Final Technical Report

Mill Pond Bathymetric Survey and Sediment Sampling Study

Durham, New Hampshire

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Durham Mill Pond Bathymetry and Sediment Sampling Study

Introduction

This Report presents the findings of a bathymetric survey and sediment sampling study conducted on the Mill Pond located in Durham, New Hampshire. This study was funded through a Technical Assistance Grant provided by National Oceanographic and Atmospheric Administration (NOAA) and administered by the New Hampshire Department of Environmental Services (NHDES) Coastal Program. The general purpose of this study was to provide additional data to the Town of Durham officials and other interested stakeholders regarding the existing water depths and the physical and chemical nature of the bottom sediments within the pond. This information would then be used to assess how conditions in and around the pond may change if the dam was to be removed, especially with respect to vegetation and bottom sediments. The principal tasks of this study as outlined in the Grant Funding and Work Agreement with the Town of Durham include the following:

- Establish topographic survey controls and lay out various transects within the impoundment to enable the bathymetric data to be tied into elevation data.
- Perform sediment core sampling of the bottom sediments to determine sediment thickness in various locations and collect samples for screening of potential contaminants.
- Perform analytical testing on suspected screened sediment samples.
- Based on topographic data, estimate potential restored limits of Oyster River channel, floodplain and the new head of tide line and extent of tidal prism if the dam was to be removed.
- Estimate the potential community response of the dewatered impoundment based on the bathymetric survey data and estimated level of tidal influence.

The work tasks of this study were completed through a combined effort between Vanasse Hangen Brustlin, Inc. (VHB) of Bedford, New Hampshire and HYDROTERRA Environmental Services LLC (HYDROTERRA) of Dover, New Hampshire. Other studies related to the dam are being conducted separately by others including an assessment of its structural integrity, which is being conducted by Stephens Associates, an engineering firm located in Brentwood, New Hampshire with assistance from University of New Hampshire (UNH) faculty engineers under a separate work agreement with the Town of Durham.

Mill Pond and Dam Description

The Mill Pond represents an impoundment within the Oyster River that is created by the existence of the Mill Pond Dam, which is sometimes referred to as the Oyster River Dam (See Figure 1 - Site Locus Map). The pond itself (i.e., including ±1000 feet of the impounded river channel upstream of the Pond) is estimated to be approximately 9.5 acres in size. The pond is relatively shallow with nearly half of the pond having less than 3 feet of water as discussed in greater detail below. The backwater effect of the dam extends approximately 3,700 feet up the Oyster River channel from the point where the river enters the pond.

The Mill Pond Dam is currently owned and operated by the Town of Durham. It is understood that the Town is currently evaluating its options to decide their best course of action in terms of whether to repair and possibly upgrade the dam or remove the dam to address several structural deficiencies that were identified during recent inspections conducted by both the NHDES Dam Bureau and Stephens Associates (independent engineering firm hired by the Town of Durham). The NHDES Dam Bureau most recently inspected the dam in April 2008 and has issued two separate Letters of Deficiencies to the Town of Durham, requesting that certain items be addressed. The issues surrounding the structural deficiencies are discussed in greater detail in the Dam Evaluation Report prepared by Stephens Associates in March 2009. It was not within the scope of this study, to evaluate the pros and cons of removing versus repairing and maintaining the dam.

The dam has a spillway length of 101.1 feet and a maximum height of approximately 10 feet. In recent years, the dam has experienced two major flooding events during May of 2006 and April 2007. During these two events, both of which were considered to be close to 100-year storm events, floodwaters overtopped the abutment walls, especially along the right abutment, flowing around the dam and causing serious erosion along the channel banks.

The dam location represents the head of tide limits where during periods of high tide, tidal waters will reach several feet above the downstream toe of dam elevation but during periods of low tide, generally only the water that spills over the dam is within the downstream channel. There is minimal, if any, intrusion of tidal waters upstream of the dam, expect perhaps if the low flow gates at the base of the dam are open during high tide conditions. Typically, the bottom gates are left closed.

Methodology

Ground Controls and Transect Layout

VHB conducted a limited topographic survey at specific locations around the pond to establish ground survey controls and transect locations and determine elevations of certain structural features associated with the dam. These elevations would be used to determine the bottom or substrate elevations throughout the pond based on subsequent water depth measurements or soundings as described below. The topographic elevation data was based on the US Geological Survey benchmark reference elevation implanted in a disk within a large boulder located at the intersection of Newmarket Road (Route 108) and Durham Point Road, approximately 0.5 mile south of the dam. As part of this survey, six horizontal transects were established in and around the pond using both horizontal (i.e., state plane coordinates) and vertical (i.e., elevation) data. Five transects were located upstream of the dam and one was located downstream of the dam. The US Geological Survey benchmark elevation is in 1929 NVGD datum. For purposes of this study, the elevation data collected in the field was converted to the more recent 1988 NAVD datum, which is 0.73feet lower than the 1929 NVGD datum.

In performing the transect layout, additional elevation data was recorded for various structural features associated with the dam. This includes the elevation of the dam spillway, the highest points on the left and right side abutments and any observed staining or marks indicating high water flood levels or high tide levels.

Bathymetric Survey

The bathymetric survey of the Oyster River impoundment was conducted by HYDROTERRA during October and November 2009. The survey was completed using several of HYDROTERRA's small survey boats to allow access to shallow draft and limited areas of the Study Area. The survey boats were equipped with recording fathometers, hand sounding probes, a Differential Global Positioning System (DGPS) and an onboard computer with hydrographic surveying software. The fathometers were calibrated using hand soundings with a metal striker plate. The onboard hydrographic surveying computer software was used to collect and log real time depth, boat speed, bearing and positioning data at 1 second intervals.

The bathymetric data was collected by traversing over six transects across the width of the impoundment and several length-wise transects (approximately 4,520 feet) taking readings at intervals of 25 to 50 feet. HYDROTERRA's survey followed the Army Corps of Engineers (ACOE) Engineering and Design - Hydrographic Surveying Guidance Document ACOE (EM-1110-2-1003) (Chapter 17, River Engineering Hydraulic and Channel Stabilization Surveys.)

Sounding data was adjusted to the appropriate vertical elevation datum established by VHB (for upstream of the Dam, control point was VHB Transect 5 North control monuments; for downstream the elevation control point was VHB Transect 1 North monuments). Positioning data was reduced to New Hampshire State Plane System (ft) (1983) and Geodetic Latitudes and Longitudes (WGS 1984).

Sediment Thickness Profiling and Sampling

To provide information regarding sediment thicknesses, HYDROTERRA conducted soft sediment probing within the impoundment area. Using steel rods with 3" diameter metal plate attached to the bottom, HYDROTERRA probed the thickness of the soft sediment to provide more information of the volume of sediment within the impoundment. A total of 32 probes were completed at various locations within the impoundment. The locations of the probes are shown on the Site Plan. At each probe location, DGPS positioning, water depth, sediment thickness, and sediment characteristic observations from the probe tip were logged.

Sediment Sampling

HYDROTERRA collected sediment core samples at twelve (12) locations. Eleven (11) sample locations were within the upstream impoundment area and one sampling location was located downstream of the dam. The sediment sampling locations are shown on the Site Plan. The sampling boat was equipped with DGPS, and an onboard computer with surveying software to log real time depth, positioning and sediment characteristic observations. The 2-inch diameter core samples were collected to depths between 3 to 5 feet below the river bottom. Cores were advanced using a hand driven weight drop. All sampling activities were overseen by a HYDROTERRA New Hampshire certified geologist to field classify the sediments and to field screen for evidence of contamination. In addition to visual classification, sediment samples were screened for total ionizable volatile organic vapors using a Photovac MicroTip HL-2000 photoionization detector (PID) equipped with a 10.6 eV lamp. Sediment samples were preserved with appropriate preservatives and stored on ice until submitted to a New Hampshire certified laboratory for analyses of:

1. PCB/ Pesticides;
2. RCRA Metals;
3. Polynuclear Aromatic Hydrocarbons (PAHs) (8270);
4. Volatile Organic Compounds (VOCs) (8260); and
5. Grain Size Analysis

Existing Vegetation Inventory

VHB environmental scientists conducted an inventory of the existing vegetation around the pond on December 2, 2009. This inventory was conducted to document the existing native located in and around the pond as a means to assess the potential vegetation response that might result if the pond was dewatered and to identify any invasive plant species in the area that may need to be eradicated, controlled and/ or monitored as part of any future river channel restoration effort. The limits of the vegetation inventory extended from approximately 1,000 feet upstream of the pond to a point approximately 300 feet downstream of the pond.

Results

Existing Pond Conditions

Bathymetric Survey

The bathymetric survey revealed that much of the pond is relatively shallow and the river channel predominantly runs through the center of the pond. On either side of channel are broad shallow areas that extend to shoreline (See Figure 2 –Existing Base Conditions). The water surface elevation during the survey was 11.4 feet (NAVD88) with approximately 4 inches of water flowing over the dam spillway. The entire pond area consists of approximately 9.5 acres of area including approximately 1,000 feet of the river channel upstream of the pond.

For much of the pond area outside of the main channel, the bottom elevations generally range between 6 feet and 11 feet (NAVD88), which translates to water depths of roughly 0 to 5 feet. The northern half of the pond (i.e., closer to Mill Pond Road) is relatively shallower, with bottom elevations generally ranging between 8 feet and 10 feet (NAVD88). This area has generally less than 3 feet of water and the pond bottom is relatively flat with minimal variation in topography. Just east of the upland peninsula that extends out from Mill Pond Road, there is small depression area having a bottom elevation of 4 feet. Closer to the main river channel, a broad shallow area exists with bottom elevations of mainly 9 feet to 10 feet and water depths of 1 foot to 2 feet. This area is vegetated with various wetland shrub species (see Existing Vegetation Survey). It is suspected that this is a depositional area from sediments that have historically scoured out from the main channel during high flow events. Slightly upstream and within the main river channel, the bathymetric data indicates a relatively deep pool with a maximum water depth of approximately 15 to 18 feet and bottom elevations of -6 to -7 feet in elevation (NAVD88).

The main river channel winds through the center of the pond that is more or less confined to elevations of 6 feet or less and in some locations the top of bank elevations extend up to 8 feet and 9 feet (NAVD88) before it flattens out into the adjacent shallower areas. The channel banks are relatively steep as can be seen in photos that were taken when the pond was recently drawn down in September 2008 and in November 2009 to allow for dam inspections (see Photos in Appendix A). The bathymetry data indicates that there is a high point in the main river channel with an approximate bottom elevation of 5.8 feet located essentially in the center of the pond in between two deeper channel pool areas that are located near where the river enters the pond and then just upstream of the dam.

Flow conditions within the Oyster River during the survey period were close to the average daily flow for this time of year based on historical stream gage data. The average daily flow recorded at the USGS stream gauge station on the Oyster River located approximately 3.0 miles upstream of the dam indicates that the average daily flow during October and November was estimated to be 8.3 and 18.0 cubic feet per second (cfs), respectively, based on 73 years of records. During the two survey dates of October 22 and November 24, the estimated daily flow recorded at the upstream station was 5.7 cfs and 17.0 cfs, respectively, which is near average flow conditions.

Sediment Probes

As shown on Table 1.0, the majority of the sediment within the impoundment is classified as Silt / Clayey Silt with silt sized particles comprising more than 80 % of the sediment material. Within the main river channel, the bottom sediment was found to have a higher percentage of sand and was classified as Sandy Silt.

In the near shore areas, particularly for the probes P17, P18 and P20, the sediment contained a much higher degree of organic matter, including shell remnants and typically had a blackish appearance indicative of a low oxygen environment. The oxygen is consumed or reduced due to the biodegradation of organic matter. The source of the organic matter can include leaf litter, plant material during seasonal die-off and that contributed from stormwater runoff. The deeper sediments typically had a more gray to olive color appearance typical of marine clay deposits.

Table 1.0 – Sediment Probe Depth and Sediment Descriptions

Sediment Probe ID	Soft Sediment Thickness (ft)	Sediment Description
P 1	2.0	Grey Clayey Silt
P 2	2.2	Grey Clayey Silt
P-3	2.1	Grey Clayey Silt
P-4	2.8	Grey Clayey Silt
P 5	1.6	Grey Fine Sand
P 6	2.0	Grey Black Silt
P 7	1.8	Grey Black Silt
P 8	1.0	Grey Fine Sand
P 9	1.8	Grey Black Silt
P 10	3.8	Grey Black Silt
P 11	1.0	Grey Fine Sand
P 12	4.0	Black Silt Organics
P 13	1.7	Black Silt Organics
P 14	1.2	Grey Silt

Sediment Probe ID	Soft Sediment Thickness (ft)	Sediment Description
P 15	3.1	Black Silt
P 16	0.6	Grey Gravelly Sand
P 17	1.3	Grey Black Silt Organics
P 18	2.1	Black Silt Organics
P 19	2.5	Grey Black Silt
P 20	2.1	Black Silt Organics
P 21	1.3	Grey Fine Sand
P 22	2.0	Grey Black Silt
P 23	2.0	Black Silt
P 24	1.5	Silty Sand
P 25	2.0	Silty Sand
P 26	1.4	Silty Sand
P 27	2.0	Grey Black Silt
P 28	1.2	Grey Black Silt
P 29	1.5	Silty Sand
P 30	1.2	Silty Sand
P 31	2.0	Grey Black Silt
P 32	2.0	Grey Black Silt

Sediment Sampling

Sediment samples were collected at 12 locations in the Study Area. The locations of these samples are shown on the Figure 2- Existing Base Conditions. Sample photos, PID readings, geologic descriptions and grain size analysis for each sample location are included in Appendix B. Sediment sample (Sed-1) is located well upstream of the impoundment within the main channel and upstream of the College Brook confluence. Sediment samples (Sed-2, 3, 5, 6 and 11) are located outside of the main channel in the shallower areas within the northern half of the pond. Sediment samples (Sed-4 and 10) are located in the shallower areas of the southern half of pond. Sediment samples (Sed-7, 8 and 9) are located in the main channel just upstream of the dam. Sediment sample (Sed-12) is located downstream of the dam and represents a composite sample of bottom sediments along Transect 1. Except for Sed-12, the sampling depth typically ranged from 0 to 4 feet below river bottom with the sediment sample cores generally penetrating through the soft sediment and into the more stiff silty clay material below. For Sed-12, the sample represents a composite of the bottom sediments in the upper 6 to 12 inches along the width of the channel. Two field duplicates were collected at sediment sample locations Sed-10 and Sed-11.

