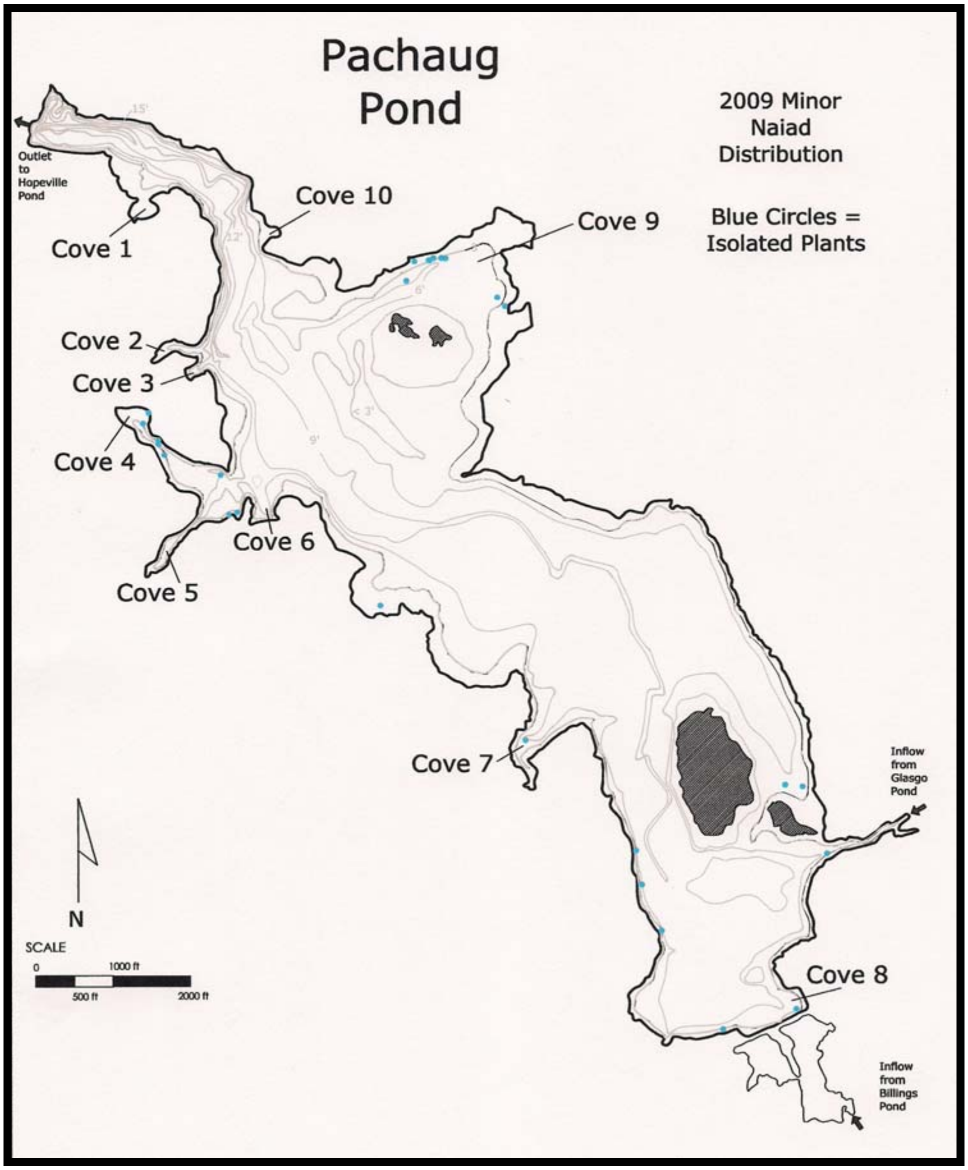
Map 13 - Pachaug Pond Eurasian Milfoil Distribution in 2009



<u>Minor Naiad</u>

Minor naiad has also shown an increase in occurrence in Pachaug Pond since 2008. Although the large bed of naiad mapped south of the large islands in 2008 appears to have decreased in size, the number of waypoints where this species was present has increased dramatically since 2008. In 2004, minor naiad was not found in Pachaug Pond. In 2008, it was found at 12 waypoints, 10 of which were the large bed south of the island. In 2009, the species was found 47 waypoints, scattered around the different coves of the lake **Map 14.**

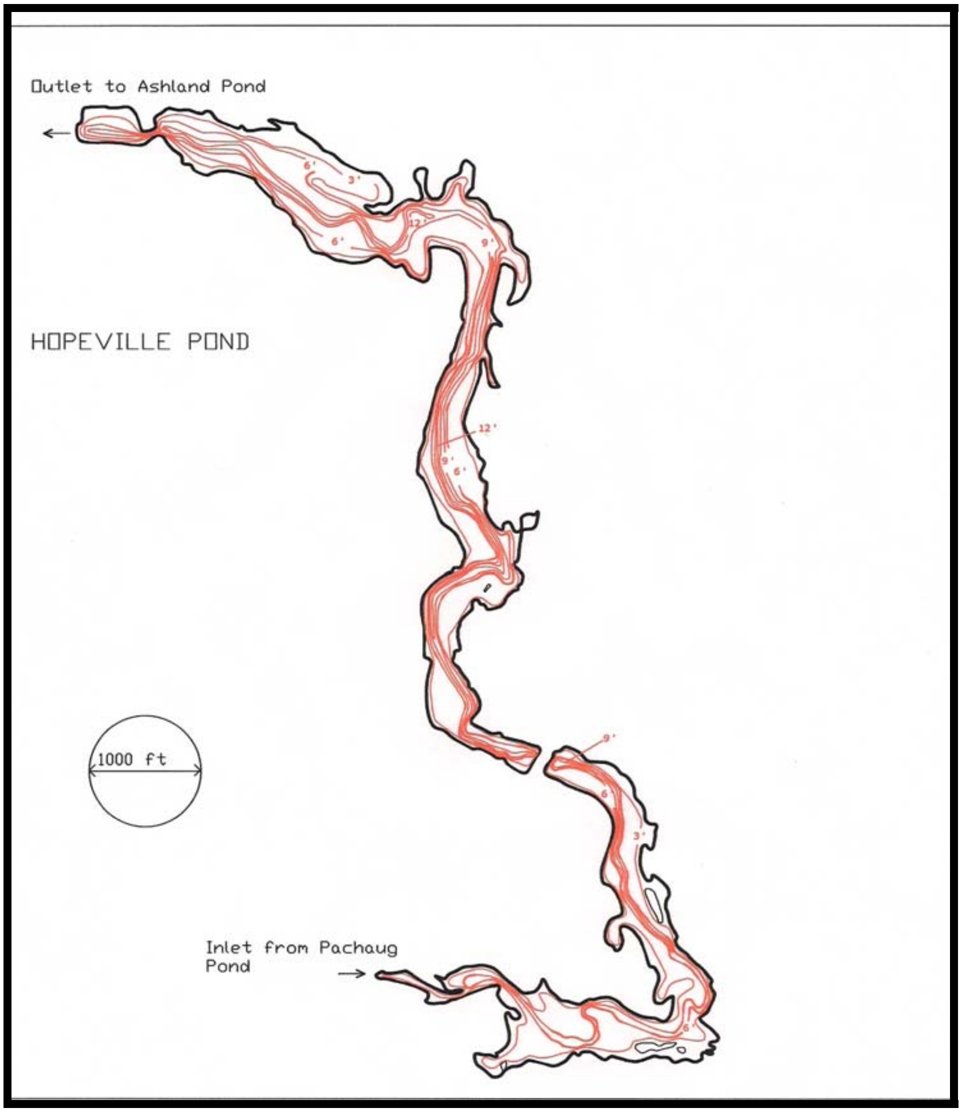
Map 14 - Pachaug Pond Minor Naiad Distribution in 2009



Hopeville Pond

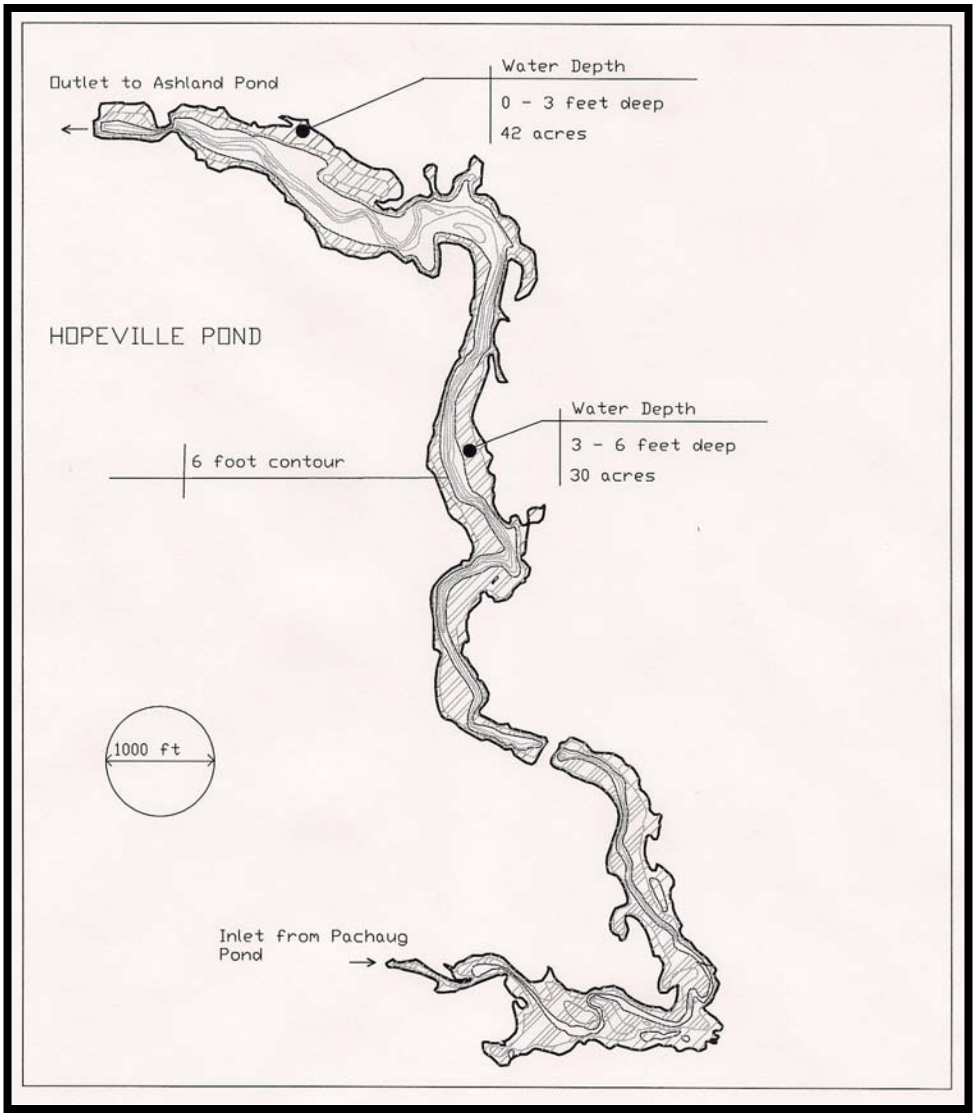
Hopeville Pond has a total surface area of 143 acres, consisting of two basins separated by a box culvert under Bitgood Road. The larger of the two, 94 acres, is north of Bitgood Road and contains most of the deeper water, the smaller basin, 48 acres, is south of Bitgood Road and has gradually shallower water especially toward the inflow from Pachaug Pond at the southern most end of the lake. The water depths of Hopeville Pond are shown in **Map 15**. The mapped contours are the 3, 6, 9, and 12 foot water depths. The pond is characterized by a band of deeper water that runs the length of the pond, presumably the original river channel. On either side of the deeper trough are flat shelf areas where depths range between 3 and 6 feet. Deepest water was near the dam where a small area of 15 feet of water depth was found.

Map 15 - Hopeville Pond Water Depth Contours



The surface area between 0 and 3 feet deep is 42 acres, with about 30 acres between 3 and 6 feet, and 54 acres between 6 and 9 feet. The total area of the littoral zone, defined here as the area of the lake shallower than 9 feet, is about 126 acres or 88% of the lake area.

Map 16 - Hopeville Pond Aquatic Plant Habitat Zones



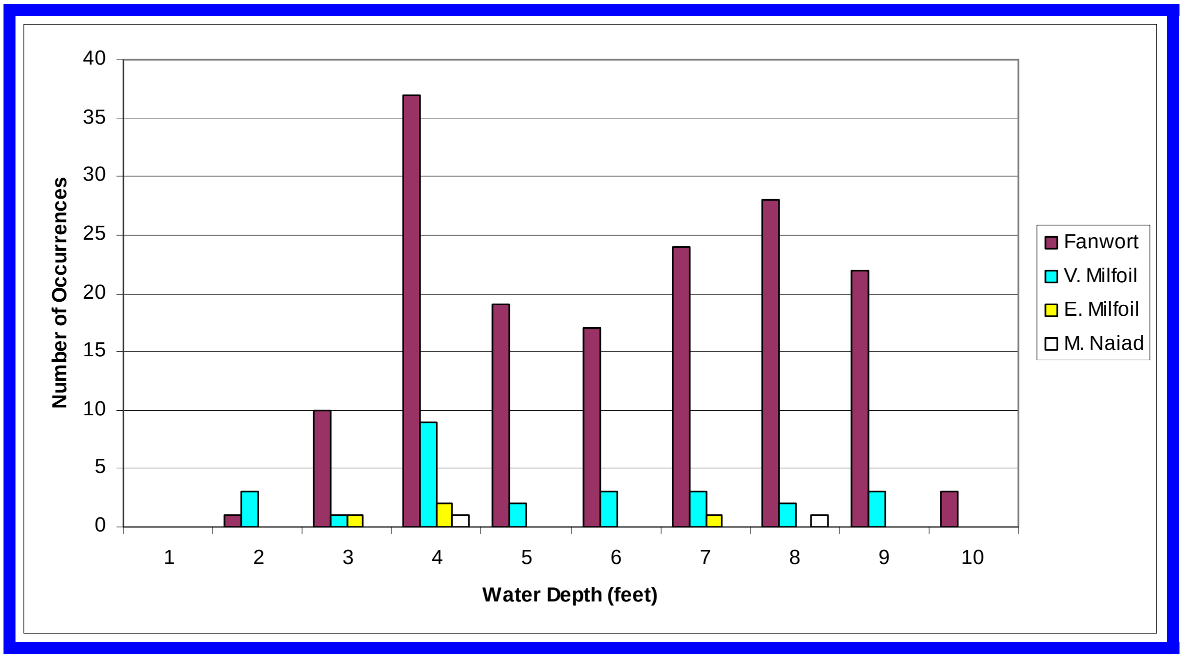
The frequency of occurrence for the 31 species of aquatic plants found at Hopeville Pond is listed in **Table 11**. Fanwort had the highest frequency of occurrence at 74%, of any of the plants found in the ponds. This was also the highest frequency of occurrence of fanwort in any of the four ponds. The other invasive aquatic plants were not as common. Variable-leaf milfoil occurrence was 13%, Eurasian milfoil 2%, and minor naiad 1%.

Table 11 - Frequency of Occurrence for Species Found in Hopeville Pond

Species	Common Name	Habitat	Percent Occurrence
Cabomba caroliniana	**Fanwort**	**S**	**74**
Utricularia vulgaris	Bladderwort	S	27
Nymphoides cordata	Floating Heart	F	26
Brasenia schreberi	Water Shield	F	26
Nymphaea odorata	White Water-lily	F	25
Nuphar variegata	Yellow Water lily	F	22
Vallisneria americana	Tape Grass	S	21
Ceratophyllum dermersum	Coontail	S	15
Myriophyllum heterophyllum	**Variable-leaf Milfoil**	**S**	**13**
Utricularia radiata	Bladderwort	F	11
Potamotegeon epihydrus	Pondweed	S	10
Potamogeton robbinsi	Pondweed	S	5
Filamentous algae		S	3
Eleocharis robbinsii	Rush	S	3
Ludwigia palustris	Water Purslane	E	2
Myriophyllum spicatum	**Eurasian Milfoil**	**S**	**2**
Potamogeton natans	Pondweed	F	2
Lemna sp.	Duckweed	F	2
Potamogeton bicupulatus	Pondweed	S	2
Potamogeton pusillus	Pondweed	S	1
Utricularia striata	Bladderwort	S	1
Sagittaria graminea	Arrowhead	S	1
Wolffia sp.	Water Meal	F	1
Najas minor	**Minor Naiad**	**S**	**1**
Najas flexilis	Water Naiad	S	1
Pontederia cordata	Pickerel Weed	E	1
Potamogeton unknown	Pondweed	S	0.5
Phragmites	Common Reed	E	0.5
Potamogeton unknown	Pondweed	S	0.5
Sparganium fluctuans	Burreed – aquatic	F	0.5
Scirpus spp.	Bulrush	E	0.5

The water depths at which the four invasive species were found in Hopeville Pond is shown in **Figure 10**. Fanwort was common in a wide range of water depths, from 3 to 9 feet water. Fanwort was most common at 4 feet and again at 8 feet but basically showed similar frequency of occurrence at all but the very shallow water depths. This may have been due to a lack of sampling waypoints were waters were less than 2 feet deep because of the dense water lily coverage in those parts of the lake. Variable-leaf milfoil was most common in 2 feet of water but was present out to 9 feet, although at these deeper depths the plant did not occur in dense stands. Eurasian milfoil and minor naiad were rare in Hopeville Pond, but both plants showed little preference for water of a certain depth.