Table 2.0 summarizes the analytical results of the sediment sampling. The analytical results indicate that none of the samples had any detectable levels of Volatile Organic

Compounds (VOCs), pesticides or polychlorinated biphenyls (PCBs) based on the laboratory reported detection limits. Several samples did, however, have levels of various Polynuclear Aromatic Hydrocarbons (PAH's) that were above the selected Ecological Screening Level Criteria (ESCL). The selected ESLC for this study represents the lowest reported Probable Effects Level (PEL) above which adverse effects are considered probable based on the NOAA 1999 Screening Quick Reference Tables. Six of the twelve sediment samples had at least one PAH compound that was above the reported PEL. Sediment sample (Sed-4), collected in the shallow areas of the southern half of the pond, had five different PAH compounds that were above their respective PELs. Sediment sample (Sed-4) also had the highest overall PAH concentrations relative to the other sediment samples. These analytical results do not necessarily mean that aquatic life species area currently being adversely affected by the detected levels. The potential for impacts on aquatic life depends on the exact location of the material within the sediment, whether the sensitive aquatic species for which the thresholds are based on exist within the pond and whether these species are in contact with the affected sediments and the relative potential for the sediments to be mobilized. Additional detailed sampling would be required to conduct a more complete assessment of the potential risks to aquatic life.

With respect to the other compounds analyzed, several heavy metals including arsenic, cadmium, chromium, lead, and mercury were also detected in various sediment samples above the reported Ecological Screening Level Criteria. Unlike the PAHs, the detected metal concentrations in sediment were not distinctly higher in any particular location versus another. There were no distinct differences in the results for sediment samples collected upstream of the pond, within the river channel as compared to outside the river channel and just upstream of the dam versus downstream of the dam. This appears particularly true for arsenic and mercury, which were some of the two most common metals detected. Arsenic has been found to be naturally abundant in the sediment and bedrock within New Hampshire. The mercury is predominantly contributed from atmospheric deposition associated with the stack emissions from major coal-fired power plants located mostly in the Midwest States. Again, a much more detailed sediment and laboratory analysis would be required to more fully understand if the concentrations found in the pond bottom sediment pose a potential risk to aquatic life.

TABLE 2.0 SEDIMENT SAMPLING ANALYTICAL RESULTS - MILL POND/OYSTER RIVER - DURHAM, NEW HAMPSHIRE

SAMPLE ANALYSIS COMPOUND	SED1 0'-4' 10/30/09	SED2 0'-4' 10/30/09	SED3 0'-4' 10/30/09	SED4 0'-4' 10/30/09	SED5 0'-2' 10/30/09	SED6 0'-2' 10/30/09	SED7 0'-3' 10/30/09	SED8 0'-2.5' 10/30/09	SED9 0'-1.5' 10/30/09	SED10a 0'-1.5' 11/01/09	SED10b 0'-1.5' 11/01/09 DUP	SED11a 0'-3' 11/01/09	SED11b 0'-3' 11/01/09 DUP	SED12 0'-1.5' 11/01/09 COMP	FreshWater ARCS PEL (5)	Freshwater Ecosystems TECs (6)	Marine Ecotox ERL (5)
SIEVE - GRAIN DESCRIPTION	1% G, 54% S, 45%S/C	0% G 13% S 87%S/C	0.2% G 43% S 57%S/C	0% G 10% S 90%S/C	NA	0% G 3% S 97%S/C	(0-2') 0.7% G 29% S 70%S/C (2-3') 0.5% G 22% S 77%S/C	1% G 24% S 75%S/C	0.5% G 12% S 88%S/C	0.1 % G 39% S 69%S/C	NA	0 % G 10 % S 90%S/C	NA	35 % G 30 % S 35%S/C	--	--	--
DETECTED VOCS (Method 8260B)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND	ND	ND	--	--	--
DETECTED PAHs (Method 8270C) (ug/Kg)	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Phenanthrene	< 640	**847**	**463**	**1100**	<800	<1000	**463**	**623**	<860	**630**	**508**	<670	<680	<990	515	204	240
Fluoranthene	<640	**1530**	**774**	2210	<800	**1220**	**774**	**1090**	<860	**1240**	**982**	<670	<680	<990	2355	423	600
Pyrene	<640	**1330**	**730**	**1970**	<800	**1100**	**730**	**1060**	<860	**1140**	**901**	<670	<680	<990	875	195	665
Benzo(a)Anthracene	<640	**583**	<740	**910**	<800	<1000	<740	**434**	<860	<990	<890	<670	<680	<990	385	108	261
Chrysene	<640	**798**	**451**	**1140**	<800	**668**	**451**	**593**	<860	**673**	**546**	<670	<680	<990	862	166	384
Benzo(b)Fluoranthene	<640	1060	658	1540	<800	945	658	809	<860	983	809	<670	<680	<990	NS	NS	NS
Benzo(k)Fluoranthene	<640	<799	<740	434	<800	<1000	<740	<810	<860	<990	<890	<670	<680	<990	NS	NS	NS
Benzo(a)Pyrene	<640	661	<740	**992**	<800	616	<740	516	<860	594	<890	<670	<680	<990	782	NS	763
Indeno(1,2,4-cd)Pyrene	<640	698	532	901	<800	806	532	659	<860	767	665	<670	<680	<990	NS	NS	NS
RCRA METALS (mg/Kg)	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
Arsenic	**12.0**	**10.4**	**9.1**	**11.4**	**12.8**	**16.1**	**11.8**	**13.5**	**12.4**	**17.6**	**15.3**	**9.1**	**9.0**	**14.6**	5.9	9.79	8.2
Barium	103	101	32	163	115	130	99	101	116	120	122	98	102	86	NS	NS	NS
Cadmium	**3.6**	**0.9**	<2.0	<0.9	<2.2	**0.8**	<2.1	<2.2	<2.4	**1.1**	**0.8**	<1.9	<1.8	<2.8	0.596	0.99	1.2
Chromium	32	**38**	11	**53**	36	**39**	37	**40**	**41**	**43**	**44**	33	33	**64**	37.3	43.4	81
Lead	**83**	**64**	6	17	**45**	**48**	21	**36**	9	**54**	**52**	17	15	14	35	35.8	46.7
Selenium	<3.4	<3.7	<2.0	<5.9	<4.4	<5.5	<4.2	<4.4	<4.8	<5.4	<5.0	<3.9	<3.7	<5.6	NS	NS	NS
Silver	<1.7	<1.9	<2.0	<2.9	<2.2	<2.7	<2.1	<2.2	<2.42	<2.7	<2.5	<1.9	<1.8	<2.8	NS	NS	1.0
Mercury	<0.09	<0.09	0.14	**0.29**	**0.35**	**0.49**	**0.53**	**0.92**	0.07	**0.86**	**1.0**	**0.19**	**0.18**	0.14	0.14	0.18	0.15
PEST/PCBS Method 246/8081 (mg/Kg)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	--	--	--

Notes:
1 < 110 = less than Laboratory Reporting Limit
2. Bold value = indicates exceedance of one of the Ecological Screening Level Criteria
3. NA = not analyzed NS = No Ecological Screening Level; ND = No compound detected above compound associated Laboratory Reporting Limit
4. Ecological Screening Level Data - NOAA Screening Quick Reference Table NOAA OR&R 08-01
6. Consensus Threshold Effect Concentration (TEC) - D.D. MacDonald - Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems (Arch. Environ. Contam. Toxicol. 39-20 -2000). Samples were collected and data summary was provided by HYDROTERRA Environmental Services, LLC

Existing Vegetation Survey

Along the northern shoreline (i.e., closest to Mill Pond Road), the existing vegetation consists of a mix of both invasive and native plant species that commonly inhabit developed and disturbed landscapes in southern and coastal New Hampshire. Observed tree species include: northern red oak (*Quercus rubra*), black cherry (*Prunus serotina*), crab apple (*Malus sp.*) and box-elder (*Acer negundo*). Directly along the pond's edges, invasive shrub species include: multiflora rose (*Rosa multiflora*), glossy buckthorn (*Frangula alnus*), and Japanese barberry (*Berberis thunbergii*). Purple loosestrife (*Lythrum salicaria*) and oriental bittersweet (*Celastrus orbiculatus*) were also observed along the pond margins (see Photos in Appendix C). Several culverts discharge to the pond likely degrading habitat for native vegetation, thereby allowing more tolerant invasive species to thrive in some locations.

Within the shallow water areas of the pond along its edges, vegetation is dominated by broad-leaved cattail (*Typha latifolia*), woolgrass (*Scirpus cyperinus*), lake sedge (*Carex lacustris*), purple loosestrife and speckled alder (*Alnus incana*). The purple loosestrife tends to become a little more abundant to the west toward the inlet into the pond. Closer to the center of the pond, there are several small wetland islands with vegetation consisting primarily of woolgrass, speckled alder, and broad-leaf cattail. These are relatively shallow water areas having water depths varying between 1 foot and 2 feet.

On the opposite shoreline, along the southern banks of Mill Pond, the area is less disturbed and has fewer invasive species. The difference in appearance of the southern banks compared to the northern bank can likely be attributed to the nearby development and numerous stormwater inputs found along the northern edge of the pond. Along the southern edge of the pond, scrub-shrub (PSS1E) wetlands are located to the rear of residential properties adjacent to the Oyster Dam. Vegetation within this wetland consists primarily of speckled alder, silky dogwood and northern arrow-wood. The terrain along the pond's southern banks is highly variable with knolls and low-lying areas. This area is dominated by an eastern white pine (*Pinus strobus*) forest with emergent marsh (PEM1E) wetlands along the water's edge. Continuing southwest towards the Oyster River inlet, a large shrub-scrub (PSS1C) wetland exists along a small tributary that drains into Mill pond from agricultural fields to the south.

Common native species that currently inhabit portions of the tidal river downstream of the dam include saltmeadow cordgrass (*Spartina patens*), prairie cordgrass (*Spartina pectinata*), blackgrass (*Alopecurus myosuroides*), and saltmarsh bulrush (*Scirpus robustus*). The invasive species known as common reed (*Phragmites austratlis*) was observed to occupy a sizeable area along the south bank approximately 1,000 feet below the dam. This area could represent a major potential seed source for new tidal marsh areas above the dam, if the dam was removed. In addition, College Brook which flows into Mill Pond is a likely source of invasive plant seeds and rhizomes for purple loosestrife and common reed. If the dam was to be removed, various eradication measures may need to taken to reduce and/or eliminate the existing stands of invasive plant species, to minimize the spread of invasive plant species into newly exposed areas under a dewatered Mill Pond.

Anticipated Pond Conditions Following Possible Dam Removal

Pond Size / Water Depths

If the existing Mill Pond dam was to be completely removed, much of the existing pond area would be drained except for the main river channel that runs through the center of the pond. Much of the pond area that currently has less than 5 feet to 6 feet of water, the bottom sediments would have little standing water but would still be subject to periodic flooding during high flow events when floodwaters may overtop the banks.

Recently, the pond was drawn down in September 2008 and in November 2009 to allow detailed inspections of the dam. Photos of the pond during the draw down periods are shown in Appendix A. The pond area with the dam removed will look similar, at least initially, to that shown in these photos until vegetation becomes established in the newly exposed areas. The likely vegetation community response is discussed further below.

Head of Tide Limits

The Mill Pond dam currently represents a barrier to the upstream movement of tidal waters, and this is often referred to as the head of tide limit. If the dam was removed, the influence of tidal waters would extend farther upstream creating additional tidal habitat. The landward extent to which tidal habitat may become established is generally influenced by three high tide parameters, which are often referred to as the Mean High Water (MHW), the Mean Higher High Water (MHHW) and the Highest Observable Tide Limit (HOTL). The mean high water (MHW) elevation represents the average of all the high water heights observed over the National Tidal Datum Epoch (NTDE)[1]. Land and channel substrate areas that have elevations below the MHW elevation are typically flooded by tidal water twice a day and generally represent the low marsh areas down to Mean Low Water (MLW). Areas that have semi-diurnal tides (i.e. two high tides each day), will typically have one tide that is higher than the other in alternating fashion. The MHHW elevation represents the

[1] The NTDE is a specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values (e.g., mean lower low water, etc.) for tidal datums. It is necessary for standardization because of periodic and apparent secular trends in sea level changes. The current NTDE runs from 1983 through 2001 and is actively considered for revision every 20-25 years.

average of the highest daily tide elevation over the NTDE. The areas that are inundated by tidal water less frequently are often categorized as High Marsh areas.

The Highest Observable Tide Limit (HOTL) elevation represents the farthest landward limit of tidal inflow and is defined by either observed strand lines of debris, the landward margin of salt tolerant vegetation, or a physical barrier which blocks the flow of the tide.

The elevations of these three high tide stages for the Oyster River / Mill Pond area were estimated based on a combination of site observations and extrapolation of data from other regional tide stage estimates for coastal projects in the Seacoast region. Estimates of the low tide stage elevations (i.e., Means Sea Level, Mean Low Water and Mean Lowest Low Water) were not estimated here, because the river channel directly below the dam currently has minimal tidal influence under low tide conditions and this is not expected to change if the dam was removed.

Data reported for other similar projects in the Great Bay region include the recent Winnicut River dam removal project in Greenland, NH where the MHW and the MHHW at the project site were based directly on tidal stage data collected at the project site using data logging acoustic stage measuring equipment provided by NHDES. The MHW elevation was calculated to be 3.6 feet, based on the average of 76 peak tidal stage measurements and the MHHW elevation was calculated as 4.4 feet based on the average of the higher of every two high tides. The HOTL elevation was determined to be 6.0 feet based on field indicators of the farthest landward extent of tidal influence (based NAVD88 datum). Similarly, for a proposed project in the tidal portion of the Lamprey River in Newmarket, NH, the MHW elevation was reported to be 4.5 feet and the HOTL elevation was 6.1 feet presumably based on 1929 NVGD datum (E. Hutchins, NOAA, pers. comm. Dec. 2009).

With respect to the Oyster River dam site, the Highest Observable Tide Limit was based on measurements of an unusually high tide that was observed during a full moon phase on December 3, 2009. During the peak of this high tide, tidal waters overtopped the sea wall embankments along the downstream river channel which is very rare according Dave Cedarholm (Durham's Town Engineer). Review of the predicted tide level data at the nearest NOAA tide station in the Great Bay (i.e., Squamscott River at the RR bridge in Stratham), indicates that the high tide level on December 3rd was one of the highest for the entire year. The annual tide chart for the Squamscott River tide station indicated that the high tide levels throughout the year, relative to Mean Low Water, ranged from a low of 6.0 feet to a high level of 8.3 feet, which was recorded on Dec. 3rd, 2009.