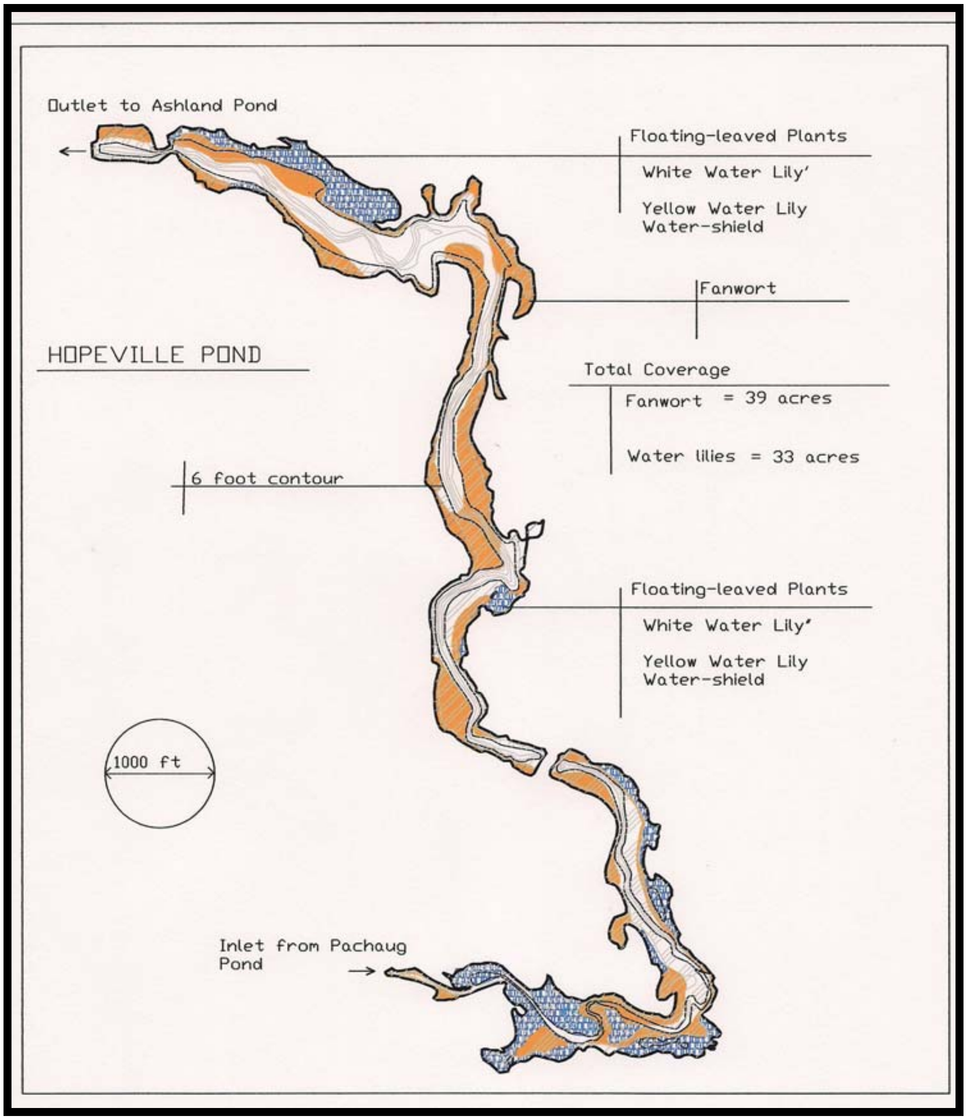
Figure 10 - Frequency of Invasive Aquatic Plant Species in Hopeville Pond at Each 1 Foot Depth Increment



<u>Fanwort</u>

The distribution of fanwort in Hopeville Pond is shown in **Map 17.** There were about 39 acres of dense fanwort beds in Hopeville Pond. **Map 17** also shows the areas of coverage with water lilies. Generally, fanwort was found growing under these water lilies beds so these areas need to be added to the total area of the Pond infested with fanwort increasing the total coverage of fanwort in Hopeville Pond to about 72 acres.

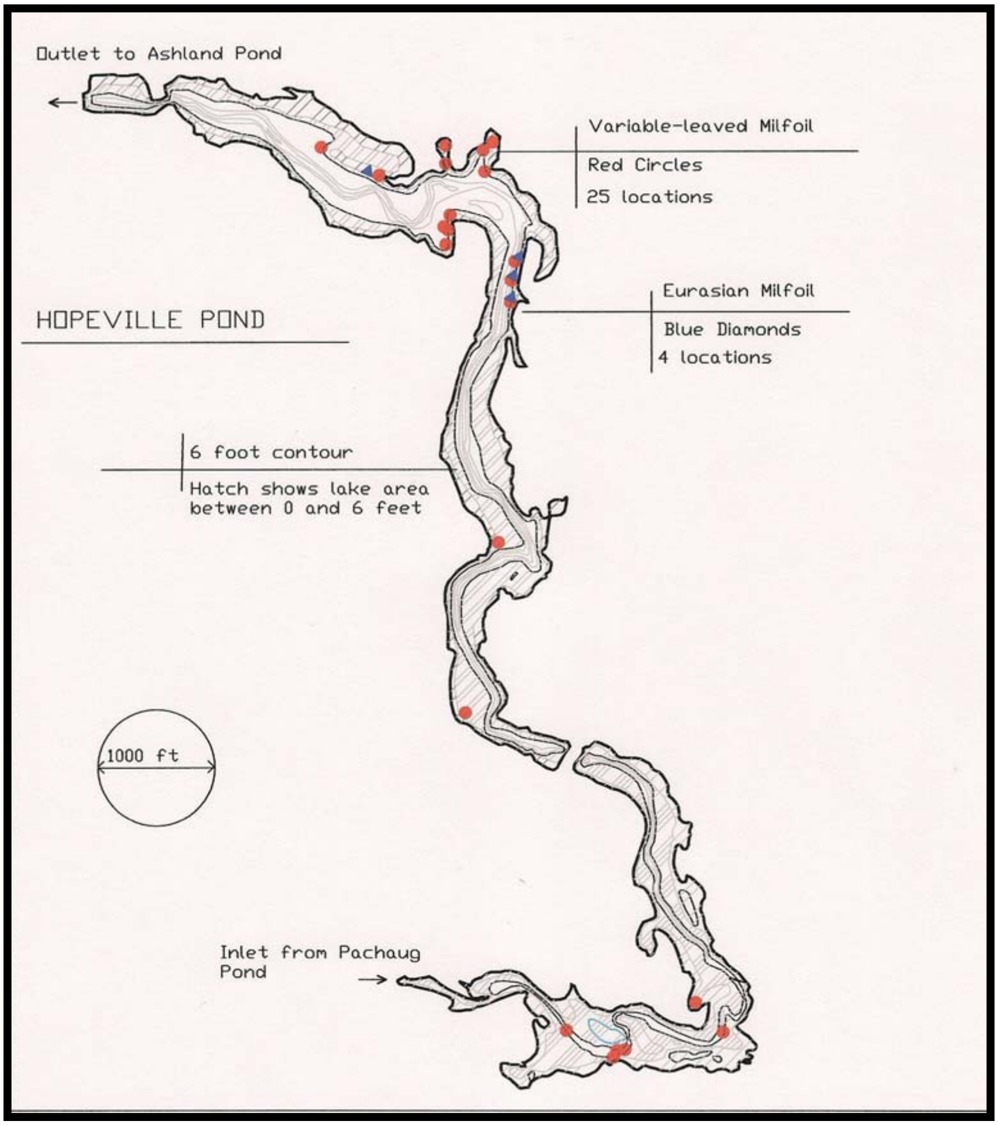
Map 17 - Hopeville Pond Fanwort and Floating Leaf Plant Distribution



Milfoils

The two invasive milfoil species, Eurasian, and variable-leaf milfoil, were both found in Hopeville Pond with locations shown in **Map 18**. Eurasian milfoil was scarce in Hopeville Pond being found at only 4 locations, all in the southern basin. Variable-leaved milfoil was found scattered throughout the pond, but was not found growing with high density at any site. The occurrence of both milfoils suggests a double vector on introduction to the pond. One set of isolated variable-leaf milfoils plants was found in the extreme southern end in the shallow water, suggesting transport from Pachaug Pond via the Pachaug River. However, all other locations of both milfoils, and Eurasian Milfoil specifically, were downstream of the boat ramp suggesting that at least some plants entered the lake via boats at the ramp.

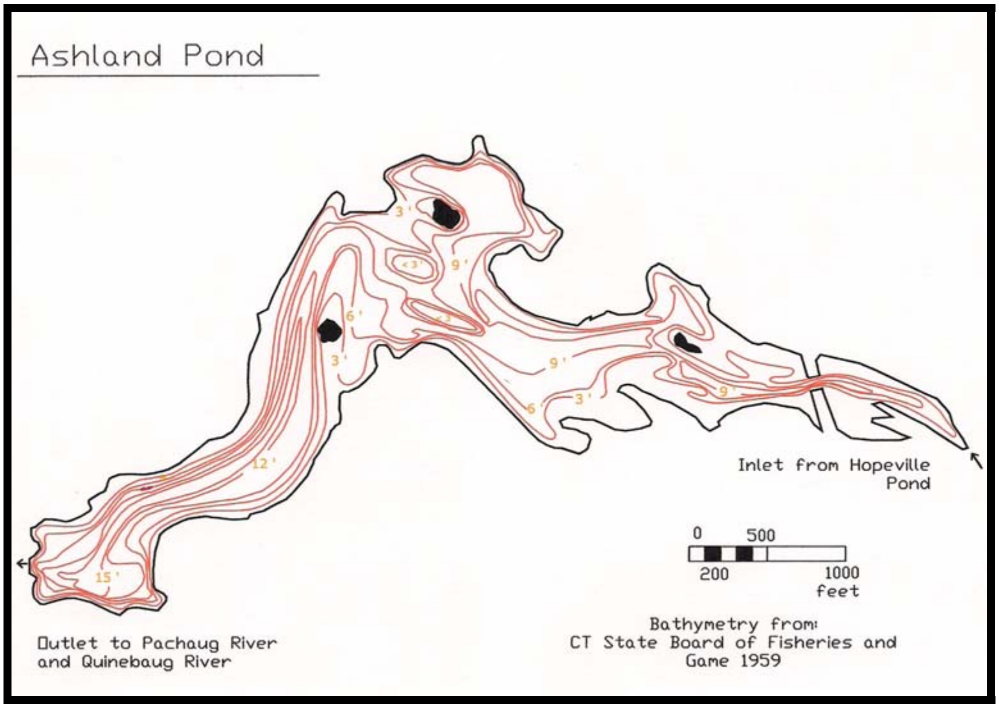
Map 18 - Hopeville Pond Invasive Milfoil Distribution



Ashland Pond

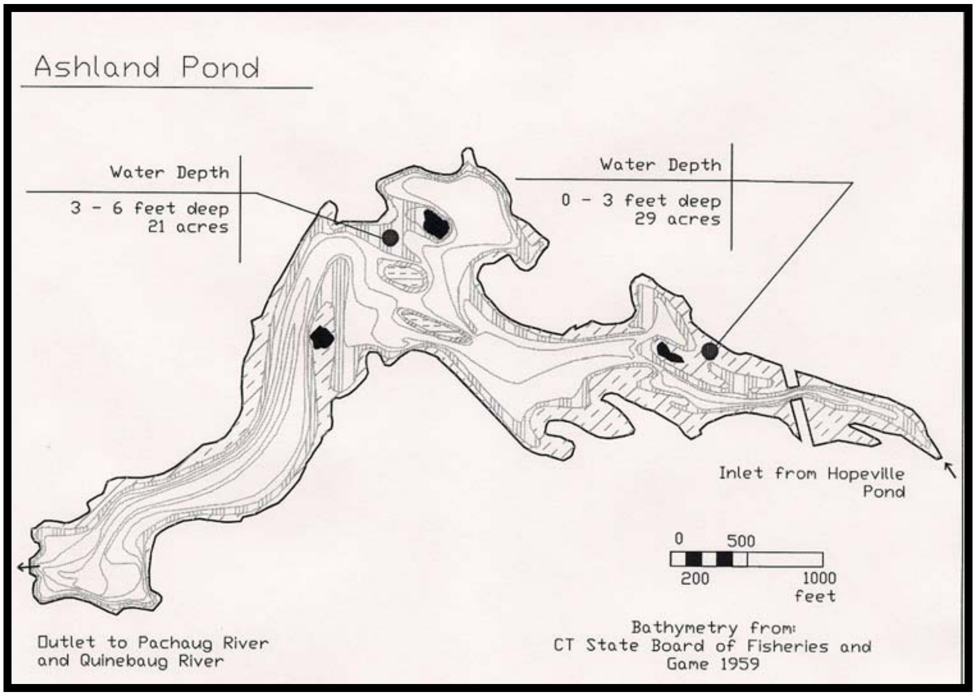
The water depth contours for Ashland Pond are shown in **Map 19**. Mapped contours include the 3, 6, 9, 12, and 15 foot water depths. The pond has mostly shallow water at the eastern end where the Pachaug River enters the Pond. Water depths become deeper toward the western end with deepest water near the dam.

Map 19 – Ashland Pond Water Depth Contours



The areas of the two water depth zones in Ashland Pond are shown in **Map 20**. The surface area between 0 – 3 feet is about 29 acres, between 3 - 6 feet is about 21 acres and between 6 and 9 feet about 23 acres. The total area of the littoral zone is about 73 acres, about 70% of the lake.

Map 20 - Ashland Pond Aquatic Plant Habitat Zones



The frequency of occurrence for the 29 species of aquatic plants found at Ashland Pond is listed in **Table 12**. Fanwort had the highest frequency of occurrence at 70%, only slightly less frequent than in Hopeville Pond. Variable-leaf milfoil was also common, found at 32% of the points. The other invasives were rare, Eurasian milfoil was found at only 1% of the points and minor naiad was not found at all.

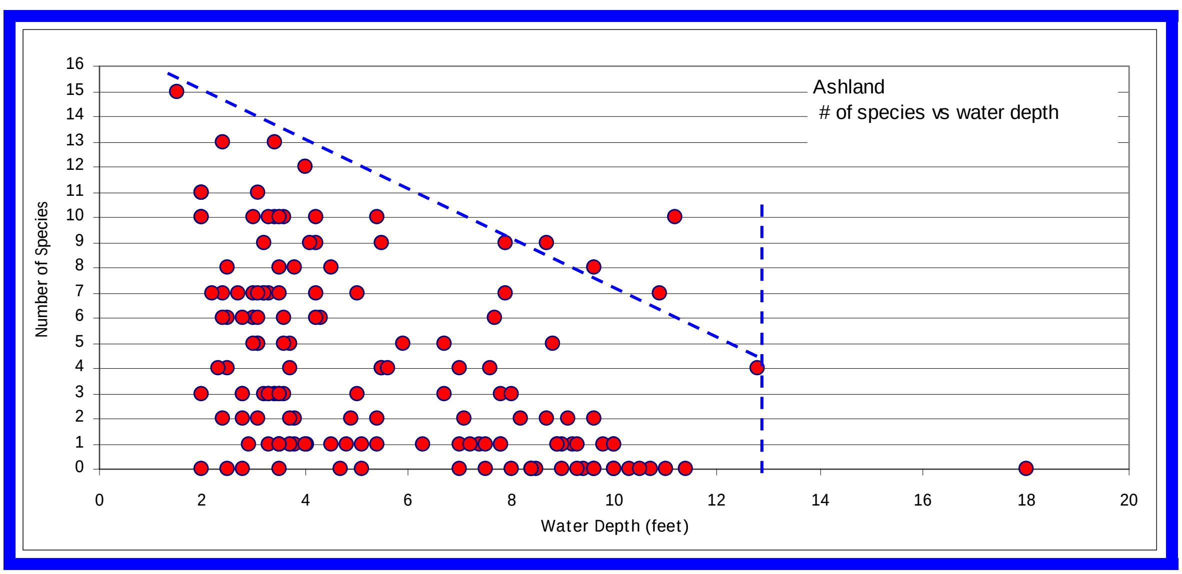
Table 12 - Frequency of Occurrence for Species Found in Ashville Pond