The measurements of the high tide elevation at the site just downstream of the Mill Pond dam on December 3rd were recorded at 1:10 and 1:15 PM (see Photos in Appendix D). This time frame coincides with the estimated peak of the high tide (i.e. slack tide) of 1:23 PM at the Squamscott River station at on Dec 3rd 2009. Based on these measurements of the observed peak high tide level on December 3rd, the high observable tide limit was determined to be approximately 5.4 feet (NAVD88). This is similar to the estimated HOTL elevation of 6.1 feet that was previously reported for the Lamprey River in Newmarket, which was presumably based on NVGD29 datum, which is 0.73 ft higher than the NAVD88 datum.

Additional observations of high tide levels and other physical evidence (e.g., high water marks) were used to estimate the MHW and MHHW elevations. During several high tide periods, the high tide line was observed to just barely reach the benchmark elevation of 3.75 feet (NAVD88) located on the rebar stake on Transect 1. On other occasions, the high tide line was observed to be higher and near the top of the granite sea wall which is approximately at 4.5 feet in elevation based on the vertical distance from the nearby bench mark elevation. Next to Transect 1, is a tidal marsh area with ground elevations that range between 3.2 to 3.8 feet, based on LIDAR data. On the upper end this marsh area, there are various species that are considered more typical of high marsh areas and include saltmeadow cordgrass (*Spartina patens*), prairie cordgrass (*Spartina pectinata*), blackgrass (*Alopecurus myosuroides*), and saltmarsh bulrush (*Scirpus robustus*). Based on these observations, a reasonable estimate of the MHW elevation in the Oyster River would be around 3.4 feet to 3.6 feet (NAVD88). This is consistent with the reported MHW estimate of 3.6 feet in Greenland as part of the Winnicut River Dam project (Stantec, 2008).

A high water mark on the downstream bridge culvert under Route 108 was determined to have an elevation of 4.6 feet (NAVD88) (see Photos in Appendix D). This elevation is lower than the HOTL of 5.4 feet, as discussed above, but higher than the estimated MHW elevation and, thus, is likely to be representative of the Mean Higher High Water (MHHW) elevation. This elevation is consistent with previously estimated MHHW elevation of 4.5 feet reported for Greenland, NH (Stantec 2008).

Table 3.0 provides a summary of the estimated MHW, MHHW and HOTL elevations for the Oyster River based on the information and observations discussed above. If, in the future, the dam is proposed for removal, more detailed and site-specific tide stage elevation data would be needed for the Oyster River to be able to more accurately predict where tidal habitat may become established upstream.

Table 3.0 – Estimated Tidal Stage Elevations for the Oyster River near Mill Pond Dam

High Tide Stage	Estimated Elevation (feet)*
MHW	3.4
MHHW	4.4
HOTL	5.4

*based on NAVD88 datum

Based on the existing bathymetry data for the pond, it appears that the upstream migration of tidal inflow following a possible dam removal would be confined primarily within the main river channel given that the top of bank elevations of the river channel are at a minimum of 6 feet, as shown in Figure 4. With an estimated HOTL elevation of 5.4 feet, even the highest tides would be contained within the existing river channel, at least initially. As discussed earlier, the main river within Mill Pond is confined with a channel with top of bank limits that are generally at elevations of 6 to 8 feet (NAVD88). In order to establish tidal habitat outside of the main river channel, portions of the existing pond would need to be dredged to lower bottom elevations and open up new channel areas that would be connected to the main channel. Over time, the top of bank elevations may become lower naturally due to erosion, subsidence, sloughing, etc. which may allow tidal inflow to inundate other areas of the dewatered pond.

With respect to how far upstream the tidal limits may reach within the channel, the bathymetry data indicates that there is a high point in the main river channel with an elevation of approximately 5.8 feet just downstream of the observed deep hole in the main channel. Under dewatered conditions, this high point in the channel would represent a riffle crest in the remaining river channel. This high point may initially become the new head of tide limit but it is quite likely that bottom elevations in this new riffle area under dewatered conditions will change as the sediments become exposed to higher flow velocities with shallower water depths and river flow is not buffered by the larger impounded water area. Bottom sediments in the channel will erode over time and possibly migrate downstream during subsequent high flow events. Thus, this high point in the channel is expected to result in a ower elevation over time. Once lowered, the tidal inflow would extend even farther upstream and perhaps as far up as the next narrow channel restriction which is located just upstream of the confluence of with College Brook. The narrow restriction is formed primarily by bedrock outcrops and is not likely to change much over time and this would likely represent the new head-of-tide location. Additional factors that may affect future tidal stage levels and tidal habitat locations are discussed further in the Discussion Section.

Salinity

Salinity is a measure of the amount of dissolved salt in water and has a major impact on the types of vegetation and aquatic species that may inhabit a particular area. The salinity of ocean water is generally at or above 30 parts per thousand (ppt) whereas freshwater generally has salinity levels of less than 0.5 ppt. Where sea water and freshwater mix in tidal estuaries, the salinity fluctuates greatly between <0.5 and 30 ppt and these areas are often referred to as brackish zones. The salinity levels at any particular location depend on its level of exposure to freshwater or saline water either by direct inundation or a mixture of both particularly during high tide periods. The extent of inundation by fresh water or saline waters will depend on both proximity to the head of tide limits and elevation relative to the tidal stages. Often a spectrum of various micro-ecosystems or zones of vegetation communities will develop within these brackish areas based on the prevailing salinity and the inherent tolerances of vegetation species to salinity at that particular location. Salinity is a critical parameter to be considered in any proposed restoration effort in a tidally influenced area in terms of providing favorable conditions for native and productive vegetation communities and limiting the establishment of invasive species.

To develop an adequate understanding of the potential salinity levels that may prevail in a proposed restoration area requires a long term, data base of site-specific salinity measurements under a variety of freshwater flow and tidal conditions. The Great Bay Monitoring Network as part of the UNH-CICEET Program has maintained a continuous water quality data sonde since April 2004 within the tidal portion of the Oyster River channel at a location near Jacksons Landing approximately 1,600 feet downstream of the dam. The data sonde records levels of various water quality parameters including salinity. Table 4.0 provides a summary of the typical salinity levels recorded in the main channel of the Oyster River downstream of the dam, during the summer months versus winter months:

Table 4.0 - Estimated Ranges of Salinity Levels in the Oyster River Channel

Time of Year	Typical Salinity Range
Summer Months (i.e. June- Oct)	**15.0 – 26.0 ppt**
Winter Months (i.e., Nov-May)	**3.0 – 15.0 ppt**

The differences in the measured salinity level between the summer and winter months are primarily due to the dilution effects of the greater freshwater inflow during the winter months and especially during spring snow melt. During the summer months, the tidal flow volume tends to dominate more as the effects of freshwater flow generally diminish. However, the data shows that even during summer months when freshwater flow increases dramatically during major storm events, the salinity levels tend to drop to near zero. Again, the salinity levels measured by the CICEET data sonde represent conditions within the downstream channel that is influenced by saline waters even under low tide conditions. Lower salinity levels would be expected farther upstream closer to the head of tide limits and at higher elevations that are less influenced by tidal inundation. Additional salinity data would be required near the existing head-of tide limits and at different elevations to obtain more representative data for the Mill Pond impoundment.

Vegetation Communities

If the dam was completely removed, the vegetation community response would involve an influx of both freshwater and salt water tolerant species. As discussed above, without the dam, the tidal influence would be primarily confined to the main river channel and would extend upstream establishing a new demarcation zone by which freshwater and salt tolerant species would prevail. Based on the estimated high tide elevations and salinity changes, discussed above, portions of the dewatered pond that have bottom elevations of 4.5 feet or less would likely be inundated or influenced by tidal waters on a daily basis. Occasionally, the brackish waters may extend as high as 5.5 feet or more based on the higher than normal tide elevation measured on Dec. 3rd, 2009. In general, the new tidally-influenced area within the potentially dewatered pond is anticipated to be contained within the eastern half of the main river channel, based on the bathymetry data. The existing salt tolerant species observed downstream of the dam could provide a seed source for salt tolerant vegetation to become established in the new tidal influenced zone. The existing salt tolerant vegetation species include saltmeadow cordgrass (*Spartina patens*), prairie cordgrass (*Spartina pectinata*), blackgrass (*Alopecurus myosuroides*), and saltmarsh bulrush (*Scirpus robustus*). However, the invasive species known as common reed (*Phragmites austratlis*) was also observed to occupy a sizeable area along the south bank approximately 1,000 feet below the dam. As with purple loosestrife, common reed is also known to be present in wetlands and along the margins of College Brook. These areas all represent major potential seed sources for the newly exposed areas above the dam. Various control efforts will be needed to limit the establishment of these invasive species. Other invasive species including multi-flora rose, glossy buckthorn (*Frangula alnus*), purple loosestrife and Japanese barberry, all of which are found adjacent to the pond, would also have to be eradicated to control the spread of these species on the exposed soils if the pond was drawn down due to dam removal. The dewatered areas would also have be monitored over time (perhaps, up to 10 years) to control and minimize the re-colonization of these invasive plant species

With respect to the various types of vegetation species that are likely to colonize or become established in the freshwater portions of the pond, much will depend on the bottom elevations and the potential hydrologic conditions (i.e., saturated, periodically flooded, or permanently flooded zones, etc.) that are likely to occur within the dewatered impoundment. Table 5.0 presents the estimated zones of various hydrologic conditions that are likely to result within the pond if the dam was removed. These estimates are based on the hydrologic conditions observed when the pond was drawn down in 2008 and 2009 as well as the field observations of the exiting vegetation species along the shoreline and surrounding areas.

Table 5.0 – Estimated Hydrologic Conditions and Vegetation Community Type within Various Zones in the Pond based on Bottom Elevations

Existing Bottom Elevations* (feet)	Anticipated Hydrology during Draw Down Conditions	Anticipated Vegetation Community/Wetland Classification
<u>Freshwater Areas</u>		
>10 ft	Moist/ Dry	Shrub/ Forested Wetland / Upland
8 - 10 ft	Seasonally Saturated	Marsh/ Shrub/ Forested Wetland
6 - 8 ft	Periodically Flooded	Freshwater Emergent Marsh/ Shrub
5 – 6 ft	Semi-Permanently Flooded	Emergent Marsh
< 5 ft	River Channel/ Permanently Flooded	Open Water

Tidally Influenced Areas		
~ 4.4 to 5.4 ft	Irregularly Flooded Zone	High Marsh
~ 3.6 to 4.4 ft	Regularly Flooded Zone	Lower High Marsh
~ 0.0 to 3.6 ft	Regularly Flooded Zone	Open Water/ Low Marsh

Notes: * These estimates are considered preliminary based on various observations and data from other studies and assume that the future bottom elevations would not change dramatically from the existing elevations.. More detailed site-specific tidal stage data would be needed to verify and/or modify tidal stage estimates if a dam removal proposal was to move forward.

The freshwater vegetation species that are likely to become established in the areas of the drawn down pond will involve a mix of woody and herbaceous species. Much of the existing pond area that has bottom elevations above 8.0 feet (+/ -) are anticipated to have no standing water but are likely to have saturated soils for a much of the growing season given the close proximity to the underlying groundwater and the fine-grained nature of the soils. These areas are likely to primarily support various wetland shrub species with a mix of herbaceous plants in the wetter areas that may develop in small depressions. The types of native shrub species that would likely become established include speckled alder, silky dogwood, and northern arrow-wood. Invasive species such as glossy buckthorn, oriental bittersweet and Japanese barberry could also become established as these plants are currently present and provide seed sources. Therefore, ongoing monitoring for these and other invasive species is recommended as noted above. Native emergent herbaceous species likely to become established include various wetland grasses, sedges and other forbs. Cattail is likely to colonize some “backwater” or depressional deeper water areas. Additionally, invasive plants such as common reed and purple loosestrife could become established if eradication and removal efforts are not conducted.

Areas within the existing pond that currently have bottom elevations between 6.0 feet and 8.0 feet (+/ -) are anticipated to be periodically flooded during higher “riverine” flow conditions and thus, have standing water occasionally and more prolonged saturated soil conditions. These areas are likely to support typical emergent marsh vegetation. The types of freshwater species that are likely to become established in this zone will include cattail, sedges, rushes and other forbs. As noted above for other re-exposed pond bottom areas, invasive species such as common reed and purple loosestrife could become established as seed sources are already present at the pond margins and along College Brook upstream of Mill Pond.

Areas within the pond having elevations between 5.0 feet and 6.0 feet are likely to become established with emergent herbaceous species tolerant of saturated and semi-permanently flooded conditions. Both freshwater marsh and tidal marsh are likely to become established with many of the herbaceous plants that were observed along the pond margins and in the tidal marsh areas downstream of the dam. Salt-tolerant species are likely to colonize areas that are subject to inundation during high tides along the margins of the river. Beyond these areas, freshwater species will take hold.

Within the river channel itself, the vegetation community response would depend on whether the newly exposed and inundated areas are freshwater or tidally influenced. The central and lower portions of the channel below the bank-full width would consist mainly of open or flowing water that is more or less permanently inundated. Above the bank-full width and long the edges of the river, in the freshwater areas, aquatic emergent beds of vegetation would become established and may include species such as bur-reed (*Sparganium*), pickerel weed (*Pontederia*), and arrow arum (*Peltandra virginica*). Over time, these areas could eventually become vegetated with woody species such as speckled alder and dogwood (*Cornus* sp.). Intentional plantings of other fast growing species such as willow (*Salix* spp.) could help stabilize newly exposed river banks. Within the tidally influenced areas (i.e. eastern half of the channel closest to the existing dam), the vegetation species would be dictated by the prevailing salinity levels and the tidal stage elevations of MHW, MHHW and HOTL, as discussed above.

Sediment Migration/ Potential Contamination Issues

With a dewatered impoundment, following a potential dam removal, the existing bottom sediments in certain areas will likely be vulnerable to erosion and sediment movement, at least initially, during high flow events. Critical areas will be along the main river channel and especially the sediment deposits that have accumulated just upstream of the dam location. Given the unconsolidated and fine-grain nature of the bottom sediments as indicated by the sediment probe and sampling results, additional channel stabilization measures are likely to be needed to minimize the movement of sediment downstream. As indicated in the photos of the pond during previous draw down conditions, the banks of the main river channel are relatively steep and will be fully exposed, at least initially. Various bioengineering methods, such as additional plantings and "soft" bank stabilization measures such as "coir" rolls, which are generally preferred by the resource agencies rather than rip-rap stone, could be used to stabilize the banks. Over time as new vegetation species become established, the threat of sediment erosion will diminish.