Species	Common Name	Habitat	Percent Occurrence
Cabomba caroliniana	**Fanwort**	**S**	**70**
Nuphar variegata	Yellow Water lily	F	35
Nymphoides cordata	Floating Heart	F	33
Myriophyllum heterophyllum	**Milfoil**	**S**	**32**
Brasenia schreberi	Water Shield	S	31
Peltandra virginica	Arrow Arum	E	25
Pontederia cordata	Pickerel Weed	E	22
Nymphaea odorata	White Water-lily	F	21
Potamogeton robbinsi	Pondweed	S	15
Sparganium americanum	Burreed	E	14
Potamogeton natans	Pondweed	S	12
Lemna sp.	Duckweed	F	11

Ceratophyllum dermersum	Coontail	S	10
Wolffia sp.	Water Meal	F	10
Polygonum amphibium	Smartweed	F	10
Utricularia vulgaris	Bladderwort	S	10
Utricularia striata	Bladderwort	S	7
Typha spp.	Cattail	E	6
Filamentous algae			5
Spirodela polyrhiza	Great Duckweed	F	5
Utricularia gibba	Bladderwort	S	4
Potamotegeon epihydrus	Pondweed	S	3
Fontinalis sp.	Aquatic Moss	S	1
Potamogeton bicupulatus	Pondweed	S	1
Sagittaria graminea	Arrow Head	S	1
Sparganium fluctuans	Burreed – aquatic	F	1
Eleocharis sp.	Spike Rush	E	1
Myriophyllum spicatum	**Milfoil**	**S**	**1**
Scirpus spp.	Bulrush	E	1

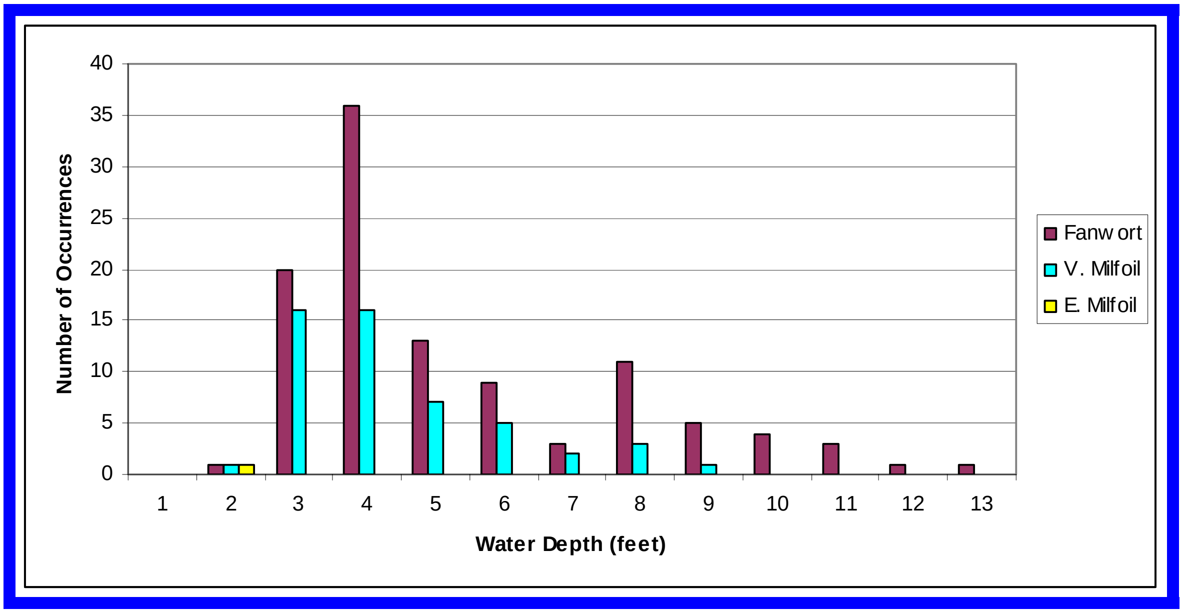
The specific species / depth curve for Ashland Pond is shown in **Figure 11**. The chart shows that plants were encountered out to a maximum depth of about 13 feet. Species richness was near maximum (15 species maximum) out to about 4 feet of water depth, and still better than half (7 species) out to about 10 feet of water depth. This indicates that the littoral zone of Ashland Pond is well populated with different species to near the maximum depth of growth, 13 feet.

Figure 11 - Ashland Pond Species Richness by Water Depth



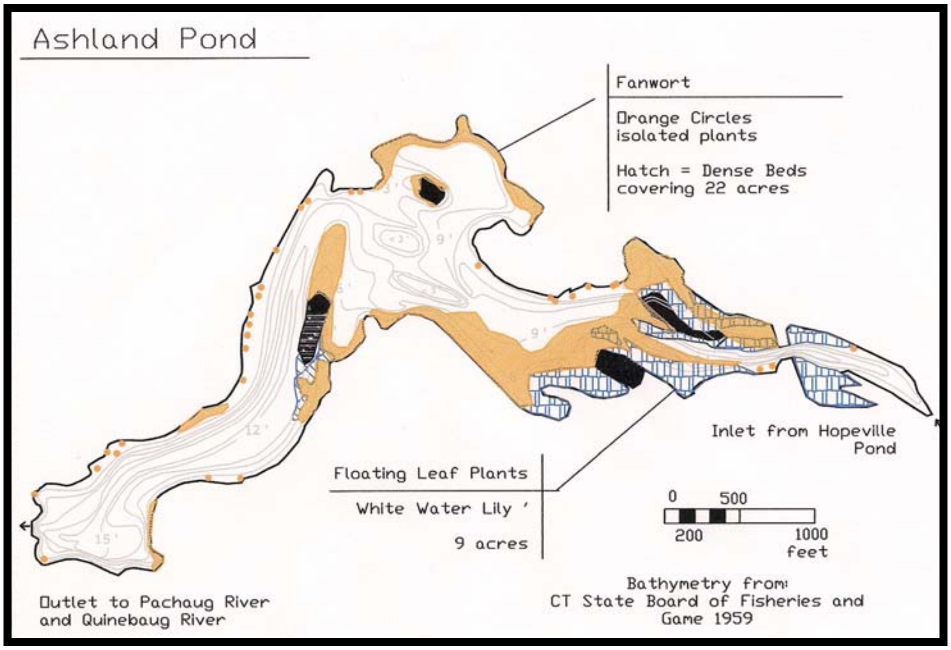
Fanwort was present at all depths in Ashland Pond out to a maximum depth of 13 feet **Figure 12**. The most common water depth for the plant to occur was 3 feet. Variable-leaf milfoil was most abundant between 3 and 6 feet, although it was found out to 9 feet of water. Eurasian milfoil was rare in Ashland Pond.

Figure 12 - Frequency of Invasive Aquatic Plant Species in Ashland Pond at Each 1 Foot Depth Increment