Discussion

The results of this study can be used to develop a better understanding of how conditions may change in the Mill Pond impoundment and the type of vegetation that may prevail if the Mill Pond dam was to be removed. In general, with the dam completely removed, the dewatered impoundment would essentially become a vegetated wetland area that would have limited permanent standing water except within the main channel that is located in the center of the pond. Initially, much of the dewatered pond area outside of the main channel would be comprised of exposed mud flats. Within a matter of a few years, these exposed soil area would be dominated by wetland shrub and herbaceous species and eventually tree species in the higher and drier areas. Portions of the main channel within the pond would become tidally influenced which would introduce more salt tolerant species. Opportunities would exist to increase the amount of tidal habitat through limited dredging to create channels that would allow tidal waters to flow beyond the limits of the main channel. Eventually, over time, natural process such as erosion and sediment subsidence may also increase the tidally influenced area.

Minimizing the spread of various invasive vegetative species, both in the freshwater and tidal portions, will be one of the biggest challenges for any future potential dam removal project. The vegetation inventory conducted in this study indentified several freshwater and salt tolerant species that currently exist in the Mill Pond area. Various eradication and control strategies would be needed as part of a more detailed restoration plan if the dam was to be removed in the future.

Given the unconsolidated and fine-grained nature of the bottom sediments, various soil stabilization measures will be needed, preferably through the use of bioengineering techniques to control and limit the downstream movement of sediments, especially in areas exposed to flowing water. The depth of the unconsolidated material appears to be limited to the upper 1 to 2 feet in most areas with more dense clay and till material underneath. Thus, major changes in the substrate elevations would not be expected. However, if even small changes in elevations of 0.5 to 1.0 feet could make a significant difference in localized, especially within areas that may be tidally influenced. Additional sediment data may need to be collected in the more vulnerable areas to develop a better assessment of the erosion potential. A hydrologic flow analysis would also be needed to estimate the potential velocities that may be encountered during various storm events without the dam in place. This is listed is a one of the next steps to be conducted as discussed and listed below, if a proposal to remove the dam moves forward.

If the dam was to be removed, additional sampling of the bottom sediments should be considered in key areas where contaminant concentrations were found to be above higher than the preliminary ecological screening levels used in this study. The preliminary screening levels used in this study do not necessarily suggest that adverse impacts to aquatic life would occur. Rather, the screening levels used in this study represent the lowest reported thresholds where the most sensitive species tested have shown some observed adverse effect. These thresholds are typically used to determine whether additional sampling and/ or whether additional analyses are necessary to assess ecological risk to indigenous species. Based on the results of this study, additional sampling should be considered along with a more formal assessment of the potential ecological risks that may be posed if the sediments were exposed and/ or mobilized as a result of dam removal.

Lastly, an assessment as to how future conditions may change due to the predicted global warming effects should be included in any future restoration plan. The predicted rise in sea level and increased intensity and frequency of major storm events are perhaps the two biggest issues that could have a major effect on future habitat conditions in the Oyster River system. Researchers studying the potential effects of global warming have recently predicted that by the year 2100, sea levels could potentially increase by as much as 3 to 4 feet. This would have a dramatic impact on the tidally influenced areas, the river hydrology, the vegetation communities and overall ecosystem in the tidal influenced portions of the Oyster River. Even a sea level rise of 1 foot could dramatically increase the size of the tidally influenced areas given the relatively flat slopes throughout much of the pond. Additionally, scientists at UNH have recently launched a study to evaluate the potential global warming effects on flood events in the Lamprey River. The findings of this study should be evaluated when available and incorporated into any future hydrologic analysis, if available and applicable.

Next Steps

In order to develop a more complete restoration plan for the Mill Pond area, the following next steps or activities should be considered:

1. **Install a continuous tidal stage and salinity data logger below the dam to obtain site specific tidal stage elevation and salinity data for at least one month.**
2. **Conduct a scour analysis and assessment of erosion potential based on estimated flow velocities in the main channel under various critical flow and water level conditions as well as in other areas subject stormwater runoff flow.**
3. **Based on the results of the scour analysis, determine whether additional sediment probe data is needed with the river channel and assess whether sediment removal/ dredging may be required to minimize the downstream movement of sediment.**
4. **Conduct additional sediment sampling for chemical analysis in key areas focusing on areas that had some of the higher contaminant levels evaluated in this study to verify and confirm a limited risk to aquatic species.**
5. **Perform sediment sampling to retrieve representative cores of the bottom sediments in locations just about the dam to investigate for remnants of historical salt marsh habitat prior to the construction of the dam.**
6. **Evaluate opportunities and/or limitations to dredge bottom sediments in key areas to potentially expand the area of tidal inundation and tidal habitat within the pond.**
7. **Coordinate with NHDES Coastal Program to review the lessons learned, project costs, permitting issues and the level of success in achieving the desired goals for the Winnicut River Dam Removal Project that is currently in progress.**

References

CICEET, Great Bay Monitoring Network. Oyster River Water Quality Data Sonde. http://www.greatbaydata.org/

Great Bay Estuary, New Hampshire's Arm of the Sea, Tidal Habitat http://www.armofthesea.info/index.html

Stantec Consulting, Inc. September 17, 2008. Memorandum of Winnicut River Final Design Tidal Data. Prepared by Michael Chelminski.

Stephens Associates Consulting Engineers, LLC. Dam Evaluation Report: Oyster River Dam, Durham, New Hampshire, SA Project No. 075-07-003. March 17, 2009

Figures

Appendices

Appendix A - Photos of Dewatered Pond during Recent Draw Down Periods
Appendix B - Sediment Probe Data and Notes
Appendix C - Existing Vegetation Photos
Appendix D - Photos of High Tide Elevation Measurements
Appendix E - Sediment Analytical Results Lab Reports

Appendix A

Photos of Mill Pond During Draw Down Conditions

Appendix A
Sept 2008 - Drawdown Photos
Mill Pond, Durham, NH

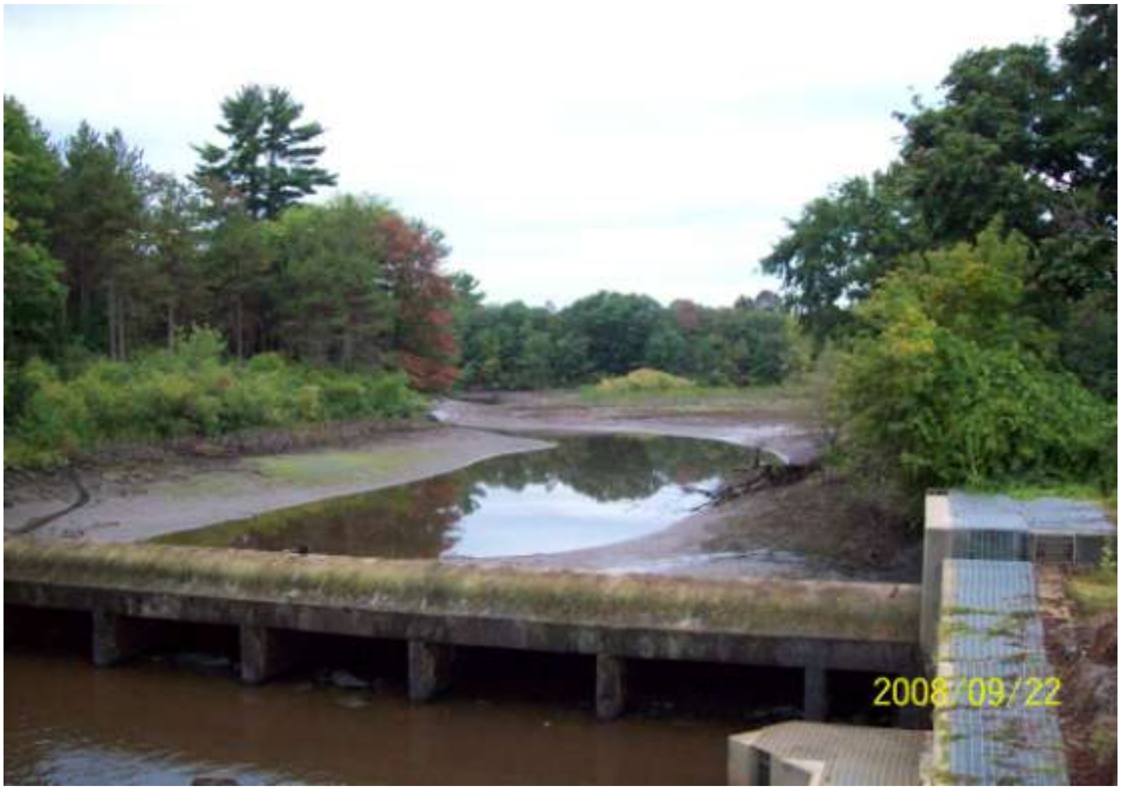


Photo 1 – View of river channel during September 2008 drawdown upstream of a dam.

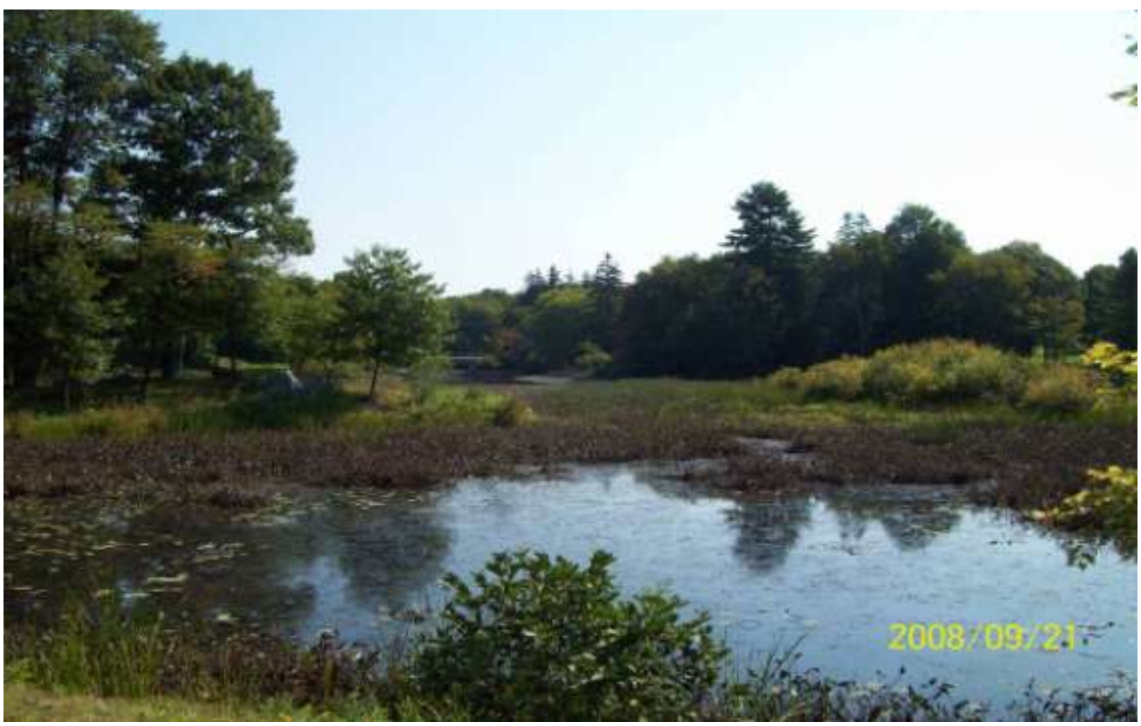


Photo 2 – View of Pond from Mill Pond Road showing a mix of vegetation and standing water.

Appendix A
Sept 2008 - Drawdown Photos
Mill Pond, Durham, NH

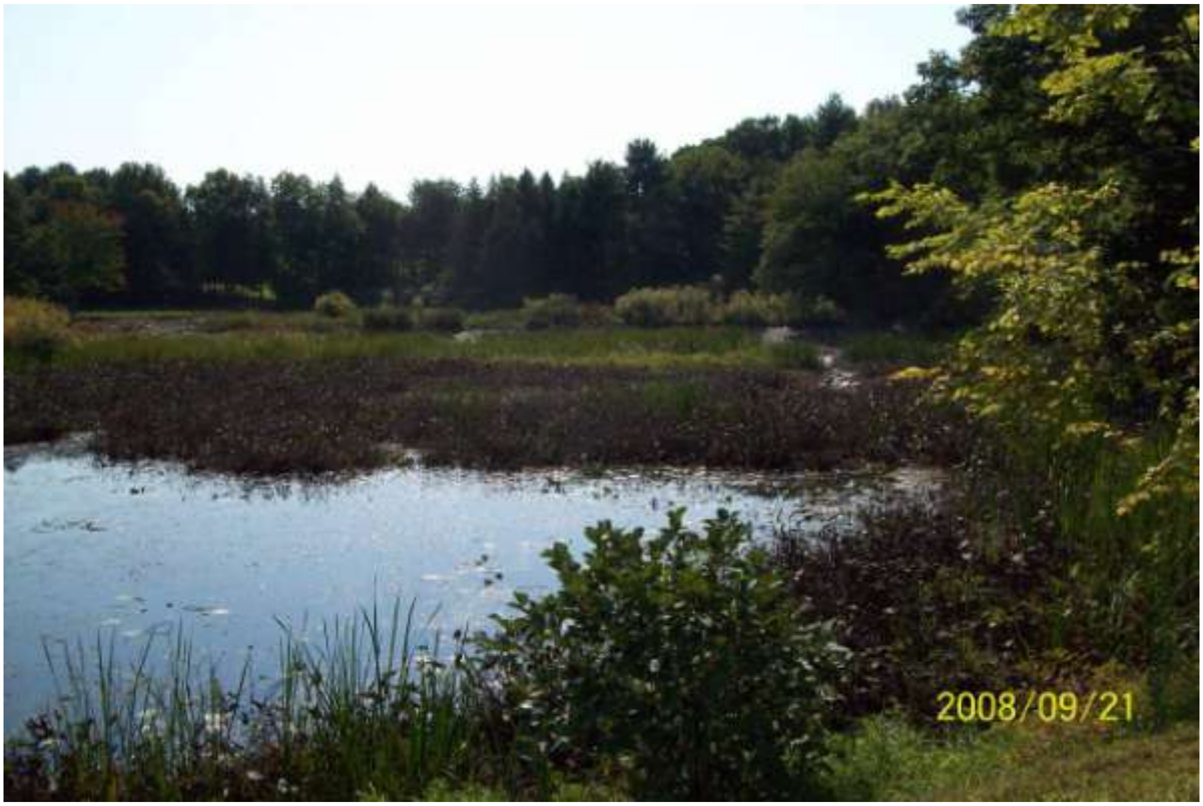


Photo 3 – view looking southwest towards inlet to the pond.