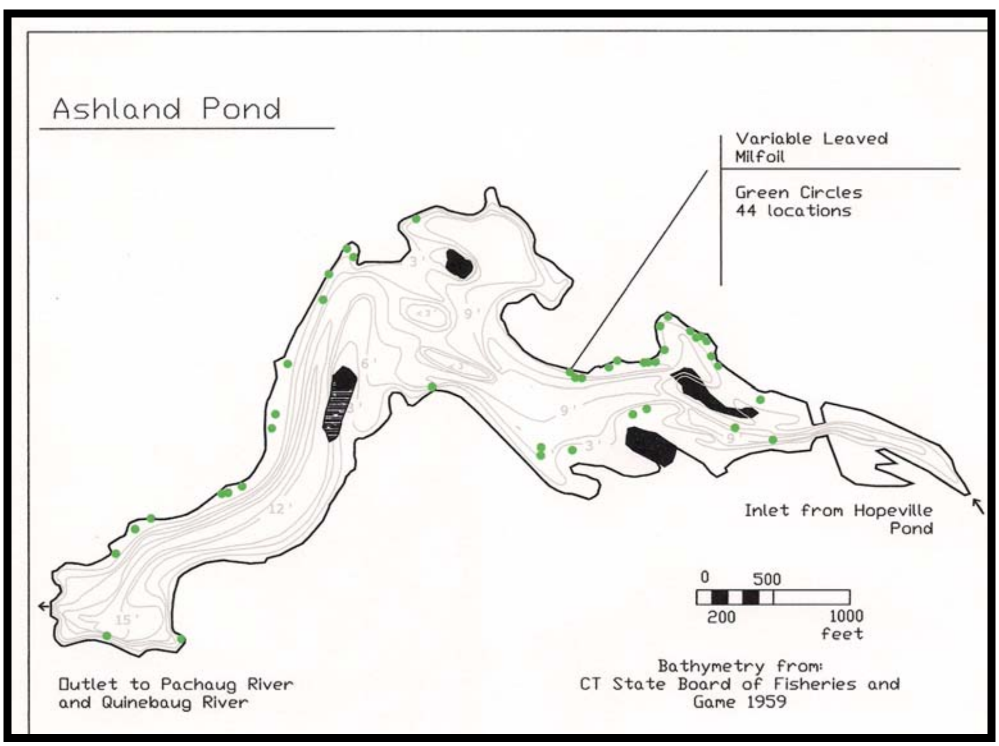
The distribution of fanwort in Ashland Pond is shown in **Map 21**. This map also shows the coverage by floating leaved plants. The area of dense fanwort in Ashland Pond was about 22 acres. Adding to this the 9 acres where floating leaved plants were dominant, increases fanwort in Ashland Pond to about 31 acres. Most of the dense fanwort was found in the eastern section of the pond. Towards the west, with deeper water fanwort was less pronounced.

Map 21 - Ashland Pond Distribution of Fanwort and Floating-leaf Plants



The distribution of the variable-laved milfoil in Ashland Pond is shown in **Map 22**. No Eurasian milfoil was found in Ashland Pond.

Map 22 – Ashland Pond Variable-leaved Milfoil Distribution



Conclusions

The aquatic plant surveys of Glasgo Pond, Pachaug Pond, Hopeville Pond, and Ashland Pond were conducted during the summer 2009. Each is an impoundment of the Pachaug River in the Town of Griswold, Connecticut. The Pachaug River has a large watershed that includes 22,000 acres east in the Town of Voluntown and nearly 1,000 acres in Rhode Island.

The distribution and abundance of four non-native invasive aquatic plants were documented in the ponds, fanwort (Cabomba caroliniana), variable-leaved milfoil (Myriophyllum heterophyllum), Eurasian milfoil (Myriophyllum spicatum), and minor naiad (Najas minor). Fanwort was the most common invasive plant in each of the ponds, followed by variable-leaf milfoil, Eurasian milfoil, and minor naiad, see **Table 13**.

Table 13 - Proliferation of Invasive Species in Griswold Ponds

Pond	Fanwort	V. Milfoil	E. Milfoil	M. Naiad
Glasgo	10 acres	32 points	8 acres	0
Pachaug	127 acres	38 acres	12 acres	47 points
Hopeville	122 acres	25 points	4 points	2 points
Ashland	31 acres	44 points	0	0

The total estimated coverage of fanwort in the four ponds is 240 acres. The extent of fanwort proliferation in Hopeville and Ashland Pond is massive, with about 50% of Hopeville Pond, and 30% of Ashland Pond, infested with dense beds that reach the surface out to about 7 feet deep, and volumetrically fill the water column out to about 8 or 9 feet deep. In Pachaug Pond, fanwort covers about 127 acres now, having spread mostly in the coves and in the bay at the southeast end of the lake. Fanwort was uncommon to scarce along the shore of open water sections of the lake. Glasgo Pond has the smallest infestation of fanwort with coverage of about 10 acres, principally along the southern shore.

There are at least four other ponds within the Pachaug River drainage basin upriver of the surveyed ponds. These are, in order of size, Beach Pond 372 acres, Billings Pond 97.4 acres, Anderson Pond 56.6 acres, Beachdale Pond 46 acres, and Hodge Pond 8 acres. Beach Pond and Beachdale Pond both drain to Glasgo Pond via Doaneville Pond. No invasive aquatic plants were found in Beach Pond by the CT Agricultural Experiment Station (CAES) in a survey performed in 2008. Beachdale Pond has not been surveyed yet. Billings Pond and Anderson Pond both independently drain to the southern end of Pachaug Pond. Fanwort and Variable-leaf milfoil were found in both ponds by CAES, Anderson in 2004 and Billings in 2005. Hodge Pond drains to Glasgo Pond via Southeast Marsh. Hodge Pond has not been surveyed yet. However, the distribution of invasive aquatic plants in Glasgo Pond suggests that Hodge Pond is also infested with invasive aquatic plants.

Historically, the Town of Griswold has attempted to control the aquatic vegetation in Pachaug and Glasgo Ponds with winter water level drawdown. However, three obstacles prevent this method from having complete success,

1. each of the lakes have very rapid flushing rates, especially during the winter months when control of the water level at a target depth is necessary,
2. target plants grow to deeper depths than feasible drawdown levels.
3. sheltered coves in Pachaug Pond are apparently immune to affects of water level drawdown.

Each pond has a high flushing rate meaning that the volume of inflow water is very much larger than the volume of water contained in the lake. The flushing rate is the time it takes new water flowing in from the river to replace all the water in the lake. Pachaug Pond has the longest flushing rate of almost once per month. The other three ponds have flushing rates of less than a week (**Table 13**).

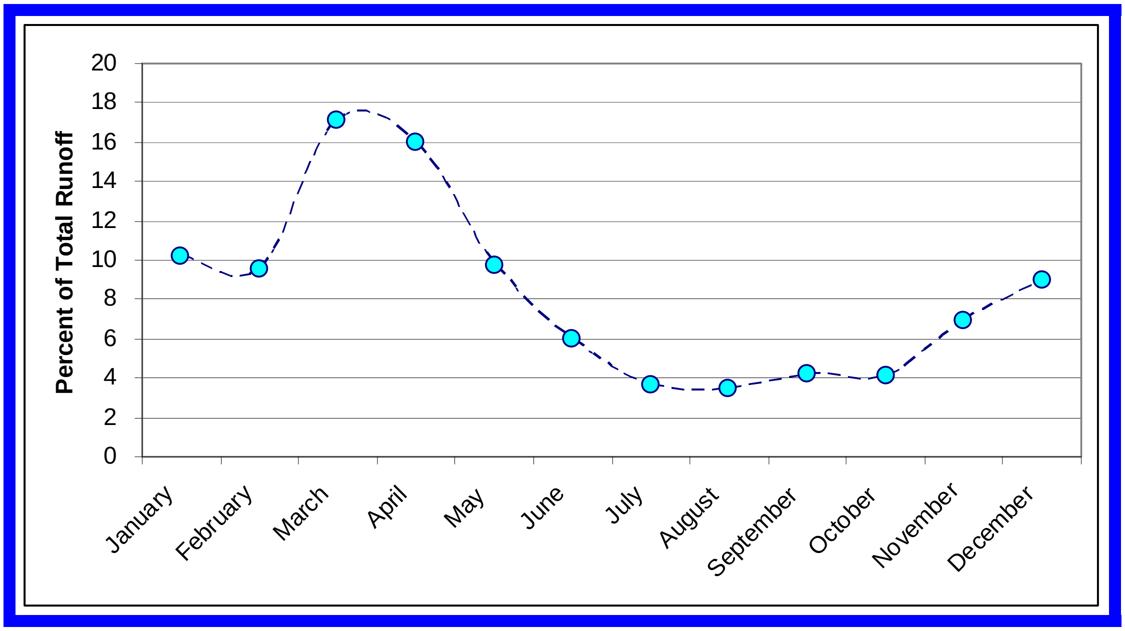
Figure 13 - Water Replacement Data for Griswold Ponds

	Drainage Area (acres)	Annual Inflow Volume (acre-feet)	Pond Volume (acre-feet)	Flushing Rate (days)	Winter inflow rate (acre-feet/mon) Dec-Feb
Glasgo Pond	23,604	46,421	664	4.3	4,640
Pachaug Pond	33,920	66,709	4,616	24.2	6,670
Hopeville Pond	37,824	74,387	759	3.7	7,440
Ashland Pond	39,065	76,828	664	3.2	7,680

A large fraction of river inflow water occurs during the winter months of December, January, and February, when the ponds can receive 30% of the total annual flow

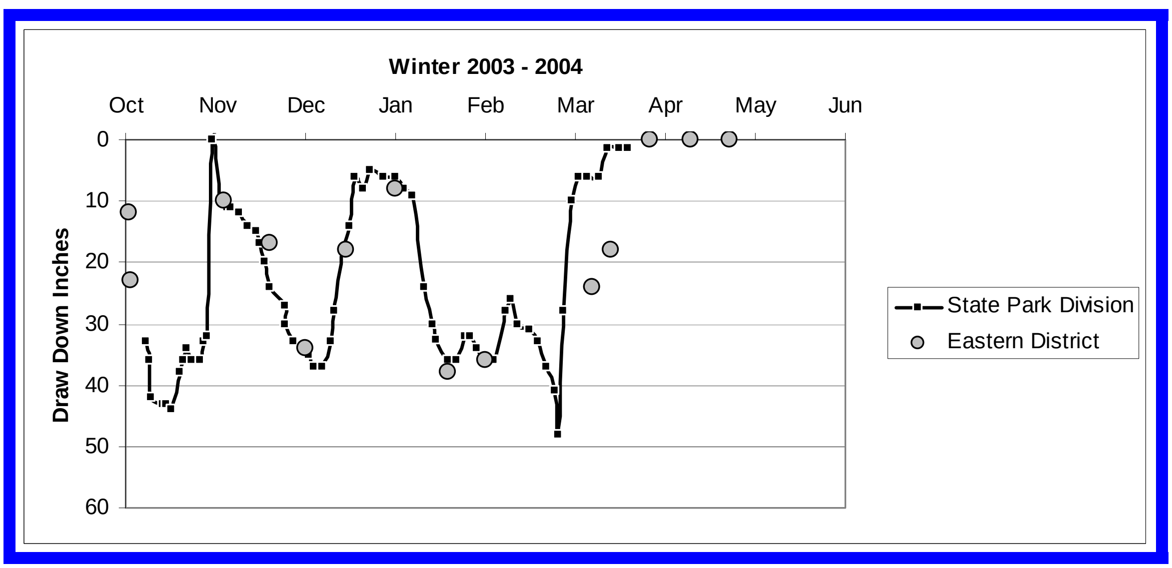
(**Figure 14**). This means that it is difficult to keep the water level at the target drawdown elevation during the winter.

Figure 14 - Estimated Annual Monthly Runoff to Griswold Ponds



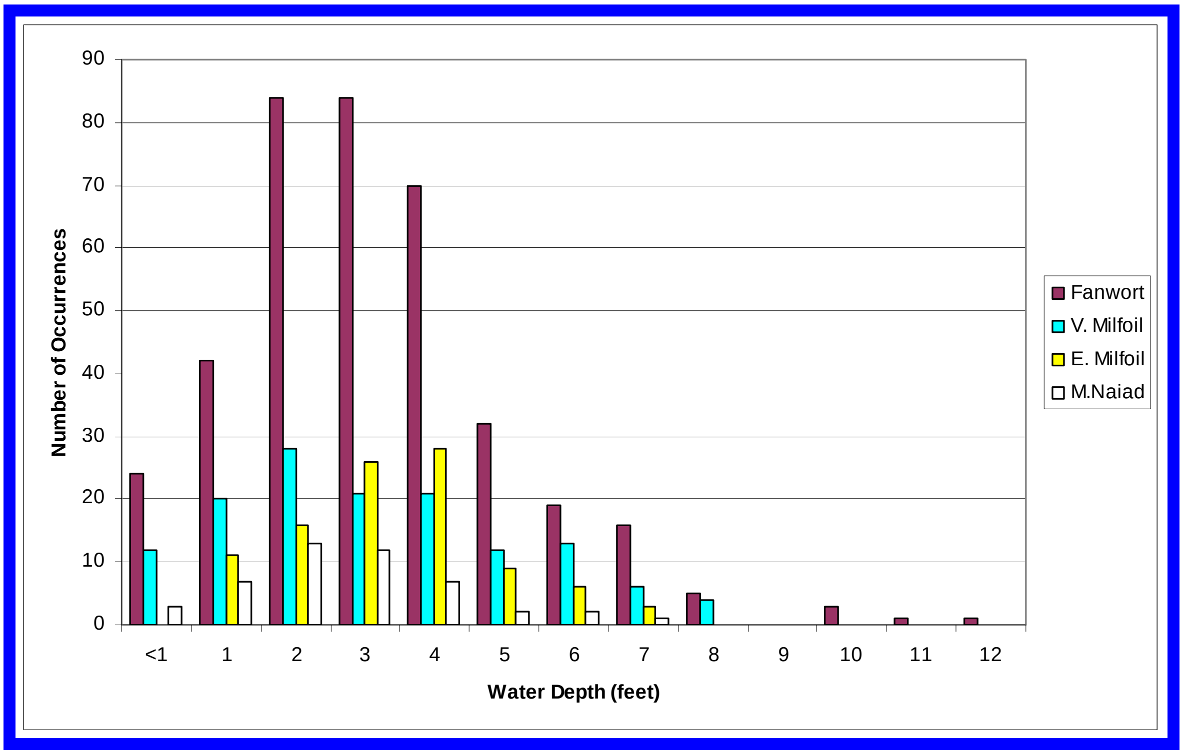
It is possible for individual rain events to fill the Pachaug Pond within a day or a few days during a winter drawdown. Water level data collected during the drawdown of Pachaug Pond during the winter of 2003 – 2004 shows three rain events that refilled the pond within days **Figure 15**.

Figure 15 - Water Level of Pachaug Pond October 2003 - March 2004



Each of the four invasive species were growing in water deeper than 3 feet. Fanwort was most frequent between 2 and 4 feet of water, but grew prolifically out to 6 and 7 feet of water. Variable-leaf milfoil was most common at 2 feet of water depth, but was found frequently out to 6 feet of water. Eurasian milfoil was most common at 4 feet of water depth, but was present at low frequency to 7 feet. Minor naiad was most common at 2 to 3 feet of water, but was found to 7 feet (**Figure 16**).

Figure 16 - Pooled number of occurrences at each 1 foot of depth of four invasive aquatic plants using data from all four ponds



These data indicate a 3 foot drawdown may be restricting growth in water shallower than 3 feet, but each of the four invasive plants has been unaffected in water deeper than 3 feet. The best a 3-foot drawdown can accomplish is to retard growth of invasive plants between 0 to 3 feet of water depth, and probably only along the open water areas of each pond. Plants growing in the small sheltered coves in Pachaug Pond have shown no control from drawdowns occurs since the survey conducted in 2004. Fanwort and variable-leaf milfoil growth in these coves is not restricted from growing in shallower water, right to the waterline along the shore. This suggests that aspects of the coves limit the effectiveness of the drawdown. Four possible reasons why drawdown does not decrease plant growth in the coves are:

1. reduced dewatering because coves provide focusing of surface and groundwater inflows.
2. sediments are predominantly thick layers of dead plant material concentrated by the high plant growths and drift accumulation from the main lake.
3. central deeper water provides refuge for invasive species during the drawdown from which roots can quick re-colonize the exposed area after refill.
4. shallow lip at the entrance to the cove precludes dewatering.

Comparing mapping from 2004, 2008, and 2009 at Pachaug Pond, colonies of fanwort in these coves not only appear to be unaffected by drawdown but are actually expanding outward from the coves covering more area each year. Variable-leaf milfoil does not appear to be expanding outward but instead seems to have remained unchanged between 2008 and 2009.

Mapping data collected during the surveys of Pachaug Pond suggest that a 3 foot drawdown provides some control of fanwort and variable milfoil along the shoreline of open water areas of the lake, but not in the secluded coves. It is likely that similar results would be realized at Hopeville Pond or Ashland Pond if those were drawn down only 3 feet. Attempting deeper drawdowns increases the likelihood of causing drawdown related negative impacts.

Drawdown has negative side affects regardless of whether the target plants are impacted. Performing a drawdown at any of the four lakes may cause other deleterious affects each time it is used. Some of the impacts include,

7. Erosion of exposed lake bed during rain events,
8. Impacts to shoreline wetland vegetation due to desiccation,
9. Impacts to fish spawning areas,
10. Impacts to a wide range of aquatic animals,
11. Increased re-cycling of nutrients,
12. Increased loss of oxygen in deep water during the summer.

During the winter under-ice water quality conditions may be impacted due to the shallow nature of each. At Hopeville Pond a deeper drawdown, say 6 feet, would essentially leave a very narrow trough running through the center of the pond, a river under the ice. It is also possible a 6-foot drawdown at Hopeville would isolate the two basins at the culvert under Bitgood Road.