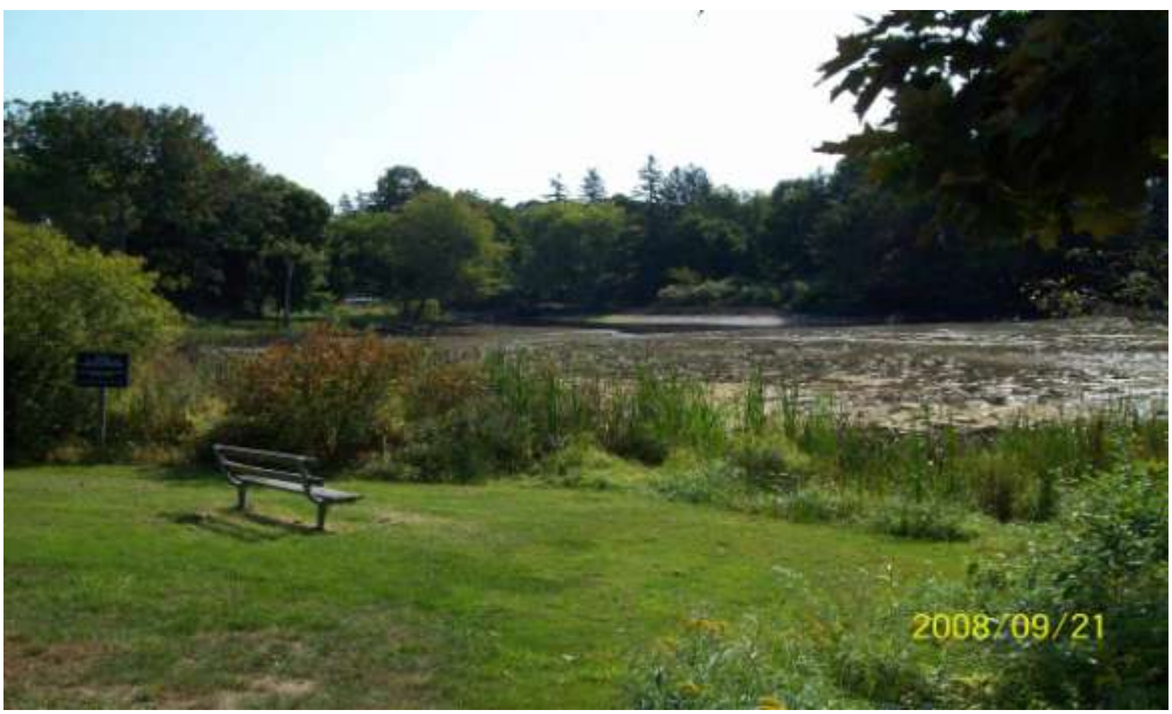


Photo 4 – View from Mill Pond Road with river channel in the background.

Appendix A
Sept 2008 - Drawdown Photos
Mill Pond, Durham, NH

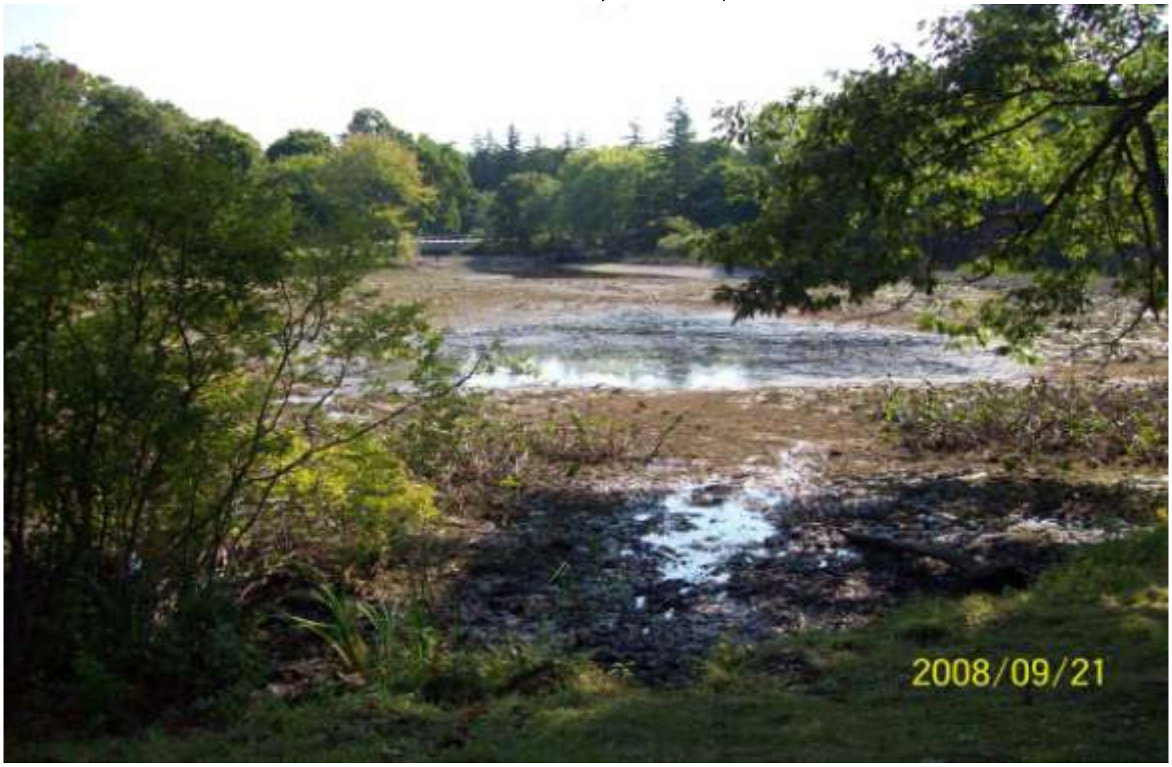


Photo 5 – View looking east from upland peninsula near the middle of the pond.

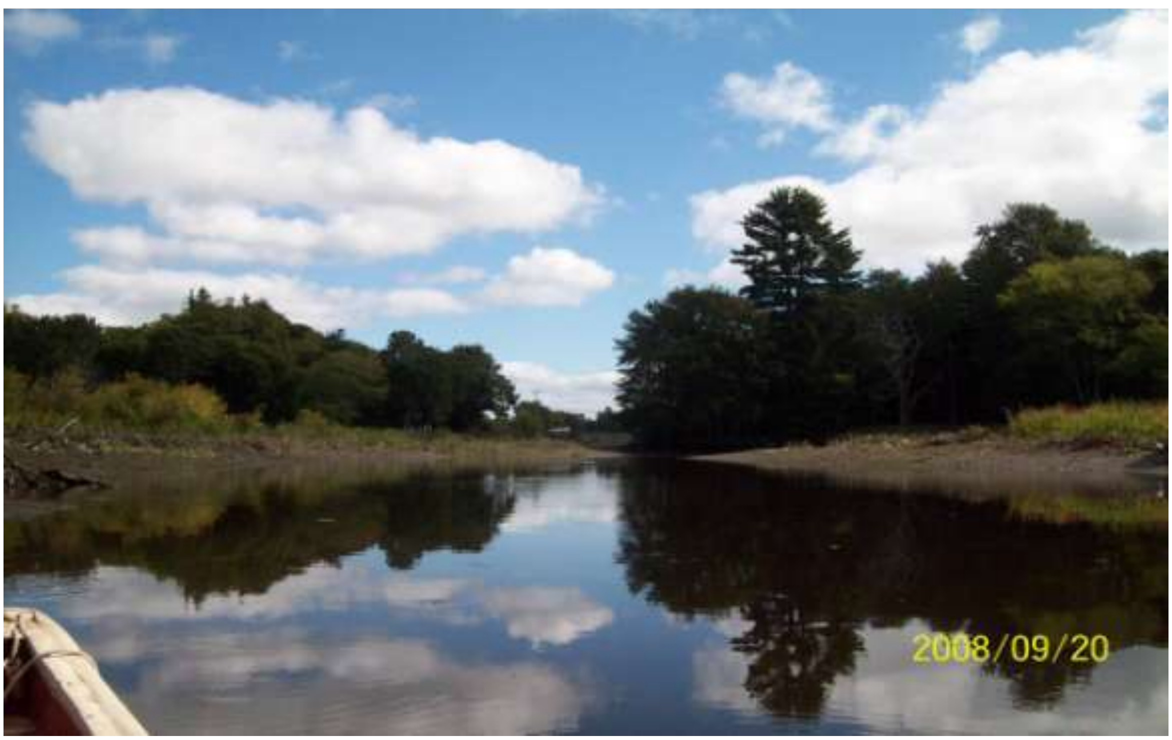


Photo 6 – View of river channel looking east towards dam showing exposed banks during the middle of drawdown period.

Appendix A
Nov 2009 - Drawdown Photos
Mill Pond, Durham, NH

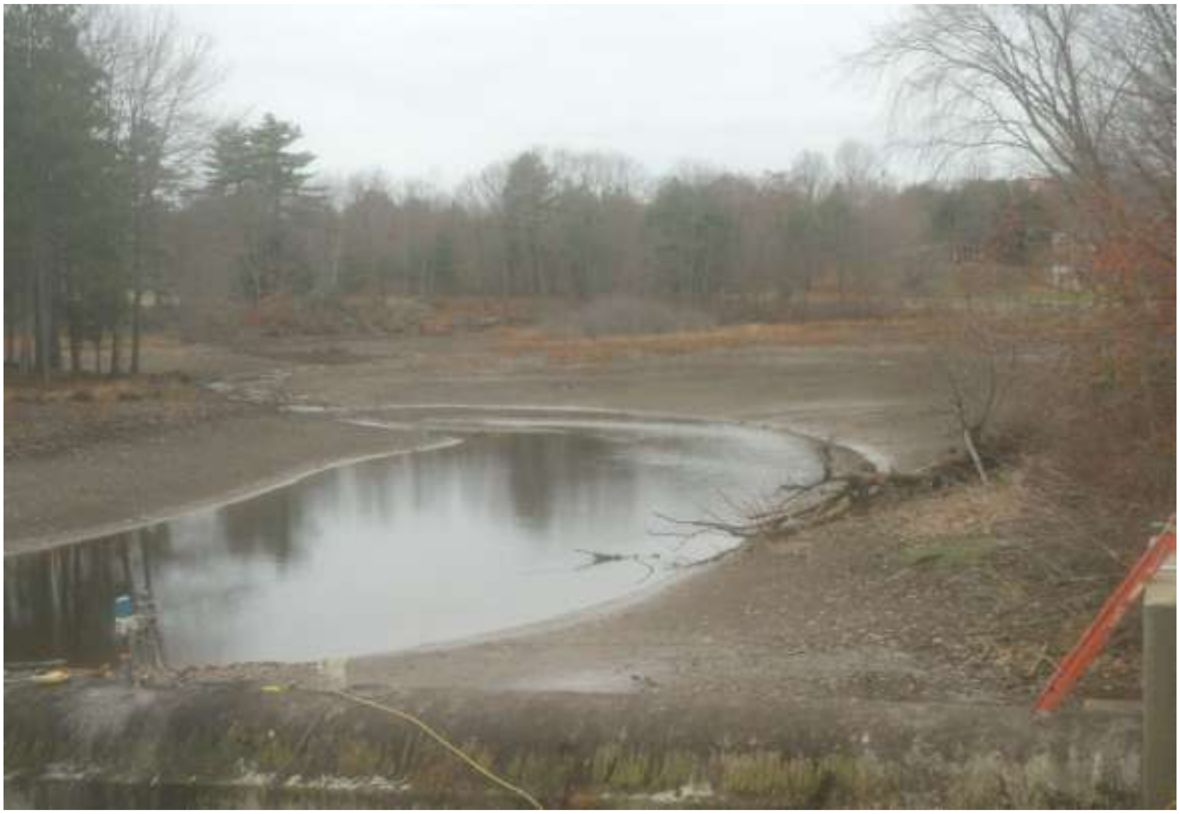


Photo 1 – View of channel just upstream of dam. Photo taken on 11/23/2009.

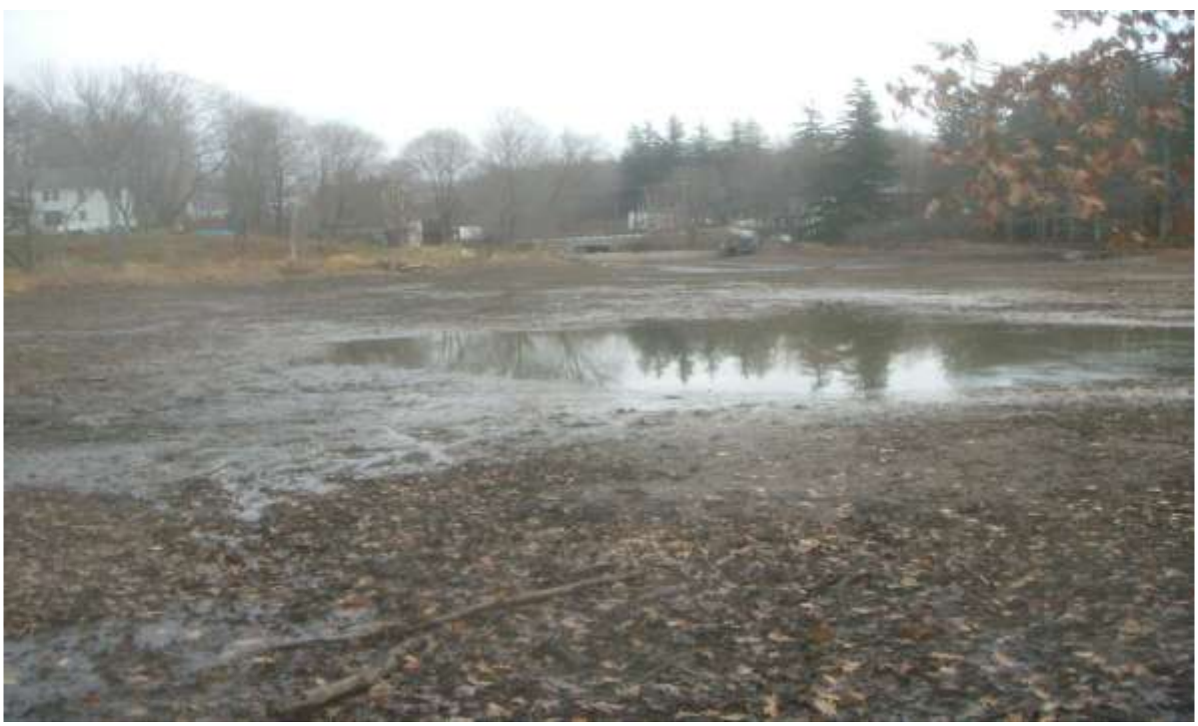


Photo 2 – View of from Mill Pond Road looking towards dam. Photo taken on 11/23/09.

Appendix A
Nov 2009 - Drawdown Photos
Mill Pond, Durham, NH

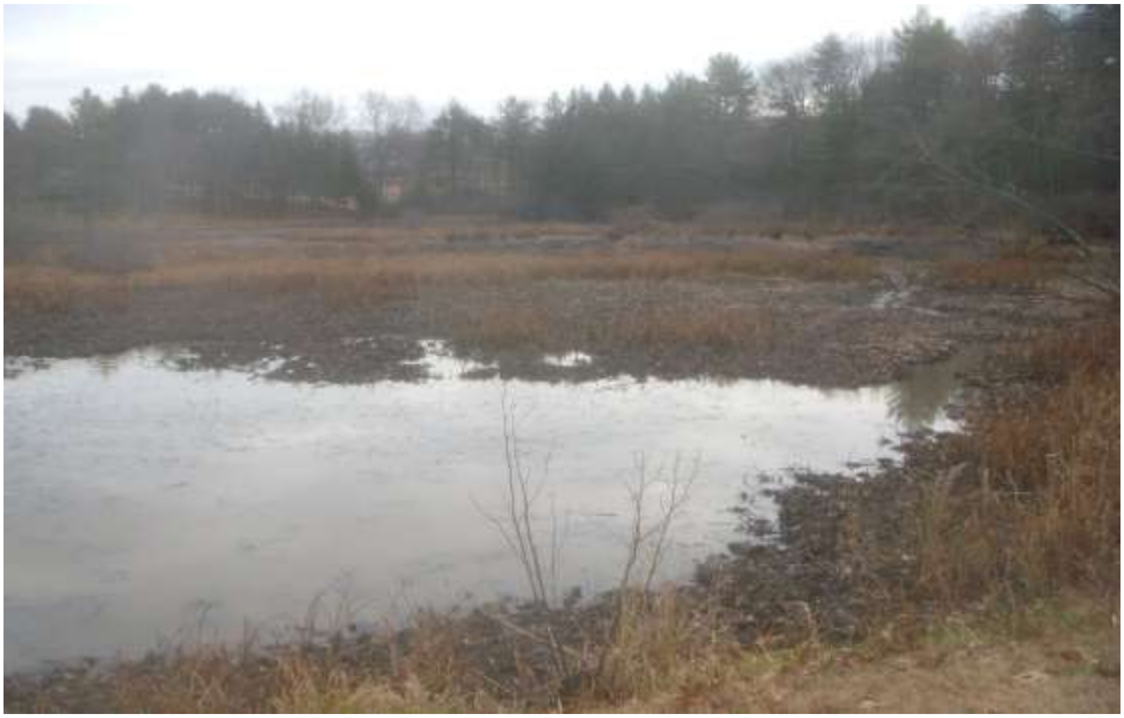


Photo 3 – View looking southwest toward inlet of pond – Photo taken 11/23/2009.

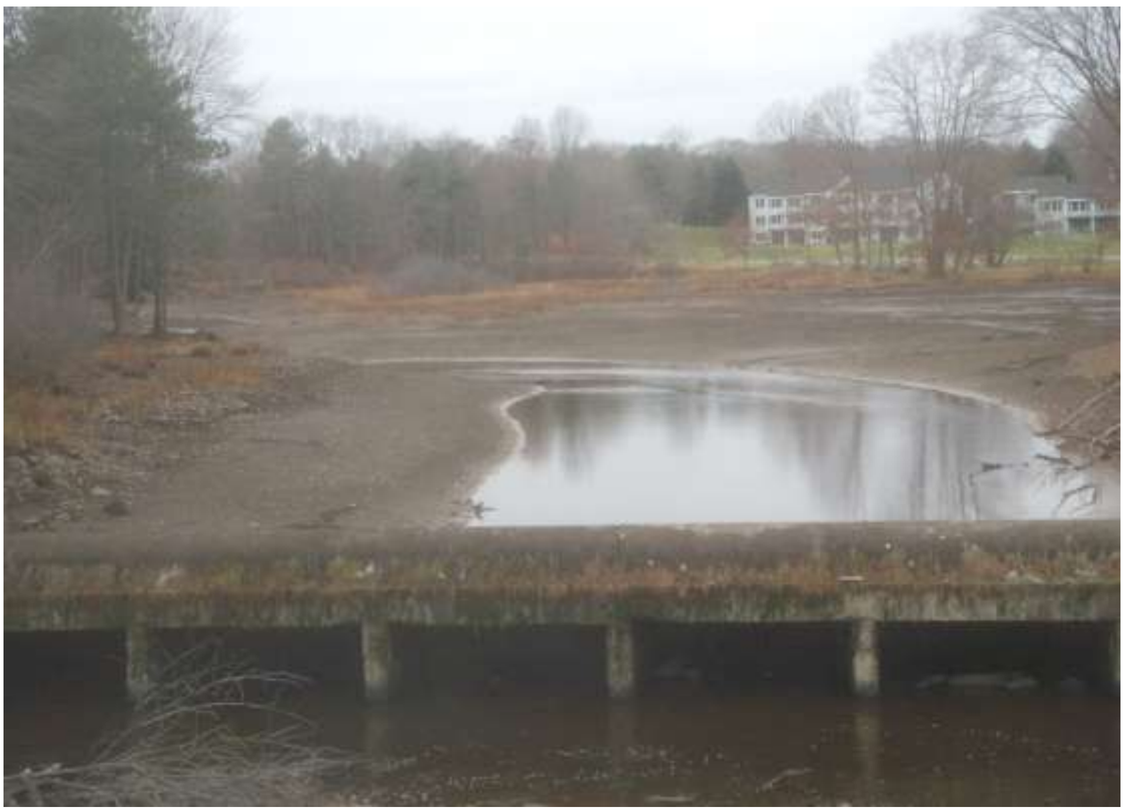


Photo 4 – View from Rte 108 Bridge looking towards Mill Pond Road and dewatered Pond. Photo taken on 11/23/09.

Appendix B

Sediment Probe Data Logs

Appendix C

Representative Photos of Existing Vegetation

Appendix C
Representative Photos of Existing Vegetation

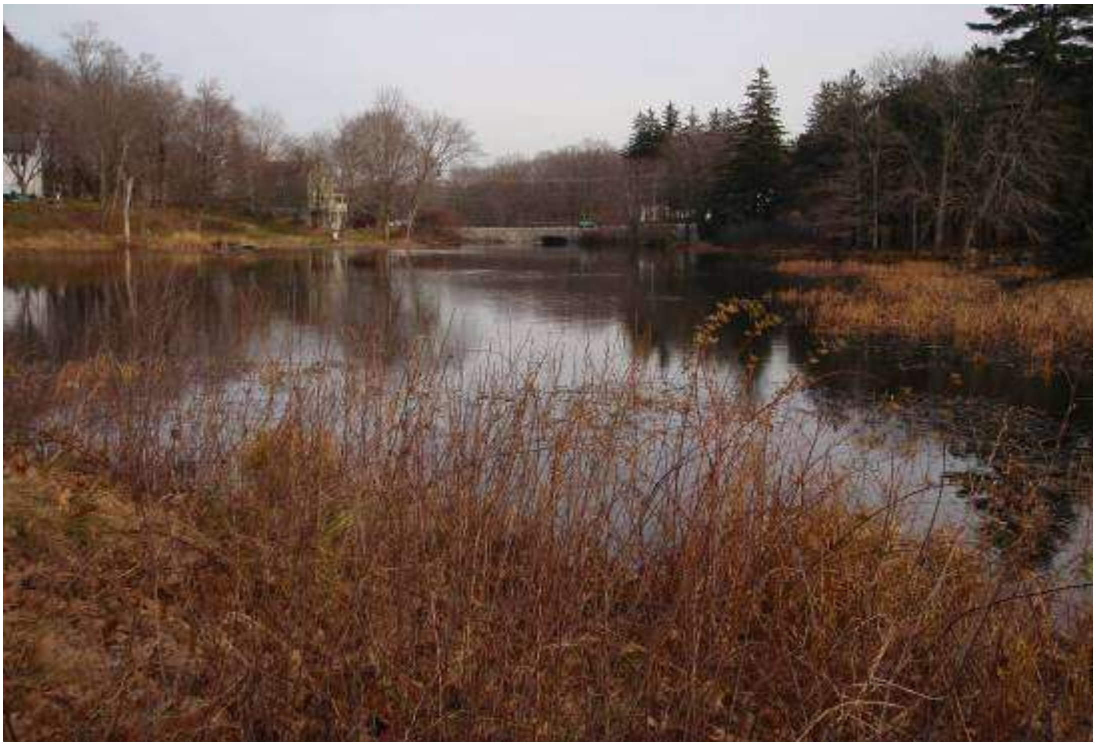


Photo 1: Multiflora rose and other invasives on bank of small plateau reaching out towards the center of Mill Pond from the western side. Oyster River Dam in the background (to the northeast).

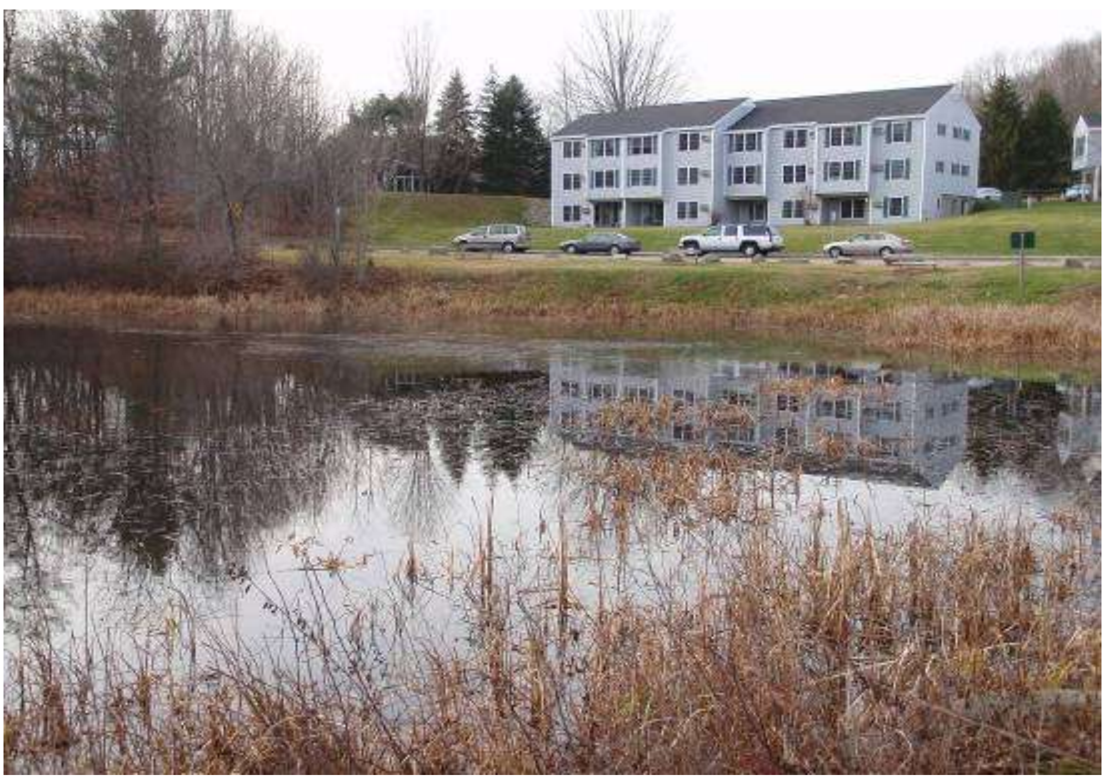


Photo 2: View southwest from small plateau to the western banks of Mill Pond. Woolgrass, broad-leaf cattail, and purple loosestrife are dominant throughout this area.

Appendix C
Representative Photos of Existing Vegetation

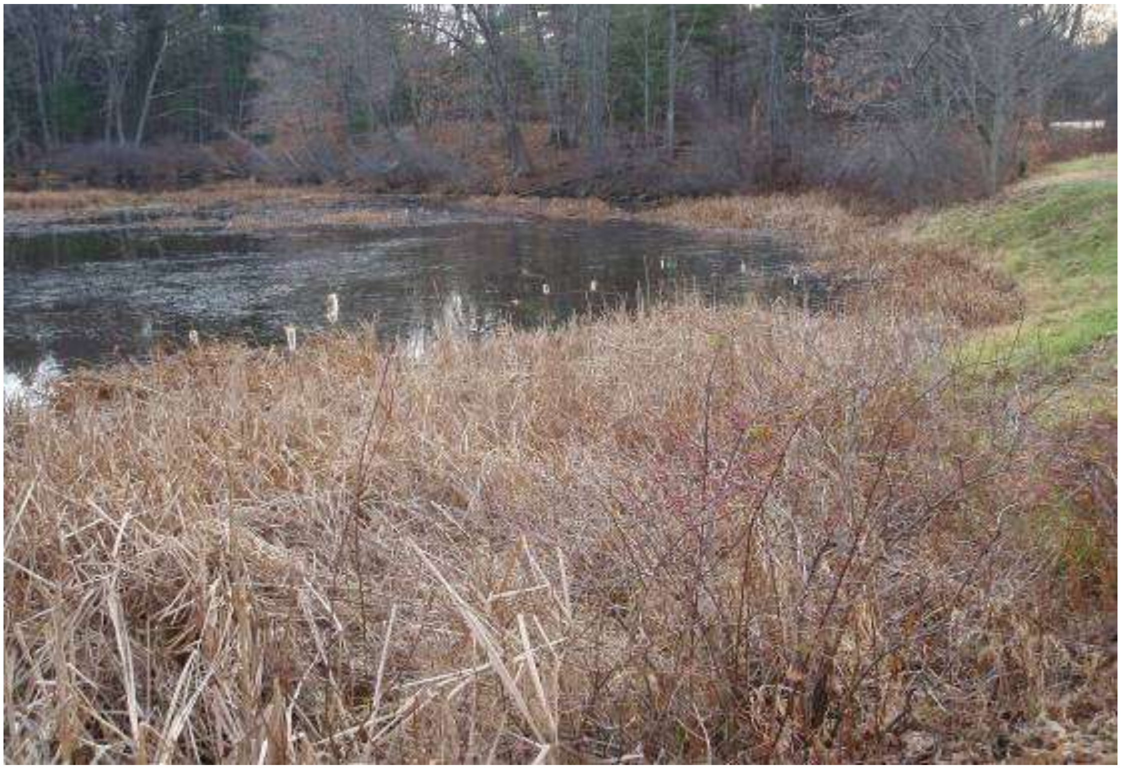


Photo 3: View south to a mixture of invasive and native emergent vegetation along the western banks of Mill Pond.