It was not part of this study to assess if either Pachaug Pond or Glasgo Pond is being impacted by semi-regular drawdown conducted at these ponds.

Few methods are affective against fanwort. Drawdown has been discussed and although it may have some positive control in Pachaug it is of only limited, perhaps preventative only, with no information about negative impacts. In addition, drawdown has not provided any control of fanwort in the sheltered coves. The coves of Pachaug have been completely choked with vegetation, often not only fanwort and variable-leaf milfoil, but also several of the natives including most of the floating leaved plants. These coves have been so completed weed bound that boat access is virtually impossible. Clearly, other methods are needed at the ponds to control aquatic plants.

The other methods known to provide affective control over fanwort include,

1. Dredging,
2. Screens,
3. Chemical Treatments, and,
4. Hand Harvesting using Suction Harvesting.

<u>Dredging</u>

Removing nutrient rich sediments and deepening water bodies is sometimes used to control nuisance aquatic vegetation. This shall be a major undertaking at any of the Griswold Ponds, when considering both the associated permitting issues and project expense. The dredging of large portions of Griswold Ponds is unlikely to provide much benefit, especially against plants like fanwort and milfoil that naturally require a small amount of nutrients and can grow fairly well in a minimum layer of soft sediment. If any dredging were to be considered, it would likely be localized in the cove areas of the ponds. Deepening of these areas would provide improved water flow and, if partitioned off in some fashion, may provide improved removal of suspended solids and nutrients. A more extensive drawdown could allow for dry-dredging selected shoreline and other shallow areas providing that the proper permits have been obtained.

Dredging as a weed control alterative works best when the water depth can be increased past the photic depth, that is the water is made deeper than the maximum depth that plants can grow. This would mean removal of sediments so that the water depth becomes greater than 8 to 9 feet in most cases. However, the maximum depth can usually only be realized in the center of a cone leaving the shoreline sediments shallow enough to support plants.

Dredging the sediments in the coves may provide a secondary benefit by removing accumulated organic matter, slowing down the rate of plant growth. It may be that dredging in the coves could be used together with other methods such as herbicides or bottom barriers. However, it is possible that dredging has occurred in some of the coves of Pachaug Pond in the past since as evidenced by deeper water in the coves. One reason why drawdown has not proved affective in the coves may be that the deep water offers a refuge for the invasive species to escape the impact of drawdown. Further dredging may only increase this condition.

<u>Screening or Bottom Barriers</u>

Bottom weed barriers are only beneficial for small applications around beach, swim or dock areas. Larger scale applications become cost prohibitive (>$25,000 per acre for material alone) and would prevent necessary interactions with the bottom sediments by benthic macroinvertebrates and other aquatic organisms. Individual lakefront owners may want to consider bottom barriers, but their widespread use is not recommended at Griswold Ponds. Bottom barriers may be the only feasible approach in the short term for home owners in the weed choked coves. Lanes of barrier could be installed to make access ways for boats to get from shore to the open water.

There are several types of weed barrier available for use. The two most common types are a PVC coated screening (Aquascreen) and a more traditional non-pourous PVC sheeting. Small apertures in the material allow for benthic gases to escape through the material and prevent billowing. Unit costs for the screening barrier type can be nearly twice the cost of traditional screening, which is in the range of $0.40-0.60 per square foot. Installation typically involves laying and weighing down the material. Deeper applications may require trained divers to install. Installation, if performed by profession can add 33-50% to the material cost.

Some benefits of bottom barrier applications include,

1. Very site specific, only the areas to be controlled
2. Usually out of sight so causes no surface water disturbance,
3. Usually easy to install, and can be moved to new locations within one season,
4. No physical impacts or chemical introduction

Disadvantages of bottom barriers include,

1. High cost limits large scale use, also covering large areas are not feasible,
2. The material requires maintenance, left alone it will quickly be buried,
3. Difficult to apply where the bottom slopes,
4. Generally ineffective if substrate has large rocks and boulders, and
5. Fanwort and milfoil have shown ability to grow on top of bottom barrier.

Chemical Treatments

Herbicides often provide for area and species selective plant control. Typically, a late spring or early summer treatment will provide season long control of the nuisance vegetation. With systemic herbicides like 2,4-D (Navigate) and fluridone (Sonar) two or more years of good plant control are typical. Contact herbicides such as diquat (Reward) and endothall (Aquathol-K) provide effective seasonal control. Plant regrowth in subsequent seasons is often reduced, allowing reductions in the frequency and amounts of chemical required. None of the currently registered products have any restrictions on swimming in treated waters, but prudent practice calls for closure of the treated area on the day of treatment. In most cases, the temporary water use restrictions following a treatment are associated with the use of treated water for irrigation or domestic purposes. Most of the herbicides are either rapidly broken down or irreversibly bound to the sediment, becoming biologically inactivated within a matter of days.

At the present time only one herbicide, Fluridone is affective against fanwort, and only at a high dose. Although Fluridone controls fanwort it needs to be applied as liquid to the entire lake at one time, and the herbicide needs to have an extended contact time with the plant for it to be affective. This requires special precautions to keep the herbicide in the lake at the required dose for at least 40 days. This would involve controlling the water level, and bumping up the dose periodically during the treatment to maintain the proper chemical level in the water. However, because of the rapid flushing rates of each pond maintaining the required high dose of Fluridone in the water of any of the four ponds will be challenging.

Hand Harvesting

Hand-pulling works best on small-localized infestations of weeds, thereby limiting its use to the small coves in Pachaug Pond, however the usefulness of hand-pulling may increase as other management techniques begin to reduce the size and severity of nuisance infestations. Hand-harvesting is usually the first round of defense against pioneering infestations of new non-native weeds, however at this time each of the four invasive species in the ponds has become wide spread and established.

Suction harvesting has become more of an acceptable plant control method in recent years. This method employs a team of divers/harvesters that remove plants via a suction venturi hose. This method is probably the most selective of all the applications but is also the most labor intensive.

The rate of removal of the target plant is based on several factors,

1. the density of the plants,
2. How many other species coexist with the target species,
3. The clarity or turbidity of the water,
4. The water depth the plants are growing in,
5. How deep the roots grow,
6. The kind of sediments the plants are growing in.

Need for a comprehensive approach

Because the four ponds are connected by the Pachaug River, activities conducted at one are likely to affect each of the downstream ponds. This applies equally to the likelihood of continued re-infestation from plants coming from upstream ponds. This study suggested that ponds upstream of Glasgo Pond and Pachaug Pond are possibly infested with fanwort and milfoil. This begs the question of the efficacy of long-term control in the Griswold ponds if sources upstream go untreated. To realize any extended management of the invasive plants in any of the ponds means that management should start with the upstream, headwater ponds and work downstream. This may not be practical in the short term for homeowners in Pachaug Pond that have no boating access to open water. Nor does this approach stem the current advance of the invasive plants or alleviate the excessively dense stands of fanwort that choke large areas of Hopeville and Ashland Ponds.

In addition to these factors, any management approach undertaken at either Hopeville or Ashland Ponds will need to consider possible impact to the Banded Sunfish. This fish is threatened in Connecticut so is protected by the Endangered Species Act.

Suggested Approach

13. Form an ad hoc committee to manage the aquatic plant control measures at the four ponds. The committee should include members from the Town of Griswold the Town of Voluntown and residents from each of the four ponds in Griswold and the upstream ponds in both towns. The committee through regular meetings would assist in the management of each of the ponds in the Pachaug River drainage basin, specifically according to the following tasks.
14. Institute regular annual aquatic plant surveys at each of the four ponds.
15. Conduct aquatic plant surveys of each of the upstream ponds not investigated during this study.
16. Submit requests to the DEP for winter water level drawdowns as needed.
17. Regularly review survey results to assess success of drawdown.
18. Begin investigations to determine if drawdown is having negative impacts to the ponds were it is used.
19. Identify specific areas of each pond where invasive aquatic plant present the greatest nuisance. Prioritize these areas for application of alternate methods to control invasives.
20. Alternate methods that appear to offer the best chance of success include
    a. Herbicides – Fluridone pellets and 2-4D
    b. Suction Harvesting
    c. Bottom barrier
    d. Milfoil weevil (Eurasian milfoil only)
21. Develop a long-range management plan prioritizing treatment management areas within each pond.
22. Set up a schedule for using alternate methods at each of the prioritized areas.
23. Track success of drawdown and any alternate methods used to control invasives.
24. Annually review the management plan for the upcoming year.