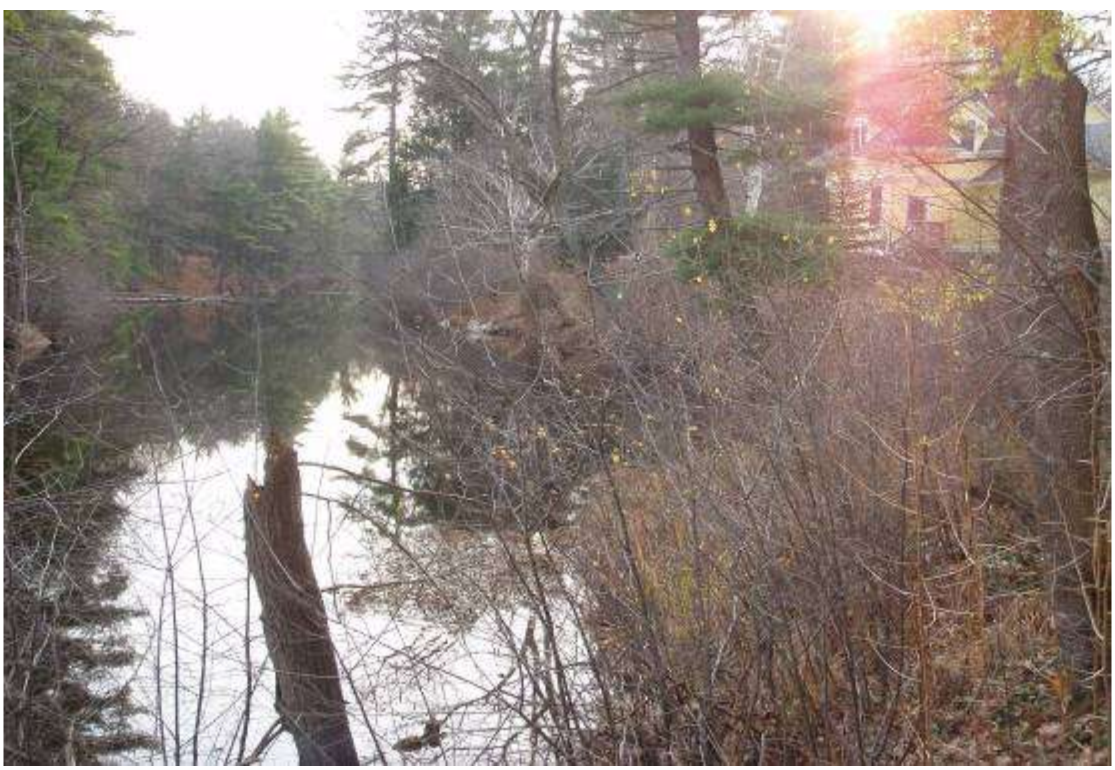


Photo 4: View south along the western banks of the Oyster River just before it flows into Mill Pond. Banks along this portion are steeply sloped with mainly eastern white pine and northern red oak.

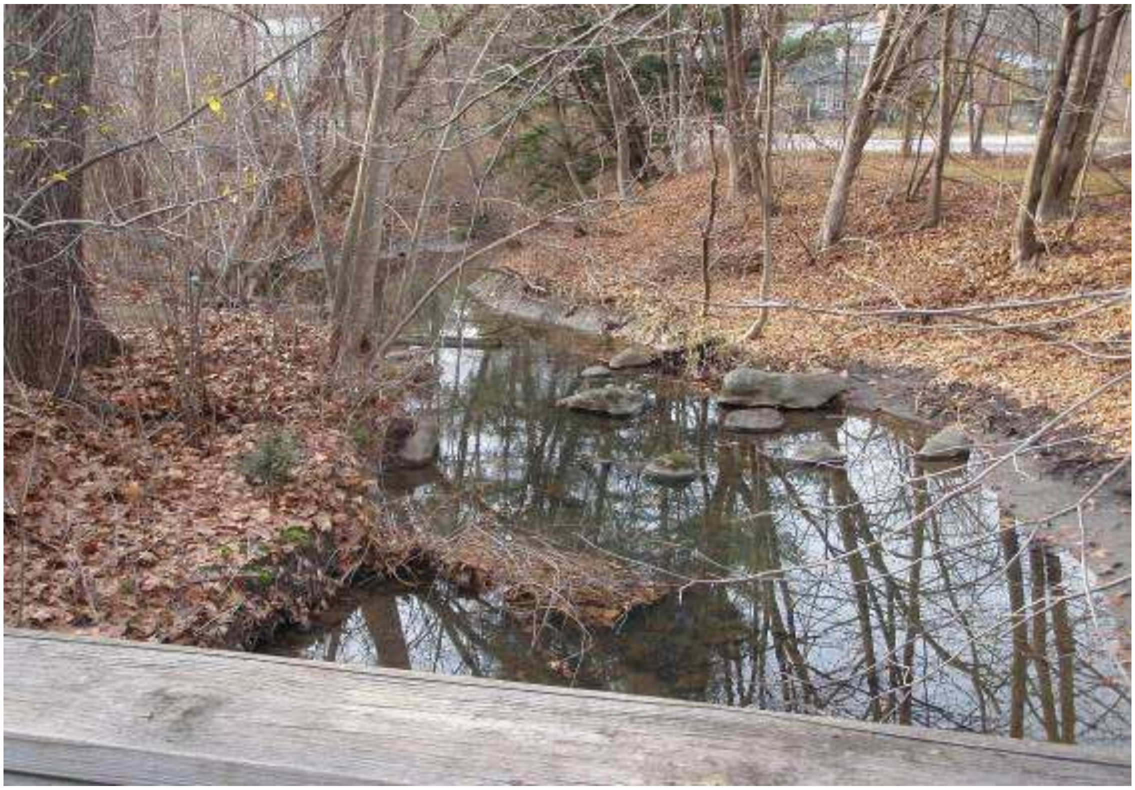


Photo 5: View west towards College Brook which flows into Oyster River just before it reaches Mill Pond.

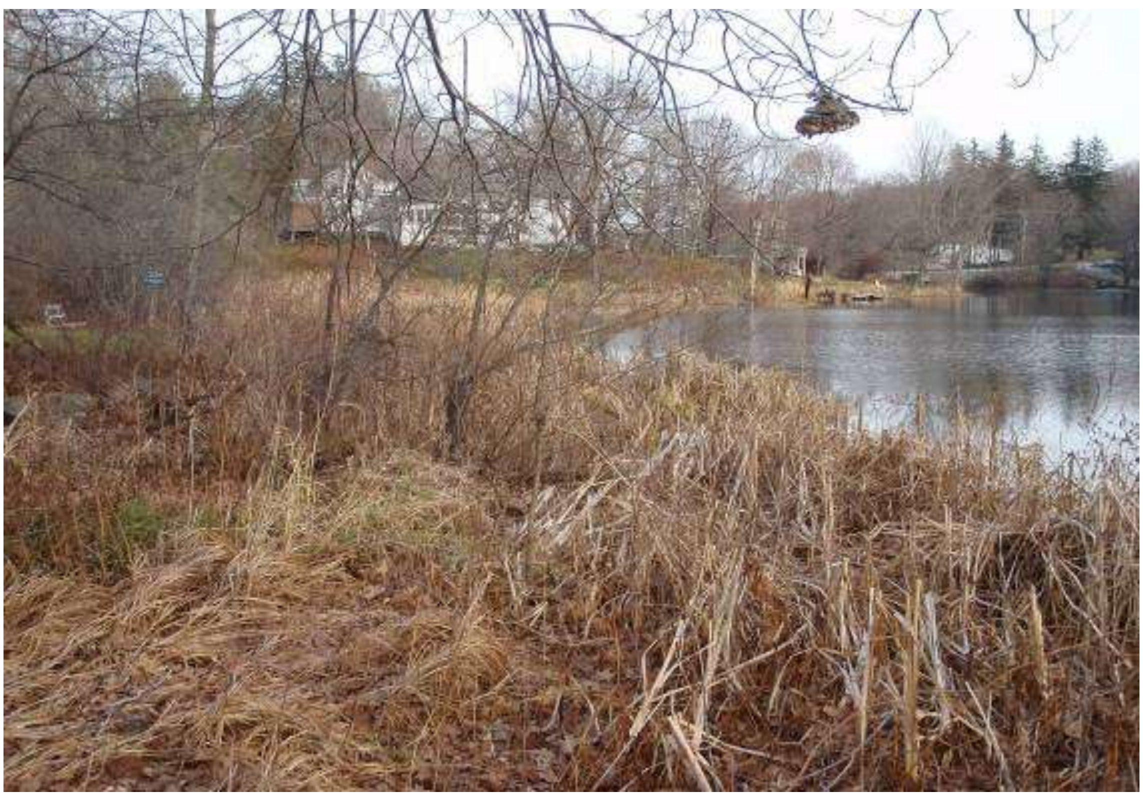


Photo 6: Emergent marsh areas along the northern portions of Mill Pond's western banks.

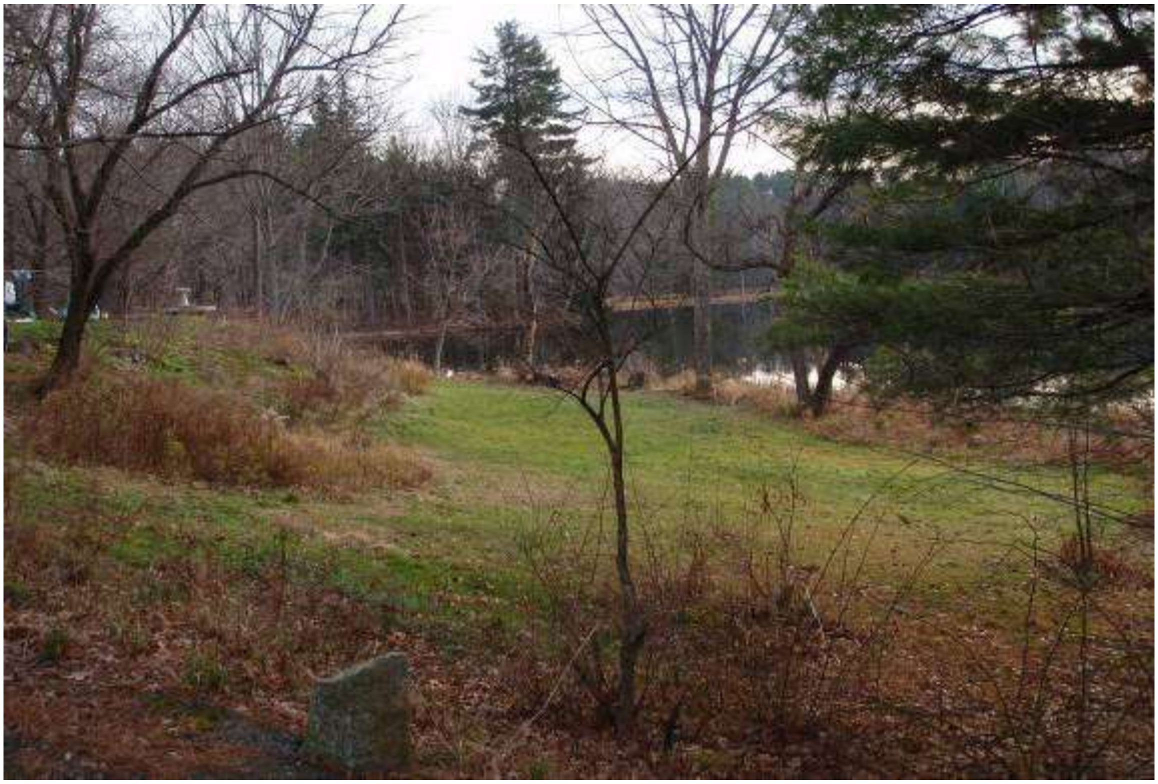


Photo 7: Large residential lawn extending to the edge of the pond on its western side.

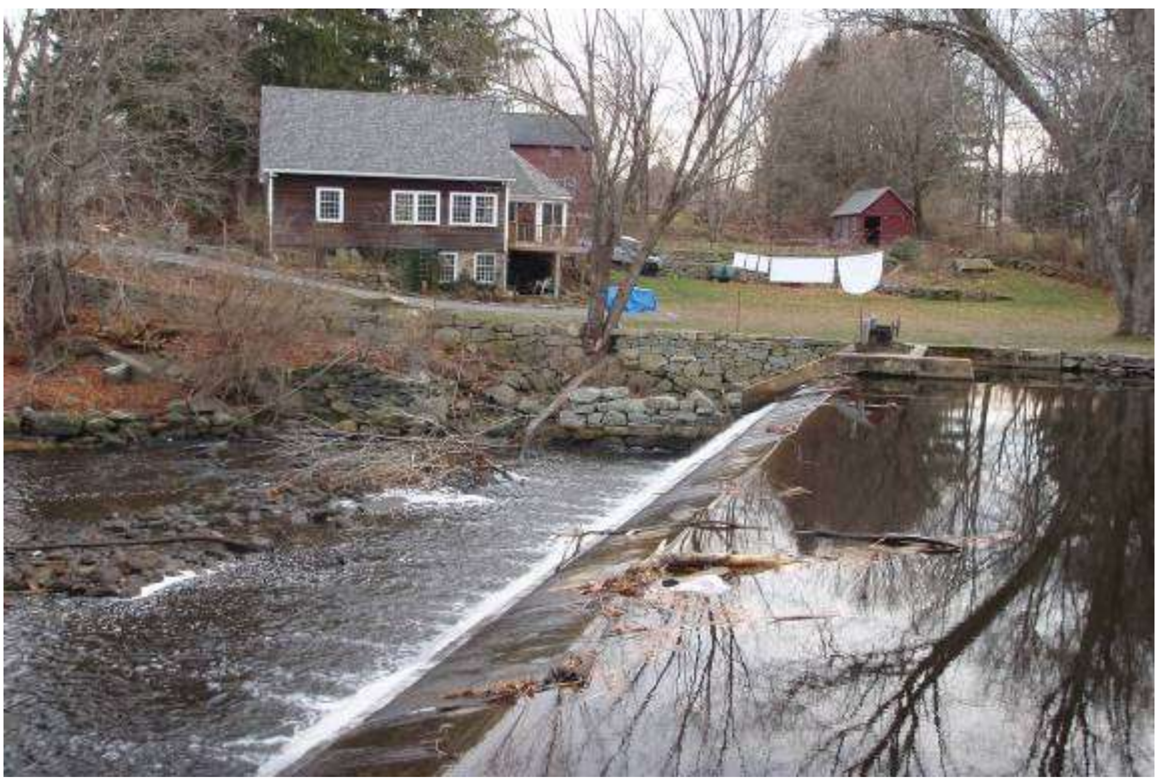


Photo 8: View south towards the existing Oyster River Dam. Stone rip-rap lines the banks surrounding the dam.

Appendix C
Representative Photos of Existing Vegetation

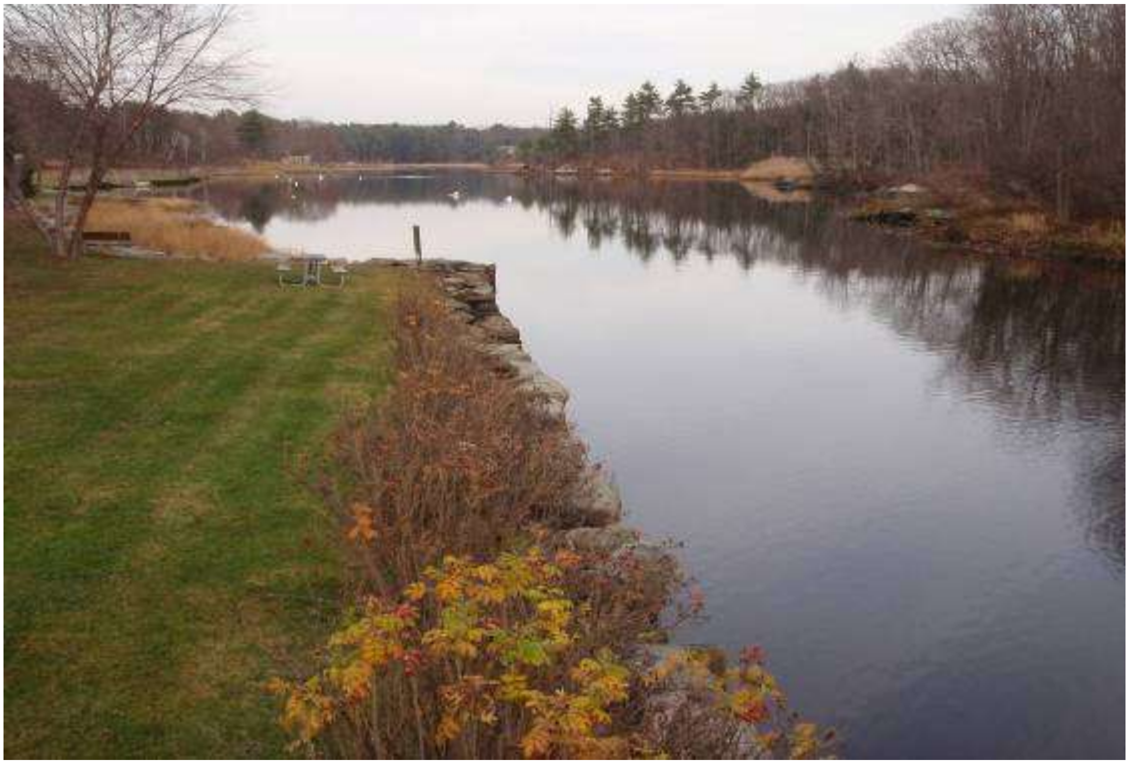


Photo 9: View east towards the banks of the Oyster River downstream of Mill Pond and the Oyster River Dam.

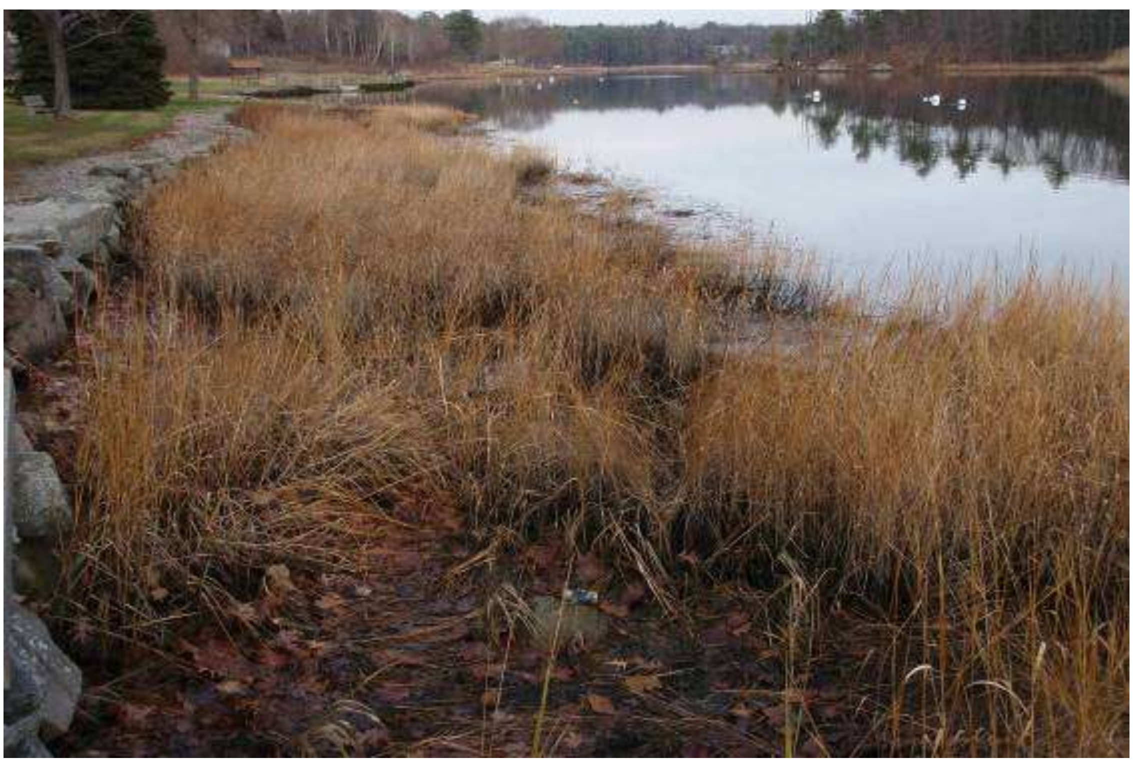
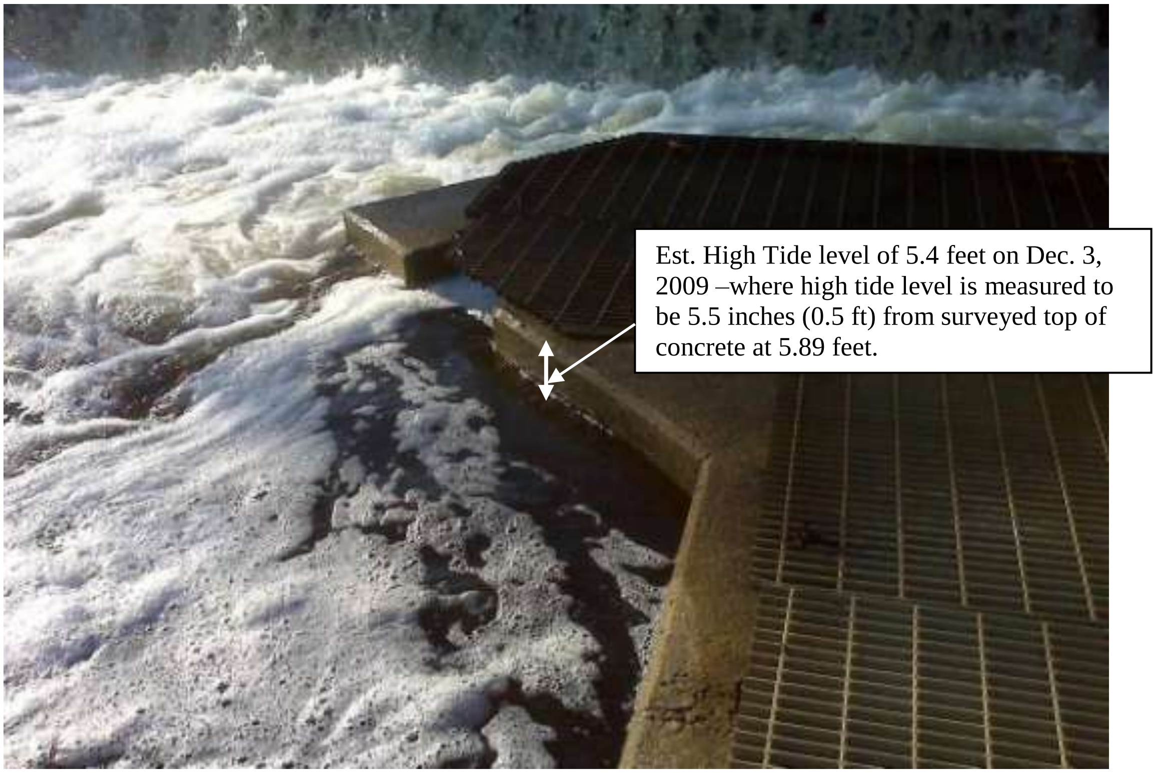


Photo 10: View east at native plant species including saltmeadow cordgrass, prairie cordgrass, blackgrass, and saltmarsh bulrush.

Appendix D

Photos of High Tide Elevation Measurements

Appendix D - Photos of Higher than Normal Tide Levels Oberved on Dec. 3, 2009.

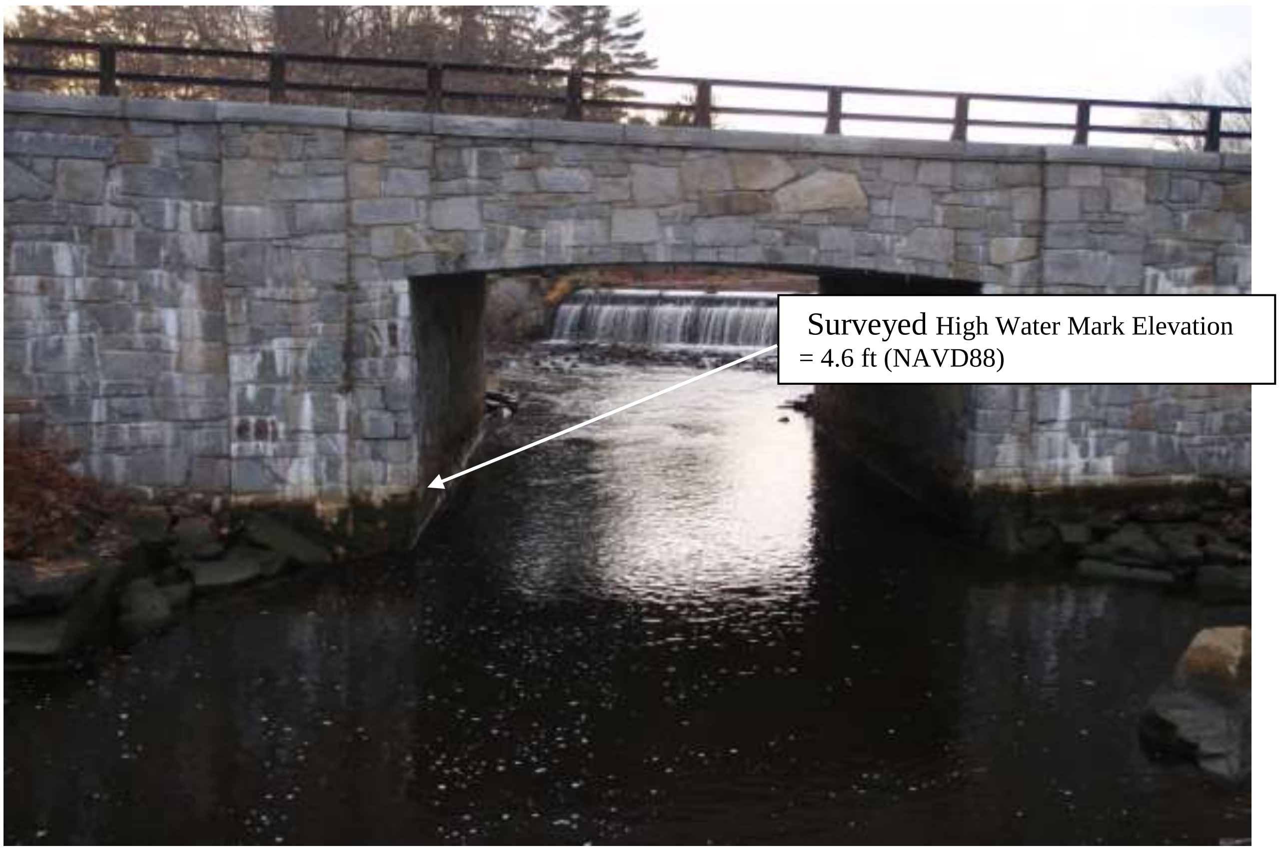


Oyster River Dam Fish Ladder Hydraulic Outlet, Durham, NH – 1:10 PM December 3, 2009

Oyster River Dam Left Abutment, Durham, NH – 1:14 PM December 3, 2009

Appendix D
Photos of High Tide Elevation Measurements

Appendix C – Photo of Potential MHHW Elevation Based on Survey of the High Water Mark on Stone Bridge Culvert



Appendix E –

Sediment Analytical Results Lab Reports